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Mapping concepts to syntax: Evidence from structural priming in Mandarin Chinese

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ABSTRACT

Theories of how people construct linguistic form during production are largely based on English and closely related languages. We report three experiments that used a structural priming paradigm to investigate grammatical encoding in Mandarin Chinese, in particular the way conceptual information is mapped onto grammatical structure. The results show that, in addition to persisting in using the same syntactic form across utterances, speakers of Mandarin persisted in their mappings from conceptual elements to syntactic elements, including both grammatical functions and linear surface word order positions. The results thus argue against a two-stage model where conceptual representations are first mapped onto grammatical functions, which are then in turn mapped onto surface linear positions. Instead, the results support a one-stage model where the processor computes in a single stage a structure that specifies both the linear order and the grammatical functions of its constituents.

Introduction

Although speakers appear to produce most utterances effortlessly, they perform many complicated processes in moving from an initial idea to a sequence of sounds. Speakers decide an idea or intention to be expressed (*conceptualization*). On the basis of this, they construct a conceptual representation (or message) that encodes information about the entities involved, their thematic roles (e.g., Agent, Theme, Recipient) in the event, and their animacy, definiteness, and emphasis (see Levelt, 1989). This representation is then mapped to a syntactic representation. As part of this process, speakers access lexical representations (*lemmas*) for elements in the conceptual representation (e.g., noun lemmas for event participants and verb lemmas for events), and integrate them into the syntactic representation. Subsequent processing involves retrieval of phonological information and the generation of an appropriate speech plan, culminating in articulation.

In this paper, we examine the relationship between conceptual structure and its syntactic realization. Specifically, we consider whether speakers map from conceptual representations to grammatical functions (e.g., subject and direct object), linear positions, or both. We do this by examining speakers' syntactic choices during production: Do they tend to choose syntactic alternatives that repeat the same mappings as in previously comprehended utterances between (some aspects of) conceptual representations and grammatical functions, linear positions, or both, in preference to structures that express the same meaning but involve different mappings?

In other words, we use a structural priming paradigm (Bock, 1986; see Pickering & Ferreira, 2008). Many experiments have used structural priming to investigate aspects of syntactic encoding; more recent studies have shown that some aspects of conceptual structure can also be primed. In this paper, we use structural priming to instead tap the relationship between these two levels of structure. We do this by considering mappings between conceptual

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elements (which for the time being we characterize in terms of thematic roles; we return to this point in the general discussion) and syntactic structure (function or word order). We study Mandarin Chinese, a language that has relatively free order and that therefore allows us to distinguish between effects associated with grammatical functions and effects associated with word order.

Speakers often have choices about how thematic roles might be realized syntactically. Consider an event involving three entities, in which a cowboy (the Agent) gives a particular sort of book (the Theme) to a sailor (the Recipient). In a sentence, the noun phrases (*NPs*) that linguistically encode such entities play different grammatical functions, such as subject, object, and oblique object (e.g., Givón, 1993). In a *double-object* (*DO*) dative sentence such as *The cowboy gave the sailor a very heavy and uninteresting book*, *the cowboy* is the subject, *the sailor* is the indirect object, and *a very heavy and uninteresting book* is the direct object. In contrast, in a *prepositional-object* (*PO*) dative sentence such as *The cowboy gave a very heavy and uninteresting book to the sailor,* or a shifted-PO sentence such as *The cowboy gave to the sailor a very heavy and uninteresting book*, *the cowboy* is the subject, *a very heavy and uninteresting book* is the direct object, and *the sailor* is the oblique object. Given these alternatives, speakers therefore have a choice about whether to realize the Recipient as an oblique object and the Theme as a direct object (as in a PO or a shifted-PO sentence) or to realize the Recipient as an indirect object and the Theme as a direct object (as in a DO sentence).

But equally, speakers must decide between alternative constituent structures, which encode the hierarchical and linear organization of constituents such as noun phrase, verb phrase (*VP*) verb (*V*), and prepositional phrase (*PP*). For instance, a DO dative sentence has a hierarchical structure in which the sentence comprises an NP and a VP, with the VP itself comprising a verb and two NPs. (In keeping with previous findings, e.g., Bock, Loebell, & Morey, 1992, we assume "simple" syntactic representations that eschew multiple levels of phrase structure or information associated with transformations; e.g., Culicover & Jackendoff, 2005; Pollard & Sag, 1994). In contrast, a PO dative sentence and a shifted-PO sentence have a hierarchical structure in which the sentence comprises an NP and a VP, with the VP comprising a verb, an NP, and a PP. Speakers can therefore choose to realize the Recipient in a dative sentence as an NP or a PP.

They also make choices about word order. The same constituents can often appear in different orders; for example, PO sentences and shifted-PO sentences have the same constituents but differ in linear order, with the NP preceding the PP in a PO sentence, but following the PP in a shifted-PO sentence, resulting in different orders of thematic roles (Theme preceding Recipient in a PO sentence, or Recipient preceding Theme in a DO or a shifted-PO sentence). (Of course, sentences can share constituent structure without necessarily sharing thematic structure; e.g., *The cowboy was kicked by the sailor* has the same constituent structure as *The foreigner was loitering by the traffic light* under at least some analyses). More broadly, speakers have choices about the order in which the different thematic roles are realized within syntactic structure.

From Garrett (1980) onwards, models of language production have standardly assumed that grammatical encoding involves an initial stage of processing during which grammatical functions are assigned (in Garrett's terms, *functional processing*), and a subsequent stage of processing during which constituent structure (hierarchical relations and linear order; in Garrett's terms, *positional processing*) is determined (e.g., Bock, 1987; Bock & Levelt, 1994). Garrett based this assumption largely on speech errors, specifically a distinction between errors that involved semantically and syntactically related but often non-contiguous elements, and errors that involved phonologically related and usually contiguous elements. For example, he observed that word exchanges usually involve elements from the same syntactic category, with exchanged elements being marked for the grammatical function in the produced utterance rather than the intended utterance (e.g., *He gave it to them,* rather than the intended *They gave it to him*). He argued that such exchanges provide evidence for a stage of processing that was specified for grammatical function but not for linear order. In contrast, sound exchanges often involve elements from adjacent words that have different syntactic categories but similar phonological content (e.g., *Do you reel feally bad?*), suggesting a level of processing that is specified for linear order and phonological but not syntactic content.

More recent models (e.g., Bock & Levelt, 1994) have followed Garrett (1980) in making a distinction between an unordered stage of grammatical function processing and an ordered stage of constituent structure processing (although they are incompatible with the speech error evidence on which Garrett based his original model because they assume that constituent structure processing occurs over elements that are not yet phonologically specified). For example, Bock (1987) proposed a mapping from conceptual representations to functions via a hierarchy in which the subject function is assigned first; and then a mapping from functions to constituent structure. But could conceptual representations be mapped to a single representation incorporating both grammatical functions and constituent structure?

Conceptual influences on grammatical encoding

Experimental research has suggested consistent relationships between conceptual information and grammatical encoding, with certain conceptual features tending to be associated with particular choices of grammatical functions and constituent structures. For example, English speakers tend to produce sentences in which the Agent of an action or an animate (e.g., human) entity appeared as the sentence-initial subject (e.g., Clark, 1965; Clark & Begun, 1971; Dewart, 1979; Harris, 1978). In such cases, it is not possible to tell whether conceptual features affected grammatical function assignment, choice of word order, or both.

Subsequent research has sought to distinguish these alternatives. Some studies suggest that conceptual information affects grammatical function assignment. Bock and Warren (1985) had participants listen to and then recall sentences involving pairs of entities that differed in

imageability. Participants tended to recall more imageable entities in higher grammatical functions than less imageable entities (e.g., recalling *The shock was administered by the doctor* as *The doctor administered the shock*), but showed no corresponding tendency to recall more imageable entities first in NP conjunctions, where the two entities bore the same grammatical function (e.g., *The hiker fought time and winter*). McDonald, Bock, and Kelly (1993) found similar effects for entities that differed in their animacy. Bock and colleagues used these results to argue for a model where, under an assumption of incremental processing, conceptual representations in the message are mapped onto grammatical functions so that more accessible concepts (e.g., concrete, animate, or given entities) are mapped onto higher grammatical functions (e.g., subject). When two NPs are within the same grammatical function, conceptual information such as imageability does not affect their linear order because conceptual information does not generally communicate with positional processing (though see Onishi, Murphy, & Bock, 2008, for other evidence concerning typicality).

However, other studies indicate that conceptual information can affect word order. Across 10 languages with different typological characteristics, Sridhar (1988) found a preference for Agents and (quasi-) human entities (e.g., dolls) to appear sentence-initially, both as subjects and as objects. Similarly, Branigan and Feleki (1999) found that Greek speakers tended to recall animate nouns sentence-initially more frequently than inanimate nouns, both when they were subjects and when they were direct objects. Kempen and Harbusch (2004) reported corpus evidence for an effect of animacy upon word order in German dative structures.

Tanaka, Branigan, McLean, and Pickering (2011) carried out two sentence-recall experiments in Japanese that independently manipulated grammatical function assignment (active vs. passive sentences) and word order (SOV vs. OSV order). Speakers were more likely both to produce animate subjects and to produce animate sentence-initial NPs. Tanaka et al. suggested that the order in which speakers retrieve concepts depends on their predicability (see also Bock & Warren, 1985). More predicable (e.g., animate or concrete) entities are integrated more easily with a predicate to form a message than less predicable entities. They are therefore more likely to claim higher grammatical functions (e.g., subject) and early word order positions.

Tanaka et al.'s (2011) study explains the association between particular conceptual features and particular grammatical function and word order choices, but makes no claim about whether the processor directly maps particular conceptual features to particular grammatical functions or to particular word order positions. Importantly, none of the evidence reviewed above is informative about the question of whether language production involves direct mappings from conceptual structure to particular grammatical functions (as current models of production assume), to particular word order positions, or to both. To resolve this question, we need a method that can tap into these mappings, and for this we turn to structural priming.

