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Syntactic representation is independent of semantics in Mandarin

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Syntactic representation is independent of semantics in Mandarin:

Evidence from syntactic priming

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Abstract

Theories of language processing generally assume that speakers construct independent representations for syntactic and semantic information, based largely on evidence from English and related languages. But it is not clear whether the assumption of autonomous syntactic representations extends to other languages with different typological characteristics. We therefore conducted two structural priming studies investigating production of dative sentences in Mandarin, a language whose interpretation appears to be more reliant on non-relational (intrinsic) semantics (e.g., animacy features). We examined whether participants' tendency to repeat syntax was affected by whether the theme and recipient arguments matched or mismatched in animacy across prime and target. Participants repeated syntax to the same extent irrespective of whether prime and target arguments had matched or mismatched animacy. These findings provide evidence that the separation of syntactic and semantic representations occurs in Mandarin and therefore may occur across languages.

Keywords: Mandarin, Animacy, Syntax, Structural Priming

When people comprehend or produce language, they have to determine both the semantics and the syntax of an utterance. Most linguistic theories assume independent representations of semantics and syntax. And theories of language processing follow their lead in assuming that people compute independent representations. On such accounts, comprehenders use the syntactic properties of each word to construct an autonomous syntactic representation that helps them to determine "relational" semantics – that is, who does what to whom. Conversely, speakers use a relational semantic representation (sentence meaning) to construct an autonomous syntactic representation.

But do speakers of all languages behave in the same way? These theories of language processing are primarily based on languages such as English, in which the structure and interpretation of sentences is greatly constrained by syntactic cues such as word order and/or inflection. But in languages such as Mandarin Chinese, such cues are typically not available and comprehenders need to rely on "non-relational" (or intrinsic) semantic properties, such as animacy – for example, assuming that an entity higher up the animacy hierarchy is the agent in a particular sentence (and likely to be the sentence subject), whereas an entity lower down the animacy hierarchy is the patient or theme (and likely to be an object; see Branigan, Pickering, & Tanaka, 2008). Therefore, comprehenders may combine the syntactic properties and non-relational semantic properties of words into an integrated representation that helps them to determine relational semantics. In a similar way, producers may use sentence meaning to construct

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integrated representations of syntax and non-relational semantics, without at any point constructing an autonomous syntactic representation.

In this paper, we report two structural priming experiments that investigate whether Mandarin-speaking participants describe pictures using sentences that are related to sentences they have just comprehended. If participants construct autonomous syntactic representations (as in English; the *autonomous account*), then they should repeat syntactic structure; but if they construct integrated syntactic-semantic representations (the *integrated account*), then they should repeat syntactic structure only if by doing so they also repeat non-relational semantics – in our experiments, animacy. The experiments specifically use conditions that manipulate the order of constituents that differ in animacy, as this provides the strongest investigation of the role of non-relational semantics.

Need syntax and semantics be separate? Evidence from Mandarin

There is considerable reason to question whether Mandarin speakers construct autonomous syntactic representations (and hence whether autonomous syntax is universal). Although linguistic theories typically assume that semantics and syntax are separate and constitute largely independent components of a general theory of language (e.g., Chomsky, 1965, 1995; Pollard & Sag, 1994), many linguists who study Mandarin have suggested that syntax is more sensitive to semantic information (e.g., animacy) in Mandarin than in languages such as English (Lu, 1997; Ma, 1998; Shao, 1998; Xing, 1995; Xu, 2000;

Zhang, 1997a, b), and so the syntactic representations assumed for languages such as English are not appropriate for Mandarin (e.g., LaPolla, 1993, 1995). Specifically, it may be that syntactic and non-relational semantic information are included in an integrated representation in Mandarin.