Using structural priming to investigate conceptual-to-syntactic mappings

Initial demonstrations of structural priming were concerned with investigating the content of syntactic representations. Early findings that structural priming can occur without the repetition of words (e.g., Bock, 1989), thematic roles, or prosody (e.g., Bock & Loebell, 1990), were interpreted as evidence that language production involves a stage of processing that is concerned with syntax independent of semantic, lexical or phonological information. Much subsequent evidence has supported the claim that some structural priming effects tap into representations that are syntactic in nature. For instance, Bock and Loebell demonstrated that an active sentence with a locative *by*-phrase such as *The foreigner was loitering by the blinking traffic light* primed the production of a passive sentence with an agentive *by*-phrase such as *The boy was stung by the bee* (see also Messenger, Branigan, & McLean, 2011). Moreover, priming can occur when the alternatives use the same words and thematic roles and do not appear to differ in meaning. Hartsuiker and Westenberg (2000) found that Dutch speakers tended to repeat the order of verb and auxiliary in the prime (e.g., *Ik kon er niet door omdat de weg geblokkerered was/was geblokkerered*, literally, "I couldn't pass through because the road blocked was/was blocked"). Similarly, Konopka and Bock (2009) found priming of order of noun phrase and particle (*pull off a sweatshirt* vs. *pull a sweatshirt off*); see also Ferreira (2003). These studies suggest that a component of structural priming reflects the surface constituent structure, which is based on the actual order of constituents rather than a putative underlying structure (see Bock et al., 1992).

Some studies have shown that structural priming may also be sensitive to semantics. One study has shown priming relating to animacy. As well as showing that people tended to repeat actives versus passives, Bock et al. (1992) found that they tended to treat an animate entity as a sentence-initial subject if they had just treated another animate entity as a sentence-initial subject, irrespective of whether it was the Agent of an active or the Patient of a passive. Note however that Bernolet, Hartsuiker, and Pickering (2009) found no such effect.

More studies have shown priming related to thematic roles. First, speakers tend to persist in assigning emphasis to particular thematic roles. Vernice, Pickering, and Hartsuiker (in press) found that Dutch participants were more likely to produce passives after *Degene die hij slaat is de cowboy* ("The one who he is hitting is the cowboy") than after *Degene die hem slaat is de cowboy* (lit., "The one who him is hitting is the cowboy", i.e., the one who is hitting him is the cowboy). In both sentences, the cowboy is emphasized, but in the former case it is the Patient, whereas in the latter case it is the Agent. In addition, Bernolet et al. (2009) found that participants were more likely to produce English active sentences after Dutch PP-initial passives (e.g., *Door de bliksem wordt de kerk getroffen,* literally "by lightning is the church struck") than after other types of Dutch passives in which the PP *door de bliksem* ("by lightning") does not occur sentence-initially. They argued that this occurred because actives and PP-initial

passives emphasize the Agent to a greater extent than English passives or other Dutch passives. Such priming would reflect processing during conceptualization, because assignment of emphasis to thematic roles involves purely semantic processes.

But other studies are more relevant to our question, namely how speakers map from the conceptual representation during formulation. Chang, Bock, and Goldberg (2003) found that speakers tend to perseverate effects relating to thematic roles, in cases when the two alternative structures do not appear to differ in emphasis. Participants were more likely to produce a *spray-on* sentence in which the Theme appeared as the direct object in the first NP position after the verb, and the Location appeared as the oblique object in the second NP position after the verb (e.g., *The workers scuffed dirt across the kitchen floor*) after another *spray-on* sentence (e.g., *The man sprayed wax on the car*) than after a *spray-with* sentence (e.g., *The man sprayed the car with wax*), where the Location appeared as the direct object in the first NP position after the verb, and the Theme appeared as the oblique object in the second NP position after the verb. Shin and Christianson (2009) showed priming from Korean datives to English datives, which share the same sets of grammatical functions, but differ in constituent structure (i.e., the dative verb is sentence-final in Korean PO and DO sentences, and medial in English PO and DO sentences).

In fact, these two studies are compatible with different accounts of perseveration. According to the *conceptual-to-function mapping* account, people perseverate in their assignment of thematic roles to functions (e.g., Theme to direct object, Recipient to indirect object). According to the *conceptual-to-linear mapping* account, people perseverate in their assignment of thematic roles to linear positions (e.g., Theme-Recipient order). Alternatively, both forms of mapping may occur.

There are a few studies that may help discriminate these accounts. Hare and Goldberg (1999) found that *provide-with* sentences (e.g., *The officers provided the soldiers with guns*) primed DO responses rather than PO responses, even though they share constituent structure ([V NP PP]) with PO sentences rather than DO sentences. These results support the conceptual-to-linear mapping account, though it is possible that a weak effect of conceptual-to-function mapping occurs as well. However, participants were only exposed to one type of sentence and so it is possible that the effects reflect long-term or strategic priming effects. Note, however, that Salamoura and Williams (2007) found cross-linguistic priming effect between Greek *provide-with* sentences and English DO sentences in a within-participants design. These results are compatible with pure conceptual-to-linear mapping but not pure conceptual-to-function mapping, though they are also compatible with a strong conceptual-to-linear priming effect outweighing a weak conceptual-to-function priming effect.

In addition, Pickering, Branigan, and McLean (2002) found that shifted-PO sentences (e.g., *The cowboy gave to the sailor a very heavy and uninteresting book*) did not prime PO sentences, but instead behaved like intransitive baseline primes, priming neither DO nor PO sentences. Pickering et al.'s data are incompatible with pure conceptual-to-function mapping, because shifted-PO sentences did not prime PO responses, even though they both involve the same mapping of Theme to direct object and Recipient to oblique object. They are incompatible with pure conceptual-to-linear mapping, because shifted-PO sentences did not prime DO responses, even though they both have Recipient-Theme order. But it is possible that conceptual-to-linear and conceptual-to-function mapping co-occurred (and cancelled each other out).

What do these possibilities tell us about the mechanisms of grammatical encoding? We assume that priming of the relationship between two properties indicates the existence of a mapping between representations that encode those properties. So priming of conceptual-to-function mapping indicates the existence of a mapping between a conceptual representation and a representation encoding grammatical functions; and priming of conceptual-to-linear mapping indicates the existence of a mapping between a conceptual representation and a representation encoding linear order. Pure conceptual-to-function mapping would therefore indicate that during production, the processor directly relates concepts to functions but not word order; pure conceptual-to-linear mapping would therefore indicate that the processor directly relates concepts to word order but not to functions. If both forms of mapping take place, then the processor directly relates concepts either to two separate representations or to a single representation that encodes both grammatical functions and linear order. We return to these accounts in the General Discussion.

To test for conceptual-to-function and conceptual-to-linear priming, we need to use constructions where we can independently manipulate one type of information while controlling for others. Specifically, we need to be able to test for conceptual-to-linear mapping while holding conceptual-to-function mapping, constituent structure, and thematic emphasis constant; and to test for conceptual-to-function mapping while holding conceptual-to-linear mapping, constituent structure, and thematic emphasis constant. To do this, we investigate the priming of the dative alternation in Mandarin Chinese. As might be expected, this alternation is susceptible to structural priming (Cai, Pickering, & Sturt, in press; Cai, Pickering, Yan, & Branigan, 2011). In addition, Mandarin permits a range of grammatical constructions that allow us to pull apart grammatical functions, linear order, and constituent structure.

Dative, topic, and Ba-constructions in Mandarin Chinese

In Mandarin, the message of a cowboy giving a sailor a book can be expressed in many ways, as shown in (1–3). First, Mandarin allows a DO structure (1a) or a PO structure (1b). But in addition, the same message can be expressed with the *Ba*-construction (2), in which the direct object of a DO structure (e.g., *naben shu* [the book][1]) occurs before the verb (e.g., *song-gei* [give-to]). It expresses affectedness

[1] Though *na* literally means "that", it is less emphatic than the English demonstrative pronoun *that*. It is often used with a noun in the kinds of sentences that we used to indicate that the relevant object is known to the speaker and listener. Thus in the present study, we translate *na* as "the". We do not translate the classifier *ben* for conciseness of presentation.

(or disposal) of this NP (here the book was being given to another person; Chao, 1968; Wang, 1954), and can apply to a DO but not a PO structure. (Note that *le* indicates perfective aspect – in this case, that the giving event is finished.) A further common possibility is the topic construction (3a and b), where a constituent is topicalized and typically appears sentence-initially (Li & Thompson, 1981).[2] Thus the direct object (the bearer of the Theme) in a DO structure can be topicalized, yielding a Topic-DO structure (3a); and similarly, the direct object (the bearer of the Theme) in a PO can be topicalized, yielding a Topic-PO structure (3b). A topic sentence often introduces new information about the topic (which has typically already been mentioned in the discourse; Shi, 2000).

1a	Niuzai song-gei le shuishou naben shu. cowboy give-to LE sailor the book. (The cowboy gave the sailor the book.)	(DO)
1b	Niuzai song le naben shu gei shuishou. cowboy give LE the book to sailor. (The cowboy gave the book to the sailor.)	(PO)
2	Niuzai ba naben shu song-gei le shuishou. cowboy BA the book give-to LE sailor. (The cowboy gave the sailor the book).	(*Ba*-DO)
3a	Naben shu niuzai song-gei le shuishou. the book cowboy give-to LE sailor. (The book the cowboy gave the sailor.)	(Topic-DO)
3b	Naben shu niuzai song le gei shuishou. the book cowboy give LE to sailor. (The book the cowboy gave to the sailor)	(Topic-PO)

These constructions allowed us to manipulate a critical aspect of thematic information while keeping others constant in ways that do not appear possible in English. In doing so, they allowed us to examine whether the processor associates particular thematic roles with particular grammatical functions only, or also with particular linear orders. Pure conceptual-to-function mapping predicts that *Ba*-DO and Topic-DO sentences should prime DO responses, because all three structures share the same functional mapping of thematic roles, with the Recipient being mapped to the indirect object and the Theme being mapped to the direct object. Pure conceptual-to-linear mapping, on the other hand, predicts that *Ba*-DO and Topic-DO sentences should prime PO responses, because all three structures have a linear order in which the Theme precedes the Recipient (whereas DO has a linear order in which the Recipient precedes the Theme).

Note, however, that although *Ba*-DO and Topic-DO both share with PO the *relative* order of the Theme and the Recipient, only *Ba*-DO shares with PO the *absolute* order of the Theme and the Recipient (i.e., Agent-Theme-Recipient; cf. Theme-Agent-Recipient in Topic-DO). The processor might register the relative order of the Theme and the Recipient (*relative* conceptual-to-linear mapping) or the absolute linear order of the two thematic roles (*absolute* conceptual-to-linear mapping). The absolute account, then, predicts that *Ba*-DO (with the same absolute order as PO) should prime PO sentences, but Topic-DO should not. In contrast, the relative account predicts that both *Ba*-DO and Topic-DO should prime PO sentences, and should do so to the same extent.

Additionally, we can determine whether priming of both conceptual-to-function mapping and conceptual-to-linear mapping occurs, because Topic-DO and Topic-PO sentences share the same linear order of thematic roles (Theme-Agent-Recipient) but differ in their functional mappings of thematic roles (Topic-DO has the same functional mappings as DO, whereas Topic-PO has the same functional mappings as PO). Table 1 summarizes the predicted priming effects of different primes according to different accounts. Importantly, the goal of our experiments was to test for conceptual-to-syntactic priming rather than specifically thematic-to-syntactic priming. As in most dative sentences, the Themes in our experiments were inanimate and the Recipients were animate. We return to this in the General Discussion.

We investigated these questions in three structural priming experiments in which participants alternately heard picture descriptions and described pictures. Because it was not our intention to test for priming of emphasis itself (as in Bernolet et al., 2009), as such priming presumably takes place during conceptualization, we first carried out a pre-test to see whether the Recipient (and the Theme) might differ in emphasis across different dative constructions in a way that might give rise to priming based on repetition of thematic emphasis.

To preview our results, the pre-test suggested that there is no difference in thematic emphasis for the Theme and for the Recipient between DO and PO. In other words, emphasis to either the Theme or the Recipient does not facilitate subsequent production of a DO or PO sentence in Mandarin. Thus, we could be assured that any thematic priming effect in our experiments was not due to thematic emphasis. Experiments 1 and 2 tested the pure conceptual-to-linear and the pure conceptual-to-function accounts, and ruled out the latter account. Experiment 2 also provided support for relative rather than absolute conceptual-to-linear priming. Experiment 3 tested for conceptual-to-function priming when conceptual-to-linear priming was held constant, and found evidence for such priming.

[2] Although in principle both the Theme and the Recipient can be topicalized, topicalization of the Recipient (but not the Theme) requires the insertion of a resumptive pronoun *ta* (meaning "he"/"she"/"it") at the canonical position of the Recipient bearer. Thus, to avoid any confound associated with a resumptive pronoun, we only considered cases where the Theme is topicalized.

Table 1
Predicted responses primed under different accounts.

Prime type	Response primed by constituent structure	Response primed by conceptual-to-function mapping	Response primed by conceptual-to-linear mapping: relative/absolute
DO prime ($NP_{Agt/Sub}$–V–$NP_{Rcpt/IObj}$–$NP_{Thm/DObj}$)	DO	DO	DO/DO
PO prime ($NP_{Agt/Sub}$–V–$NP_{Thm/DObj}$–$PP_{Rcpt/OObj}$)	PO	PO	PO/PO
Ba-DO prime ($NP_{Agt/Sub}$–*ba*-$NP_{Thm/DObj}$–V–$NP_{Rcpt/IObj}$)	–	DO	PO/PO
Topic-DO prime ($NP_{Thm/DObj}$–$NP_{Agt/Sub}$–V–$NP_{Rcpt/IObj}$)	–	DO	–/PO
Topic-PO prime ($NP_{Thm/DObj}$–$NP_{Agt/Sub}$–V–$PP_{Rcpt/OObj}$)	–	PO	–/PO

Note: "DO" and "PO" indicates the structure that is primed; "–" indicates that neither DO nor PO is primed. The parentheses following a prime contains the constituent structure, functional structure and thematic order of that prime. Agt, Agent; Thm, Theme; Rcpt, Recipient; Sub, subject; Obj, object; DObj, direct object; IObj, indirect object; OObj, oblique object.

Pre-test

The pre-test examined whether DO, PO, and *Ba*-DO sentences (e.g., 1a, 1b, and 2, above, repeated below as 4a, 4b, and 4c)[3] differ in the emphasis (i.e., focus) given to the Theme (and the Recipient) (we did not include Topic-DO or Topic-PO sentences because a topic-construction often introduces emphasis to the topicalized thematic role). Following Bernolet et al. (2009), we asked participants to read the sentences such as those in (4) and choose which of the two underlined and numbered phrases (the Theme and the Recipient) was the more emphasized.

4a Niuzai song-gei le <u>shuishou</u> (1) <u>naben shu</u> (2). (DO)
cowboy give-to LE sailor the book
(The cowboy gave the sailor the book.)

4b Niuzai song le <u>naben shu</u> (1) gei <u>shuishou</u> (2). (PO)
cowboy give LE the book to sailor
(The cowboy gave the book to the sailor.)

4c Niuzai ba <u>naben shu</u> (1) song-gei le <u>shuishou</u> (2). (*Ba*-DO)
cowboy BA the book give-to LE sailor
(The cowboy gave the sailor the book.)

Method

Participants

Twenty-eight native speakers of Mandarin from the University of Edinburgh community were paid £1 to take part.

Materials

We constructed 24 sets of dative sentences; each set included a DO sentence, a PO sentence, and a *Ba*-DO sentence (see Appendix A in Supplementary material). These dative sentences were created using 12 Mandarin dative verbs (i.e., *song* "give", *huan* "return", *reng* "throw", *mai* "sell", *shang* "reward", *diu* "toss", *jie* "lend", *di* "pass", *zu* "rent", *pao* "chuck", *na* "hand", *jiao* "submit"). We also included 48 fillers (e.g., *Niuzai ti le shuishou* "The cowboy kicked the sailor") using a variety of transitive verbs. For dative target sentences, the Theme and the Recipient were underlined and numbered, as in (4). For fillers, the Agent and the Patient were underlined and numbered.

Procedure

The pre-test was conducted using E-prime software (MacWhinney, St. James, Schunn, Li, & Schneider, 2001). All the sentences were individually pseudo-randomized for each participant so that every two target sentences were separated by 1, 2, or 3 filler sentences. Participants were given examples as to what emphasis meant and how to carry out the task, using transitive active and passive examples, and three practice items. On each trial, they saw a sentence and decided which underlined noun phrase was more emphasized by pressing a key (*F* for the noun phrase underlined with 1 and *J* for the noun phrase underlined with 2). The pre-test lasted about 10 min.

Results and discussion

We scored whether participants chose the Theme or the Recipient as the more emphasized thematic role (see Table 2). As the dependent variable was binomial in this pre-test and all experiments, we used logit mixed effects (LMEs) modelling for statistical analyses (Baayen, Davidson, & Bates, 2008; Jaeger, 2008). In the analyses, we first built a base model where we included fixed predictors (i.e., the variables we manipulated) and random intercepts for participants and items. Then we determined whether the final model should also include a random participant or item slope for a fixed effect; we did this by model comparisons. If the inclusion of a random slope into the base model significantly improved the model fit (in terms of log-likelihood ratio χ^2 test), then we included that random slope in the final model. For results in the pre-test, as inclusion of neither participant nor item slope significantly improved the model fit, the final model included sentence type as a fixed effect, and participant and item intercepts as random effects. Although LME with categorical fixed predictors gives level comparisons, it does not give main

[3] In Mandarin, when the Theme is placed after *ba* (as in the *Ba*-DO construction) or at a sentence-initial position, it is more natural to for the Theme to be preceded by the demonstrative pronoun *zhe* ("this") or *na* ("that"). The Theme was therefore always preceded by the demonstrative pronoun *na* in our topic-construction and *Ba*-construction sentences. To keep the Theme noun constant across all conditions, we also used *na* with the Theme noun in our canonical DO and PO sentences.

Table 2
Counts of recipient and theme emphasis, and percentage of theme emphasis, by sentence type in the pre-test.

Sentence type	DO	PO	Ba-DO
Recipient emphasis	58	49	51
Theme emphasis	110	119	117
% Theme emphasis	65%	71%	70%

effects and interactions straightforwardly. Thus, following Baayen (2008), we applied centering to fixed predictors so that we could obtain ANOVA-like main effects and interactions in a single step. Our analyses showed that there was a significant intercept (estimate = 1.07, $SE = .30$, $z = 3.60$, $p < .001$), indicating that the Theme was considered to be more emphasized on more trials than the Recipient. Sentence type did not have a significant main effect (estimate = .09, $SE = .14$, $z = .68$, $p > .1$) indicating that the Theme and the Recipient did not receive different emphasis in different sentence types. Pairwise comparisons indicated no difference between DO and PO sentences ($z = 1.08$, $p > .1$), between DO and *Ba*-DO sentences ($z < 1$), or between PO and *Ba*-DO sentences ($z < 1$).

Thus, although participants treated the Theme as more emphasized than the Recipient – perhaps because it was preceded by the definite demonstrative *na* (lit., "that"; -*ben* is a classifier) – emphasis on the Theme versus the Recipient was unaffected by sentence type. Similarly there could be no animacy emphasis priming. In what follows, we therefore assume that any conceptual priming that occurs in datives cannot be attributed to conceptual emphasis priming. We note that the absence of differences in thematic emphasis between the Recipient and the Theme in Mandarin dative sentences contrasts with Bernolet et al.'s (2009) finding of differences in thematic emphasis between the Agent and Patient in Dutch transitive sentences; a number of differences between the studies might underlie such a discrepancy (e.g., language, number of arguments, contrast between a subject and a non-subject function vs. between two non-subject functions).

Experiment 1

The pre-test established that the Theme and the Recipient do not differ in thematic emphasis between DO and PO sentences. Hence any priming between dative sentences that is associated with thematic roles must be due to priming of mappings between conceptual representations and syntactic structure. In Experiment 1, we investigated conceptual-to-function and conceptual-to-linear mapping by observing how exposure to a PO prime, a DO prime, a *Ba*-DO prime, and an intransitive baseline (as illustrated in 5) affected production of PO and DO sentences. We assume, as in previous studies, that intransitive baselines have syntactic structures and thematic roles sufficiently unrelated to either PO or DO sentences that they should not lead to priming of conceptual-to-linear mapping, conceptual-to-function mapping, or constituent structure (e.g., Bock & Griffin, 2000; Pickering et al., 2002).

5a	Niuzai song-gei le shuishou naben shu. cowboy give-to LE sailor the book. (The cowboy gave the sailor the book.)	(DO)
5b	Niuzai song le naben shu gei shuishou. cowboy give LE the book to sailor (The cowboy gave the book to the sailor.)	(PO)
5c	Niuzai ba naben shu song-gei le shuishou. cowboy BA the book give-to LE sailor (The cowboy gave the sailor the book.)	(*Ba*-DO)
5d	Wupo ku le. witch cry LE (The witch cried.)	(Baseline)

We first consider possible constituent structure priming effects. Any priming based on constituent structure should manifest itself as an increased tendency to produce DO responses following DO primes, and PO responses following PO primes, relative to the baseline. *Ba*-DO sentences differ in constituent structure from both DO and PO sentences, so *Ba*-DO primes could not prime either sentence type on the basis of surface constituent structure (e.g., Bernolet et al., 2009; Pickering et al., 2002).

Any priming associated with mappings from conceptual representations to syntactic structure (whether grammatical functions, linear order, or both) should manifest itself as an increased tendency to produce DO responses following DO primes, and PO responses following PO primes, relative to the baseline. In terms of conceptual-to-function mapping, *Ba*-DO and DO sentences have the same mapping of Recipient to indirect object and Theme to direct object. In terms of conceptual-to-linear mapping, *Ba*-DO and PO sentences have the same absolute order of thematic roles (i.e., Agent-Theme-Recipient).

Thus given that *Ba*-DO sentences do not share constituent structure with DO or PO, any priming of DO responses, relative to the baseline, would support conceptual-to-function mapping; any priming of PO responses, relative to the baseline, would support conceptual-to-linear mapping. But as we have noted, neither pattern rules out the possibility that both conceptual-to-function and conceptual-to-linear mapping occur.

Experiment 1 (and Experiment 2) used a dialogue paradigm (Branigan, Pickering, & Cleland, 2000), in which a confederate (who pretended to be a naïve participant) and a naïve participant alternated describing pictures to each other. The confederate followed a script to produce her descriptions; on experimental trials, she produced one of the four sentence types in (5).

Method

Participants

Twenty-eight Mandarin speakers from the University of Edinburgh community were paid £4 to take part.

Materials

We created 24 experimental sets (see Appendix A in Supplementary material) and 72 filler sets. Each set consisted of a prime description picture and associated prime sentence, a prime match picture (to be matched with the prime sentence), a target description picture and associated target preamble (e.g., *Jingcha song* [Policeman give] _____), and a target match picture (to be matched with the target sentence; see Fig. 1). For the experimental sets, the prime and target description pictures depicted a dative event (e.g., a cowboy giving a sailor a book) that could be described using one of the twelve dative verbs used in the pre-test. There were four versions of each associated prime sentence, corresponding to the four priming conditions, as in (5a–d). The target description picture always depicted the same action (e.g., giving) as in the prime description picture, but differed from the prime description picture in all other aspects (i.e., the Agent, the Recipient, and the Theme). The dative verb corresponding to the action in the target description picture was printed under the picture. In all the experimental sets (except the baseline condition), a prime or target description picture and its associated match picture involved the same action. The match pictures matched their corresponding description picture in half of the sets; in the other half, they differed from their corresponding description picture in only one of the event participants (e.g., the Agent). The locations of the Agent and the Recipient in dative pictures (Agent on the left and Recipient on the right vs. Agent on the right and Recipient on the left; with the Theme object always in the middle) were counterbalanced across items (similar counterbalancing also applies to the filler transitive and intransitive pictures).

For the filler sets, description pictures always depicted a transitive event (e.g., a waitress kicking a cowboy) or an intransitive event (e.g., a waitress smiling), except for 32 of the participant's description pictures, which depicted dative events and had a sentence preamble that could be continued only as a DO sentence (e.g., *Jingcha song-gei* [Policeman give-to]_____). We did this in order to boost up the proportion of DO descriptions for participant's target description pictures.[4] In 30 of the 72 filler sets, a prime or target description picture and its associated match picture involved the same action (e.g., kicking, running). Thus overall, the action was the same between the description and match pictures in half of the sets (i.e., 18 experimental sets and 30 filler sets) in the experiment as a whole. The match pictures matched their corresponding description picture in half of the sets; in the other half, they differed from their corresponding description picture in only one of the event participants (e.g., the Agent).

[4] A pilot study that did not include these DO fillers was found to yield predominantly PO responses; we therefore included DO fillers to counteract this tendency.

Procedure

The participant and the confederate (a female speaker of Mandarin) were both seated in front of a computer and could not see each other's computer screen (though they could see each other's face). Both the participant and the confederate were familiarized with the figures and objects that were to appear in the experiment and the experimental task. They then carried out a practice session with four example sets of materials. On half of the trials (including all the experimental trials), the confederate first read out the script under the guise of describing a picture (i.e., the confederate's prime description picture), after which the participant saw a picture (i.e., the prime match picture) and decided whether the picture matched the confederate's description by pressing *F* (for match) or *J* (for mismatch). Another picture (the participant's target description picture) then appeared on the participant's screen for him or her to describe to the confederate by repeating and completing the preamble printed beneath the picture in Mandarin. The confederate feigned matching a picture (the confederate's match picture) with the description she had heard. The description and matching trials occurred consecutively, so that from the participant's perspective, the confederate and participant simply alternated describing pictures to each other and matching pictures to their partner's description, and there was no distinction between experimental trials and fillers. Each participant received an individually randomized order, with the constraint that experimental trials were separated by 2–4 filler trials. The experiment took about 25 min.

Scoring

All descriptions of target pictures were coded as DO, PO, or Other responses. A description was a DO response if the sentence preamble was completed in such a way that the verb stem in the preamble was supplied with the bound morpheme *gei* and was further followed by the Recipient and then the Theme to form a grammatical sentence (e.g., *Jingcha song-gei shibing yiding maozi*, "The policeman gave the soldier a hat"), and a PO response if the sentence preamble was completed in such a way that the verb was followed by the Theme and a preposition phrase headed by the preposition *gei* and containing the Recipient (e.g., *Jingcha song yiding maozi gei shibing*, "The policeman gave a hat to the soldier"). All the other descriptions were categorized as Other responses, including cases where the sentence preamble was not preserved (e.g., use of the *Ba*-DO construction); the description was not grammatical (e.g., without attaching *gei* to the verb stem in an intended DO description); and unrecorded or unrecognizable descriptions.

Results

Table 3 presents the results from the experiment. The final LME model had prime type as a fixed effect, and participant and item intercepts and participant slope for prime type as random effects. There was a significant intercept (estimate = 1.40, $SE = .40$, $z = 3.52$, $p < .001$), showing that there were more PO than DO responses. Prime type had a significant main effect (estimate = .45, $SE = .12$, $z = 3.83$,

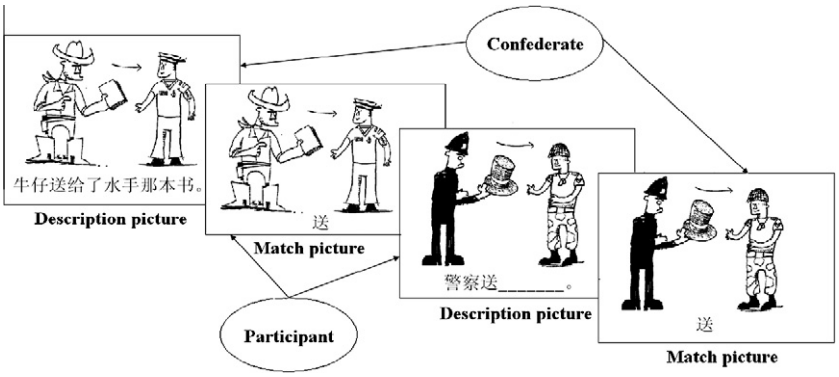

Fig. 1. The paradigm and procedure in Experiment 1. It illustrates a trial where the confederate "describes" a picture to the participant who then decides whether the prime picture he or she later sees matches the picture the confederate has "described" before he or she described his or her description picture (by completing the sentence preamble) to the confederate. The confederate's description picture has a script which means "The cowboy gave the sailor the book"; the character provided in the both match pictures means "give" and indicates the action in the pictures. The participant's description picture has a preamble literally meaning "the policeman give_____.".

Table 3
Response counts by prime condition and % of DO responses in Experiment 1.

Prime	DO	PO	*Ba*-DO	Baseline
DOs	85	24	38	59
POs	82	144	128	109
Others	1	0	2	0
% of DOs	.51	.14	.23	.35

$p < .001$), indicating that responses were affected by prime type. Pairwise comparisons (Table 4) showed that there were most DO sentences following DO primes, second most following baseline primes, third most following *Ba*-DO primes (assuming the marginal difference between baseline and *Ba*-DO reflects a real difference), and fewest following PO primes. There were too few Other responses for statistical analysis.

Discussion

As expected, DO primes yielded more DO responses and fewer PO responses than baseline primes, and PO primes yielded fewer DO responses and more PO responses than baseline primes. This indicates that the PO and DO primes in Mandarin behaved similarly to PO and DO primes in English (e.g., Pickering et al., 2002). More interestingly, *Ba*-DO primes led to fewer DO responses and more PO responses than baseline primes (though this effect was marginal). In other words, there was a tendency for *Ba*-DO sentences to prime PO responses. This finding suggests that *Ba*-DO sentences primed PO rather than DO responses. As *Ba*-DO and PO sentences share conceptual-to-linear mappings (i.e., Agent-Theme-Recipient order) but not conceptual-to-function mappings or syntactic structure, our results provide evidence for the existence of conceptual-to-linear priming. We return to the question of whether there is also a conceptual-to-function priming effect in Experiment 3.

Experiment 2

The finding of priming from *Ba*-DO sentences to PO sentences supports conceptual-to-linear mappings, but does not determine whether the these mappings are defined with respect to the absolute or relative order of thematic roles. In Experiment 2, we investigated these alternatives by examining priming following Topic-DO sentences, which share with PO sentences the relative order of thematic roles (Theme-Recipient) but not the absolute order (Theme-Agent-Recipient vs. Agent-Theme-Recipient). Under the absolute conceptual-to-linear mapping account, Topic-DO primes should not induce PO responses, relative to the baseline. Under the relative conceptual-to-

Table 4
Pairwise comparison among primes in Experiment 1.

Prime pairs	Estimate	*SE*	*z*	*p*
DO vs. baseline	1.41	.35	3.99	<.001
DO vs. *Ba*-DO	2.27	.41	5.48	<.001
DO vs. PO	4.48	.69	6.54	<.001
Baseline vs. *Ba*-DO	.87	.47	1.83	=.07
Baseline vs. PO	3.07	.68	4.55	<.001
Ba-DO vs. PO	2.22	.55	4.01	<.001

Table 5
Response counts by prime condition and % of DO responses in Experiment 2.

Prime	DO	PO	Topic-DO	Baseline
DOs	90	15	42	66
POs	74	151	120	99
Others	2	0	5	3
% of DOs	.55	.09	.26	.40

linear mapping account, in contrast, Topic-DO primes should induce PO responses, and should do so to the same extent as *Ba*-DO primes. This experiment was therefore the same as Experiment 1, except that we used a Topic-DO prime condition in place of a *Ba*-DO prime condition (see 6a–d).

6a	Niuzai song-gei le shuishou naben shu. cowboy give-to LE sailor the book. (The cowboy gave the sailor the book.)	(DO)
6b	Niuzai song le naben shu gei shuishou. cowboy give LE the book to sailor (The cowboy gave the book to the sailor.)	(PO)
6c	Naben shu niuzai song-gei le shuishou. the book cowboy give-to LE sailor (The book the cowboy gave the sailor.)	(Topic-DO)
6d	Wupo ku le. witch cry LE (The witch cried.)	(Baseline)

Method

Participants

Twenty-eight further Mandarin speakers from the University of Edinburgh community were paid £4 to take part.

Materials, procedure and scoring

These were the same as Experiment 1, except that we replaced the *Ba*-DO prime condition with the Topic-DO prime condition (see Appendix A in Supplementary material).

Results

Table 5 presents the results of the experiment. The final LME model included prime type as a fixed predictor, and random participant and item intercepts. The intercept was significant (estimate = 1.08, $SE = .32$, $z = 3.35$, $p < .001$), indicating that there were more PO than DO responses. Prime type had a significant main effect (estimate = .18, $SE = .09$, $z = 2.03$, $p < .05$). Pairwise comparisons (Table 6) showed that the highest proportion of DO responses occurred after DO primes, the next highest following the baseline, the third highest following Topic-DO primes, and the least following PO primes. There were too few Other responses for statistical analysis.

Combined analysis of Experiments 1 and 2

To determine whether Topic-DO primes in Experiment 2 had similar effects to *Ba*-DO primes in Experiment 1, we compared the two experiments, treating experiment and prime type (DO, PO, *Ba*/Topic-DO, and Baseline) as predictors. Fig. 2 shows the proportion of DO responses following the primes in the two experiments. The final model included experiment and prime type as fixed predictors, with participant and item intercepts and participant slope for prime type as random effects. LME analyses produced a significant intercept (estimate = 1.26, $SE = .28$, $z = 4.55$, $p < .001$), indicating that participants produced more PO than DO responses. The experiment factor did not have a significant main effect (estimate = .21, $SE = .48$, $z = .44$, $p > .1$), indicating similar DO and PO responses across the two experiments. Prime type had a significant main effect (estimate = .37, $SE = .08$, $z = 4.34$, $p < .001$). Pairwise comparisons (see Table 6) indicated the highest proportion of DO responses following DO primes, the next highest following the baseline, the third highest following *Ba*/Topic-DO primes, and the least following PO primes. There was no interaction between experiment and prime type (estimate = .19, $SE = .17$, $z = 1.10$, $p > .1$). Importantly, there was no difference in the priming of DO and PO responses between the Topic-DO prime in Experiment 2 and the *Ba*-DO prime in Experiment 1 (estimate = .31, $SE = .67$, $z = .46$, $p > .1$).

Discussion

As in Experiment 1, DO primes led to more DO responses and fewer PO responses than baseline primes, and PO primes led to fewer DO responses and more PO responses than baseline primes, again indicating that the PO and DO primes in Mandarin behaved similarly to PO and DO primes in English. Additionally, Topic-DO primes led to fewer DO responses and more PO responses than baseline primes. In other words, Topic-DO sentences primed PO (rather than DO) responses. Given that Topic-DO sentences and PO sentences share linear mappings but not function mappings of thematic roles, these results provide further evidence for the existence of conceptual-to-linear mapping.

Table 6
Pairwise comparisons among primes in Experiment 2 (DO, PO, Topic-DO, and Baseline) and the combined analysis (DO, PO, *Ba*/Topic-DO, and Baseline).

Prime pairs	Experiment 2				Combined analysis			
	Estimate	*SE*	*z*	*p*	Estimate	*SE*	*z*	*p*
DO vs. baseline	1.01	.29	3.48	<.001	1.25	.24	5.18	<.001
DO vs. Topic-DO (*Ba*/Topic-DO)	2.02	.32	6.36	<.001	2.28	.30	7.61	<.001
DO vs. PO	4.23	.44	9.20	<.001	5.66	.61	9.22	<.001
Baseline vs. Topic-DO (*Ba*/Topic-DO)	1.02	.31	3.27	<.01	1.03	.30	3.38	<.001
Baseline vs. PO	3.02	.43	7.05	<.001	4.41	.60	7.36	<.001
Topic-DO (*Ba*/Topic-DO) vs. PO	2.00	.42	4.74	<.001	3.38	.57	5.97	<.001

They suggest further that the relevant mappings are defined with respect to the relative order of thematic roles. Topic-DO sentences primed PO sentences, with which they shared Theme-Recipient order, even though they differed in their absolute order (Theme-Agent-Recipient vs. Agent-Theme-Recipient); moreover, they did so to the same extent as *Ba*-DO primes in Experiment 1 (which shared absolute thematic role order with PO sentences). Thus priming of conceptual-to-linear mappings in Mandarin datives appears to be tied to repetition of the relative but not absolute linear order of relevant thematic roles.

As in Experiment 1, we found no evidence of conceptual-to-function priming, which would have manifested itself as priming of DO responses following Topic-DO primes. As in Experiment 1, we cannot be certain whether the pure conceptual-to-linear mapping account is correct or whether a weaker conceptual-to-function priming effect also exists. In Experiment 3, we therefore compared primes which differed in only conceptual-to-function mapping but were similar in other relevant aspects.

Experiment 3

Experiment 3 compared Topic-DO and Topic-PO primes (e.g., 7c and 7d), which have the same (relative) conceptual-to-linear mappings (i.e., Theme-Recipient), but different conceptual-to-function mappings, with Topic-DO having the same functional mapping as DO (e.g., 7a), and Topic-PO having the same functional mapping as PO (7b). Thus, conceptual-to-function mapping predicts that Topic-DO should prime DO to a greater extent than Topic-PO primes DO.

7a	Niuzai song-gei le shuishou naben shu. cowboy give-to LE sailor the book (The cowboy gave the sailor the book.)	(DO)
7b	Niuzai song le naben shu gei shuishou. cowboy give LE the book to sailor (The cowboy gave the book to the sailor.)	(PO)
7c	Naben shu niuzai song-gei le shuishou. the book cowboy give-to LE sailor (The book the cowboy gave the sailor.)	(Topic-DO)
7d	Naben shu niuzai song le gei shuishou. the book cowboy give LE to sailor (The book the cowboy gave to the sailor.)	(Topic-PO)

In this experiment, participants listened to a pre-recorded prime sentence rather than a confederate (as in Experiments 1 and 2). This change of paradigm was due to a lack of appropriate software to control for stimuli presentation in a dialogue paradigm in Guangzhou, China, where the experiment was run.

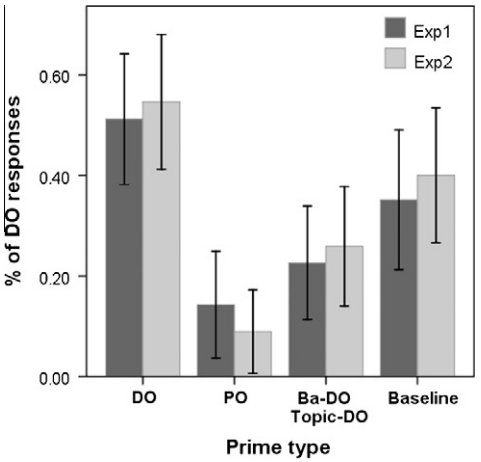

Fig. 2. Proportion of DO responses following primes in Experiments 1 and 2 (*Ba*-DO was used in Experiment 1 and Topic-DO in Experiment 2; error bar stands for 95% confidence interval in by-participant analysis).

Method

Participants

Twenty-four Mandarin speakers recruited from the student community in Guangdong University of Foreign Studies were paid 10 RMB (roughly £1) to take part in the experiment. Four participants were replaced with new participants because that they produced Other responses (see Scoring in Experiment 1) for more than one-third of the target description pictures.

Materials

We created 32 sets of experimental materials (see Appendix B in Supplementary material) and 96 sets of filler materials. Each set consisted of a prime sentence, an associated match picture (to be matched with the prime sentence), and a description picture (with a sentence preamble). These were similar to the materials in Experiment 1, except that the prime description picture was replaced with an auditory prime sentence. Experimental prime sentences were dative sentences such as those in (7a–d); they were constructed using 14 dative verbs (12 verbs used in previous experiments, plus *zeng* "bestow" and *juan* "donate"). Prime sentences (and the associated match pictures) and description pictures in the filler sets described/depicted transitive or intransitive events, except for a third of the prime sentences that were DO sentences (and their associated match pictures depicted dative events); these served to boost the DO responses, as in Experiments 1 and 2. All the prime sentences were read by a female Mandarin speaker and recorded as .wav files. The match picture and the description picture were similar to those in Experiments 1 and 2.

Procedure

The experimental procedure was similar to that in Experiments 1 and 2 (see Fig. 1), except that participants listened to pre-recorded prime sentences (rather than to descriptions produced by a confederate) and decided whether a match picture they later saw matched the sen-

tence they had listened to, before describing a description picture by repeating and completing the sentence preamble. The experiment was run using DMDX (Forster & Forster, 2003) on a computer and took about 40 min.

Scoring

This was the same as in previous experiments.

Results

Table 7 presents the results of Experiment 3. The final LME model included prime type as a fixed predictor, with participant and item intercepts and the participant slope for prime type as random effects. There was a significant intercept (estimate = .86, *SE* = .32, $z = 2.69$, $p < .01$) suggests significantly more PO than DO responses. Prime type had a significant main effect (estimate = .88, *SE* = .17, $z = 5.31$, $p < .001$). Detailed comparisons among the primes were presented in Table 8. The results suggest that DO induced more DO responses than any other prime; Topic-DO induced more DO responses than Topic-PO and PO primes, which did not differ significantly (though Topic-PO prime yielded numerically more DO responses than the PO prime). More critically, Topic-DO induced more DO responses than Topic-PO.

Discussion

Topic-DO sentences primed DO responses, relative to Topic-PO sentences (which behaved similarly to PO primes). This cannot be a priming effect based on constituent structure, because Topic-DO and DO sentences do not share constituent structure. It also cannot be due to priming of conceptual-to-linear mappings, because Topic-DO and Topic-PO sentences share conceptual-to-linear mappings (i.e., Theme-Recipient). Hence, this priming effect must be due to priming of conceptual-to-function mappings, with Topic-DO and DO sentences sharing one set of mappings (i.e., Theme to direct object and Recipient to indirect object), and Topic-PO and PO sentences sharing another (i.e., Theme to direct object and Recipient to oblique object).[5]

The experiment therefore showed the existence of conceptual-to-function mapping. However, it is unclear whether priming of conceptual-to-linear mapping also occurred alongside priming of conceptual-to-function mapping. If so, we would expect to find a smaller difference in priming between Topic-PO and PO primes (because they shared both conceptual-to-linear and conceptual-to-function mappings and differed only in constituent structure) than between Topic-DO and DO (because they shared only conceptual-to-function mapping and differed in both conceptual-to-linear mapping and constituent structure). To test this, we carried out a further LME analysis with construction (DO vs. PO) and word order (canonical vs. topic) as fixed predictors, and with participant and item intercepts and participant slopes for the two fixed effects and their interaction as random effects. Besides the significant intercept (estimate = 1.06, *SE* = .42, $z = 2.52$, $p < .05$), the significant main effect of construction (estimate = 3.27, *SE* = .42, $z = 7.84$, $p < .05$), and the marginal main effect of word order (estimate = .72, *SE* = .40, $z = 1.80$, $p = .07$), critically, there was a significant interaction between construction and word order (estimate = −2.38, *SE* = .69, $z = 2.52$, $p < .001$), which confirms that there was a larger difference in priming between DO and Topic-DO than between PO and Topic-PO. Such a finding therefore suggests that priming of conceptual-to-function mapping occurred alongside priming of conceptual-to-linear mapping.

Table 7
Response counts by prime condition and % of DO responses in Experiment 3.

	DO	PO	Topic-DO	Topic-PO
DO	136	28	80	43
PO	50	162	105	145
Other	6	2	7	4
% DO	.73	.15	.43	.23

Table 8
Pairwise comparisons among primes in Experiment 3.

	Estimate	*SE*	*z*	*p*
DO vs. Topic-DO	1.95	.39	4.95	<.001
DO vs. Topic-PO	3.87	.58	6.71	<.001
DO vs. PO	4.49	.63	7.17	<.001
Topic-DO vs. Topic-PO	1.92	.39	4.90	<.01
Topic-DO vs. PO	2.53	.51	4.94	<.001
Topic-PO vs. PO	.61	.56	1.09	=.28

General discussion

In three experiments, we examined the priming of dative structures in Mandarin between which the relative emphasis of the Recipient and the Theme do not differ. In all experiments, participants were most likely to produce DO targets after DO primes, and least likely after PO primes. But more importantly, Experiments 1 and 2 showed structural priming of mappings from conceptual representations to linear positions in the sentence structure. In Experiment 1, *Ba*-DO sentences primed PO sentences (with which they share the order of the Agent, Recipient and Theme), rather than DO sentences (with which they share grammatical function assignment), relative to an intransitive baseline. Experiment 2 similarly showed priming of PO sentences following Topic-DO sentences, which share only the relative order of the Recipient and Theme. Moreover, the magnitude of priming was the same following *Ba*-DO and Topic-DO primes. Experiment 3 showed that Topic-PO sentences primed PO sentences (with which they share both conceptual-to-function and relative conceptual-to-linear mappings) to a greater extent than Topic-DO sentences primed DO sentences (with

[5] It might be possible to attribute the priming difference between Topic-DO and Topic-PO to the order of the closed-class bound morphemes *-gei* and *-le* (as a result of linearization; Hartsuiker & Westenberg, 2000). However, there is no evidence for priming of bound morphemes (Bock, 1989; Pickering & Branigan, 1998). In addition, there is evidence that the inclusion of *le* does not affect the priming of datives in Mandarin: Cai et al. (2011) showed priming of DO responses with *–le* following DO primes without *–le*.

which they share conceptual-to-function but not conceptual-to-linear mappings).

Note that our experiments all repeated the verb between the prime and target sentences (except in the baseline conditions of Experiments 1 and 2). Some accounts of structural priming assume that priming under conditions of verb repetition involves additional processes (perhaps involving explicit memory) to those that occur when the verb is not repeated (e.g., Chang, Dell, & Bock, 2006), though others do not make a fundamental distinction (e.g., Pickering & Branigan, 1998). We repeated the verb in our experiments primarily because it greatly enhances priming, thus making it easier to distinguish the effects of different experimental conditions. Whether or not priming with and without verb repetition engage different processes, any account of language production needs to explain the effects of both forms of priming.

Taken together, these results provide evidence for priming of two types of mapping from conceptual representations to syntactic structure. Thus, speakers track mappings between conceptual representations and grammatical functions, and persist in such mappings in later utterances so that the same conceptual elements tend to be assigned the same grammatical functions. Additionally, they track mappings between conceptual representations and linear positions, and persist in such mappings so that the same conceptual elements tend to be assigned the same relative linear positions.

We now propose a model of grammatical encoding that is compatible with these results, discuss how it differs from alternative possibilities, and argue that it is consistent with evidence from language production (in particular, priming, conceptual effects on grammatical encoding, subject–verb agreement, and patterns of speech errors).

Fig. 3 depicts how a speaker constructs the PO sentence *Niuzai song le yiben shu gei shuishou* ("The cowboy gave a book to the sailor"). The conceptual message is shown at the top, and includes the semantic tokens (such as COWBOY) corresponding to the entities and the action, and thematic roles for the entities (such as the Agent). In addition, one entity (here, COWBOY) is emphasized (highlighted in a jagged cloud). This representation is then mapped onto the phrase structure shown at the bottom. Importantly, the phrase structure incorporates information about grammatical functions in the nodes (e.g., NP-Subj). The dashed arrows from the lexicon depicts lexical selection: Speakers retrieve lexical concepts, which they link to appropriate thematic roles for the message to be expressed, and their associated lemmas (the syntactic component of a lexical entry), whose contents (e.g., subcategorisation information) play an important role in generating constituent structure. The dashed arrows between the conceptual rep-

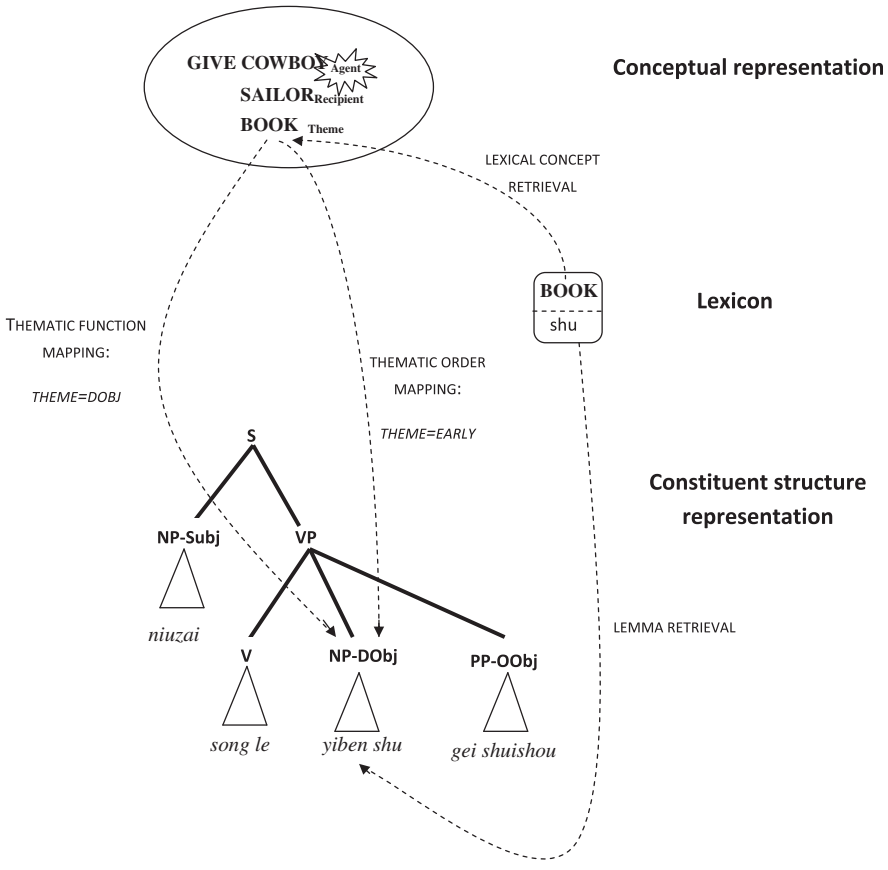

Fig. 3. A sketch of the process by which a conceptual representation is converted into a syntactic structure that encodes both grammatical functions and linear order of constituents. Subj = Subject, DObj = Direct Object, OObj = Oblique Object. The jagged cloud indicates a highlighted concept.

resentation at the top and the grammatical representation at the bottom represent mappings from the conceptual representation to the grammatical representation. Thematic order mappings allow speakers to choose between alternative word orders in order to place a particular thematic role either earlier or later in the sentence, which may enhance incremental processing (e.g., Tanaka et al., 2011). Thematic function mappings allow speakers to choose between alternative functional assignments for different thematic roles, thus allowing – for example – agents to preferentially appear as subjects (e.g., Bock & Warren, 1985; Tanaka et al., 2011).

This account explains constituent priming as the tendency to perseverate in syntactic representations, as at the bottom of Fig. 3. It explains conceptual-to-linear priming by assuming that the use of particular mappings strengthens the associations between particular thematic roles (or other conceptual information) and relative word order positions (*early* and *late* in Fig. 3). A speaker who has just placed a word representing a Theme early will tend to place another word representing a Theme early. It explains conceptual-to-function priming in the same way: A speaker who has just assigned a word representing a Theme the direct object function will tend to do the same again.

The architecture of grammatical encoding

We now discuss our account in relation to other accounts of grammatical encoding, and consider how it can accommodate previous findings in sentence production. Our proposal is a "one stage" account of grammatical encoding, in which functional and constituent-structure information are co-represented. It contrasts with traditional "two stage" theories (e.g., Bock & Levelt, 1994), in which speakers map initially from a conceptual representation to a functional representation (that does not incorporate word order), and subsequently from a functional representation to a constituent structure representation that incorporates word order. Such two-stage accounts are consistent with conceptual-to-function priming but not with conceptual-to-linear priming.

In addition, our results are incompatible with an account (that is perhaps consistent with Chomskyan linguistics) in which there is no functional representation, and where speakers map directly from a conceptual representation to a constituent structure representation that incorporates word order (but does not incorporate functional information). This one-stage account is consistent with conceptual-to-linear priming but is not consistent with conceptual-to-function priming. (In fact, it would also not be consistent with Tanaka et al., 2011.)

Our results are compatible with an account in which the speaker uses conceptual information to construct functional and constituent-structure representations in parallel. The speaker would then map from these two distinct representations onto a common phonological representation during phonological encoding. However, it is not clear what role the functional representation would play in this process, because word order is specified in the constituent-structure representation, and presumably information about intonation is specified at the conceptual level or in constituent structure.

Thus the most likely possibility is that speakers construct a single syntactic representation incorporating both constituent-structure information (including word order) and functional information. Such an account is consistent with Chomskyan proposals that involve complex phrase-structure trees and in which functions are defined in terms of their position within a phrase-structure tree (but are not central to linguistic analysis). But on the basis of the evidence against such complex syntactic representations in language production (e.g., Bock et al., 1992), we favor an account involving a "simple" phrase-structure tree which is augmented with functional information (and where linguistic analysis might depend on constituent-structure position, function, or both), as illustrated in Fig. 3.

Such integrated representations then serve as the basis for syntactic generalizations. For example, bound pronouns refer to c-commanding antecedents in a way that is "read off" the constituent-structure aspect of the representation, whereas verbs agree with their subjects in a way that can be "read off" the functional information (the "labels"). This representation can also then be fed into the phonological representation. Note that this integrated representation is compatible with linguistic accounts (e.g., Lexical Functional Grammar; Bresnan & Kaplan, 1982) that assume functional and constituent-structure representations; in this account, these can be seen as different components to a single representation rather than different stages in production.

Explaining evidence from language production

We first consider evidence from structural priming. Priming of emphasis (Bernolet et al., 2009; Vernice et al., in press) is straightforwardly explained in terms of priming at the conceptual level, with speakers tending to repeat the assignment of emphasis to particular thematic roles, and speakers then choosing syntactic alternatives that are compatible with that emphasis (e.g., passives or left-dislocations when the Patient is emphasized). Priming of bindings between conceptual and syntactic information, such as the effects found in the current experiments and previous studies (e.g., Bock et al., 1992; Chang et al., 2003; Hare & Goldberg, 1999), is explained in terms of perseveration of mappings from the conceptual representation to the syntactic representation. Note that it may not be the case that all conceptual-to-syntactic mappings always perseverate. Some previous studies suggest thematic-to-syntactic priming (e.g., Chang et al., 2003; Hare & Goldberg, 1994). In contrast, only one study has found animacy-to-syntactic priming (Bock et al., 1992), and other studies have found no such effect (Bernolet et al., 2009).

The present study demonstrates conceptual-to-syntactic mappings (both conceptual-to-function and conceptual-to-linear) but does not determine whether the conceptual mapping is based on thematic repetition, repetition of animacy, or both. In our experiments, the Themes were always inanimate and the Recipients were always animate (in keeping with the animacy features that are typically associated with Theme and Recipient roles). Hence it is possible that the effects that we have character-

ized in terms of thematic role mappings could instead be based on mappings of animacy features. However, given the strong evidence for priming associated with thematic roles, and the correspondingly weak evidence for priming associated with animacy features reviewed above, we suggest that thematic-to-syntactic priming constituted at least a large component of the priming that we observed.

Finally, priming of phrase structure (e.g., Bock, 1986; Pickering & Branigan, 1998) is explained in terms of priming at the syntactic level. Priming of this level explains why speakers tend to repeat choice of phrase structure, irrespective of conceptual/semantic information (Bock & Loebell, 1990; Messenger et al., 2011).

In this account, priming at more than one level can co-occur. This account can therefore explain Pickering et al.'s (2002) finding that a shifted-PO construction (i.e., V PP NP), which shares conceptual-to-function mappings with a PO construction but conceptual-to-linear mappings with a DO sentence, primes neither a PO nor a DO sentence. Following Pickering et al., we assume the shifted-PO prime does not syntactically prime either construction. But we now propose that it simultaneously primes the PO construction (via the conceptual-to-function mappings) and the DO construction (via the conceptual-to-linear mappings); Pickering et al. proposed that these effects cancelled each other out, yielding no overall priming effect. This explanation is also consistent with the results of our Experiment 3, which showed both conceptual-to-function and conceptual-to-linear mappings. Note that in Experiments 1 and 2, conceptual-to-linear mappings appeared to outweigh conceptual-to-function mappings, unlike Pickering et al. This discrepancy may reflect a cross-linguistic difference, with the more flexible word order of Mandarin than English emphasizing conceptual-to-linear mappings, resulting in stronger conceptual-to-linear priming.

Of course, independent conceptual-to-function and conceptual-to-linear priming may favor the same structure. In our account, Chang et al.'s (2003) finding that *spray-with* sentences and *spray-on* sentences primed differently, despite sharing constituent structure, occurred because they differ in both conceptual-to-function mappings and conceptual-to-linear mappings. Thus *spray-with* sentences prime other *spray-with* sentences not only in terms of conceptual-to-function mappings (as Chang et al. argued), but also in terms of conceptual-to-linear mappings.

Hare and Goldberg (1999) showed long-term priming from *provide-with* sentences to DO responses. On our account, this must be due to the priming of conceptual-to-linear mappings, with these mappings (eventually) trumping both syntactic priming and conceptual-to-function mapping priming. Salamoura and Williams (2007) found that similar effects occur in short-term cross-linguistic priming.

The assumption that priming can co-occur at different levels also suggests a different interpretation of a number of findings of cross-language structural priming. Bernolet et al. (2009) found that the Dutch PP-initial passive, a construction which has the Patient to subject and the Agent to oblique object functional mappings, but Agent-Patient ordering, behaved similarly to the baseline, priming neither actives nor passives in English. Though it is possible that this pattern reflected equal emphasis on the Agent and the Patient, in our account, the PP-initial passive might have primed actives on the basis of thematic emphasis and/or thematic order, and primed passives on the basis of functional mapping of thematic roles, with the two effects cancelling each other out. Finally, active sentences with object-verb-subject order (e.g., *Baletnicę przygniata sportowiec*, meaning The ballet dancer$_{OBJ}$ squashes the sportsman$_{SUBJ}$ in Polish) prime English passives (Fleischer, Pickering, & McLean, in press; see also Hartsuiker, Pickering, & Veltkamp, 2004; Heydel & Murray, 2000). These results could reflect cross-linguistic conceptual-to-linear priming (rather than conceptual-to-function priming). However, they could also be due to priming of thematic emphasis (of the Patient).

This account is also compatible with evidence that conceptually prominent entities tend (under certain circumstances at least) to be realized as subjects (e.g., Bock & Warren, 1985; Clark, 1965) or early in the sentence (e.g., Branigan & Feleki, 1999; Kempen & Harbusch, 2004), and in some cases both (Tanaka et al., 2011). The existence of mappings from conceptual representations both to grammatical functions and to linear positions means that conceptual features can be realized through both aspects of structure. As we have noted, the relative weighting of conceptual-to-function and conceptual-to-linear mappings (and hence the extent to which conceptual features such as animacy may be consistently realized in grammatical function assignments versus linear order assignments) may differ from language to language on the basis of language-specific characteristics (e.g., word-order flexibility).This account can also explain evidence from subject–verb agreement. Some aspects of agreement appear to be semantic in nature (e.g., distributivity effects; Eberhard, 1999) and those effects are best explained at a conceptual level. Other effects appear to be syntactic in nature, and these are best explained at the syntactic level in our model, which includes information about grammatical functions, hierarchical structure, and – critically – word order. This model can therefore explain why agreement is affected by linear order (Haskell & MacDonald, 2005), with intervening and non-intervening NPs yielding different types of interference (Staub, 2010). We suggest that the finding of comparable numbers of errors in declarative sentences and inverted questions (Vigliocco & Nicol, 1998) does not reflect the existence of an unordered level of syntactic representation, but rather results from two distinct sources of difficulty (linear intervention and non-canonical word order respectively) that lead to similar levels of errors, hence cancelling each other out.

Our model can also account for other kinds of speech errors. Speakers may make errors in the mapping between the conceptual representation and the syntactic representation. This can result in NPs being assigned the wrong grammatical function (with morphological processing being based on this assignment, so that the NP ends up with the correct morphology for the grammatical function it has actually been assigned, e.g., *He likes her* where *She likes him* was intended). Such errors are well attested in speech error corpora (e.g., Garrett, 1980). Additionally, NPs might be assigned the wrong linear position, so that they end up in – for example – an unemphasized position

where an emphasized position was intended. Most speech error evidence comes from languages such as English that have restricted word order variation, and such errors would not necessarily be detectable, but our account predicts that they should occur under some circumstances, in languages with more flexible word order. Other errors, such as sound exchanges and perseverations, which appear insensitive to semantic and grammatical information, would occur at a subsequent stage of morphophonological processing (which is outside the scope of our model).

In conclusion, we found that different components of structural priming can co-occur, with ultimate choice of structure being simultaneously influenced by persistent conceptual-to-function mappings, conceptual-to-linear mappings, and constituent structure. These results provide evidence that the processor maps conceptual representations such as thematic roles onto both surface syntactic positions and grammatical functions. They support a one-stage model of grammatical encoding, where the processor converts a conceptual representation into a structure which specifies both linear order and grammatical functions. Overall, our experiments suggest that structural priming can be used to map out details of language production.

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A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jml.2012.03.009.

References

Baayen, R. H. (2008). *Analyzing linguistic data: A practical introduction to statistics using R*. Cambridge: Cambridge University Press.

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language, 59*, 390–412.

Bernolet, S., Hartsuiker, R. J., & Pickering, M. J. (2009). Persistence of emphasis in language production: A cross-linguistic approach. *Cognition, 112*, 300–317.

Bock, J. K. (1986). Syntactic persistence in language production. *Cognitive Psychology, 18*, 355–387.

Bock, J. K. (1987). An effect of the accessibility of word forms on sentence structures. *Journal of Memory and Language, 26*, 119–137.

Bock, J. K. (1989). Closed-class immanence in sentence production. *Cognition, 31*, 163–186.

Bock, J. K., & Griffin, Z. M. (2000). The persistence of structural priming: Transient activation or implicit learning? *Journal of Experimental Psychology: General, 129*, 177–192.

Bock, J. K., & Levelt, W. J. M. (1994). Language production: Grammatical encoding. In M. A. Gernsbacher (Ed.), *Handbook of psycholinguistics* (pp. 945–984). San Diego: Academic Press.

Bock, J. K., & Loebell, H. (1990). Framing sentences. *Cognition, 35*, 1–39.

Bock, J. K., Loebell, H., & Morey, R. (1992). From conceptual roles to structural relations: Bridging the syntactic cleft. *Psychological Review, 99*, 150–171.

Bock, J. K., & Warren, R. K. (1985). Conceptual accessibility and syntactic structure in sentence formulation. *Cognition, 21*, 47–67.

Branigan, H. P., & Feleki, E. (1999). Conceptual accessibility and serial order in Greek language production. In *Proceedings of the 21st conference of the cognitive science society*. Vancouver.

Branigan, H. P., Pickering, M. J., & Cleland, A. A. (2000). Syntactic co-ordination in dialogue. *Cognition, 75*, B13–B25.

Bresnan, J., & Kaplan, R. M. (1982). Introduction: Grammars as mental representations of language. In J. Bresnan (Ed.), *The mental representation of grammatical relations* (pp. xvii–lii). Cambridge, MA: MIT Press.

Cai, Z. G., Pickering, M. J., Yan, H., & Branigan, H. P. (2011). Lexical and syntactic representations in closely related languages: Evidence from Mandarin and Cantonese. *Journal of Memory and Language, 65*, 431–445.

Cai, Z. G., Pickering, M. J., & Sturt, P. (in press). Processing verb-phrase ellipsis in Mandarin Chinese: Evidence against the syntactic account. *Language and Cognitive Processes*. http://dx.doi.org/10.1080/01690965.2012.665932.

Chang, F., Bock, J. K., & Goldberg, A. (2003). Can thematic roles leave traces of their places? *Cognition, 90*, 29–49.

Chang, F., Dell, G. S., & Bock, K. (2006). Becoming syntactic. *Psychological Review, 113*, 234–272.

Chao, Y.-R. (1968). *A grammar of spoken Chinese*. Berkeley: University of California Press.

Clark, H. H. (1965). Some structural properties of simple active and passive sentences. *Journal of Verbal learning and Verbal Behavior, 4*, 365–370.

Clark, H. H., & Begun, J. S. (1971). The semantics of sentence subjects. *Language and Speech, 14*, 34–46.

Culicover, P., & Jackendoff, R. (2005). *Simpler syntax*. Oxford: Oxford University Press.

Dewart, M. H. (1979). Role of animate and inanimate nouns in determining sentence voice. *British Journal of Psychology, 70*, 135–141.

Eberhard, K. M. (1999). The accessibility of conceptual number to the processes of subject–verb agreement in English. *Journal of Memory and Language, 41*, 560–578.

Ferreira, V. S. (2003). The persistence of optional complementizer production: Why saying "that" is not saying "that" at all. *Journal of Memory and Language, 48*, 379–398.

Fleischer, Z., Pickering, M. J., & McLean, J. F. (in press). Shared information structure: Evidence from cross-linguistic priming. *Bilingualism: Language and Cognition*. http://dx.doi.org/10.1017/S1366728911000551.

Forster, K. I., & Forster, J. C. (2003). DMDX: A window display program with millisecond accuracy. *Behavior Research Methods, Instruments & Computers, 35*, 116–124.

Garrett, M. F. (1980). Levels of processing in sentence production. In B. Butterworth (Ed.). *Language production* (Vol. 1, pp. 177–220). London: Academic Press.

Givón, T. (1993). *English grammar: A function-based introduction*. Amsterdam and Philadelphia: Benjamins.

Hare, M. L., & Goldberg, A. E. (1999). Structural priming: Purely syntactic? In M. Hahn & S. C. Stones (Eds.), *Proceedings of the 21st annual meeting of the cognitive science society* (pp. 208–211). Mahwah, NJ: Erlbaum.

Harris, M. (1978). Noun animacy and the passive voice: A developmental approach. *Quarterly Journal of Experimental Psychology, 30*, 495–501.

Hartsuiker, R. J., Pickering, M. J., & Veltkamp, E. (2004). Is syntax separate or shared between languages? Cross-linguistic syntactic priming in Spanish–English bilinguals. *Psychological Science, 15*, 409–414.

Hartsuiker, R. J., & Westenberg, C. (2000). Word order priming in written and spoken sentence production. *Cognition, 75*, B27–B39.

Haskell, T. R., & MacDonald, M. C. (2005). Constituent structure and linear order in language production: Evidence from subject verb agreement. *Journal of Experimental Psychology: Learning Memory and Cognition, 35*, 891–904.

Heydel, M., & Murray, W. S. (2000). Conceptual effects in sentence priming: A cross-linguistic perspective. In M. De Vincenzi & V. Lombardo (Eds.), *Cross-linguistic perspectives on language processing* (pp. 227–254). Dordrecht, The Netherlands: Kluwer.

Jaeger, T. F. (2008). Categorical data analysis: Away from ANOVAs (transformation or not) and towards logit mixed models. *Journal of Memory and Language, 59*, 434–446.

Kempen, G., & Harbusch, K. (2004). A corpus study into word order variation in German subordinate clauses: Animacy affects

linearization independently of grammatical function assignment. In T. Pechmann & C. Habel (Eds.), *Multidisciplinary approaches to language production* (pp. 173–181). Berlin: Mouton de Gruyter.

Konopka, A. E., & Bock, K. (2009). Lexical or syntactic control of sentence formulation? Structural generalizations from idiom production. *Cognitive Psychology, 58*, 68–101.

Levelt, W. J. M. (1989). *Speaking: From intention to articulation*. Cambridge, MA: MIT Press.

Li, C. N., & Thompson, S. A. (1981). *Mandarin Chinese: A functional reference grammar*. Berkeley: University of California Press.

MacWhinney, B., St. James, J. D., Schunn, C., Li, P., & Schneider, W. (2001). STEP – A system for teaching experimental psychology using E-Prime. *Behavior Research Methods, Instruments & Computers, 33*, 287–296.

McDonald, J. L., Bock, K., & Kelly, M. H. (1993). Word and world order: Semantic, phonological, and metrical determinants of serial position. *Cognitive Psychology, 25*, 188–230.

Messenger, K., Branigan, H. P., & McLean, J. F. (2011). Evidence for (shared) abstract structure underlying children's short and full passives. *Cognition, 121*, 268–274.

Onishi, K. H., Murphy, G. L., & Bock, K. (2008). Prototypicality in sentence production. *Cognitive Psychology, 56*, 103–141.

Pickering, M. J., & Branigan, H. P. (1998). The representation of verbs: Evidence from syntactic priming in language production. *Journal of Memory and Language, 39*, 633–651.

Pickering, M. J., Branigan, H. P., & McLean, J. F. (2002). Constituent structure is formulated in one stage. *Journal of Memory and Language, 46*, 586–605.

Pickering, M. J., & Ferreira, V. S. (2008). Structural priming: A critical review. *Psychological Bulletin, 134*, 427–459.

Pollard, C., & Sag, I. A. (1994). *Head-driven phrase structure grammar*. Chicago: University of Chicago Press.

Salamoura, A., & Williams, J. N. (2007). Processing verb argument structure across languages: Evidence for shared representations in the bilingual lexicon. *Applied Psycholinguistics, 28*, 627–660.

Shi, D. (2000). Topic and topic-comment constructions in Mandarin Chinese. *Language, 76*, 383–408.

Shin, J. A., & Christianson, K. (2009). Syntactic processing in Korean–English bilingual production: Evidence from cross-linguistic structural priming. *Cognition, 112*, 175–180.

Sridhar, S. N. (1988). *Cognition and sentence production: A cross-linguistic study*. New York: Springer-Verlag.

Staub, A. (2010). Response time distributional evidence for distinct varieties of number attraction. *Cognition, 114*, 447–454.

Tanaka, M., Branigan, H. P., McLean, J. F., & Pickering, M. J. (2011). Conceptual influences on word order and voice in sentence production: Evidence from Japanese. *Journal of Memory and Language, 65*, 318–330.

Vernice, M., Pickering, M. J., & Hartsuiker, R. J. (in press). Thematic emphasis in language production. *Language and Cognitive Processes*. http://dx.doi.org/10.1080/01690965.2011.572468.

Vigliocco, G., & Nicol, J. (1998). Separating hierarchical relations and word order in language production: Is proximity concord syntactic or linear? *Cognition, 68*, B13–B29.

Wang, L. (1954). *Zhongguo yufa lilun [Theory of Chinese grammar]*. Beijing: Zhonghua shuju.