Many researchers have also highlighted Mandarin's pervasive ambiguity, and the implications of this ambiguity for processing. 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, analogous to *group* (noun) versus *group* (verb) in English. At the same time, it does not morphologically mark syntactic category or syntactic features such as person, number, case, or tense. Instead, information about verb tense and aspect, word-class subcategorization, and phrase grouping is conveyed by markers that need not be adjacent to the elements that they mark (Chu, 1998; Li & Thompson, 1989) and may therefore be ambiguous (e.g., regarding which verb they mark). As a result, a sentence may have many possible interpretations. For example, *Zhuangdaole siji de che,* 'hit-LE driver DE car' can mean either that the driver was hit by the car or that the driver's car was hit by someone, depending on the context. Moreover, there is considerable ambiguity in the spoken language (because of extensive homophony) and in the written language (with respect to how sequences of characters are grouped; Yang, Perfetti, & Liu, 2010). Together, these characteristics mean that relational semantics cannot easily be determined in Mandarin without recourse to non-relational semantic information, such as

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animacy. Accordingly, some researchers have suggested that comprehenders must rely on non-relational semantics to a much greater extent when interpreting sentences in Mandarin than in languages such as English (Hoosain, 1991).

Consistent with this claim, Mandarin comprehenders rely greatly on non-relational semantic information (and specifically animacy) over syntactic information when determining who did what to whom (Cai & Dong, 2007; Chen, Chen, & He, 2012; Li, 1996; Li, Bates, & MacWhinney, 1993; Miao 1981, 1986). For example, when comprehending sequences of words that included nonsense verbs (e.g., *lightning girl pesit*), animacy accounted for 77% of the variance in Mandarin speakers' interpretations (with word order accounting for 13%), compared to 17% for English speakers (with word order accounting for 86%; Cai & Dong, 2007). Similarly, Li et al. found that when participants listened to sentences involving two nouns and a verb in different orders (e.g., *xi damen nanhai,* 'wash door boy'), they tended to rely more on animacy than word order as a cue to determine which noun was the agent, and their reaction times were influenced more strongly by animacy than by word order.

Other evidence shows different patterns of ERP components for sentences that involve anomalous syntactic and non-relational semantic features in Mandarin versus German and French. German and French speakers showed P600 effects but not N400 effects when they encountered a word whose syntactic and non-relational semantic features were anomalous, suggesting that

failure to resolve syntactic category information prevented semantic integration (Friederici, Steinhauer, & Frisch, 1999; Isel, Hahne, Maess, & Friederici, 2007; see Friederici, 2011). In contrast, Mandarin speakers showed both P600 and N400 effects, consistent with the detection of both syntactic and semantic anomalies (Liu et al., 2010; Zhang et al., 2010, 2013) and suggesting that semantic processing was not dependent on successful syntactic processing.

In sum, these results support the importance of non-relational semantic information in Mandarin sentence processing. They are clearly consistent with the integrated account, under which comprehenders would construct representations that contained both semantic and syntactic information within the same representation (i.e., tree structures whose nodes specify both syntactic and semantic features). In contrast, the autonomous account would require Mandarin speakers to independently process syntax even in cases where it is difficult to propose syntactic representations with any degree of confidence.

But these results do not provide direct evidence for the integrated account. In particular, they do not demonstrate whether Mandarin speakers construct syntactic representations that are independent of non-relational semantic information (i.e., tree structures whose nodes specify only syntactic features), nor do they determine the specific role of such semantic information during language processing. In fact, evidence that Mandarin speakers do construct autonomous syntactic representations would provide strong support for the universality of such representations.

Constructing representations during processing

According to the autonomous account, people construct separate syntactic and semantic representations during production or comprehension (e.g., Bock, 1986; Frazier & Rayner, 1982; Levelt, 1989; MacDonald, Pearlmutter, & Seidenberg, 1994). For *The doctor gave a book to the teacher* (a prepositional object or *PO* sentence), they construct a syntactic representation, for example containing a verb phrase consisting of a verb (for *give*), a noun phrase (for *a book*), and a prepositional phrase (for *to the teacher*) in that order (V NP PP). The representation does not contain semantic information about the roles that the entities play in the utterance (e.g., that the teacher is the recipient). Most important for present purposes, it also does not contain information about the entities' intrinsic semantic properties (e.g., that the teacher is animate). Thus people may construct separate representations of semantics (e.g., teacher is animate, book is inanimate) and syntax (e.g., V NP PP), but they do not construct an integrated representation – for example, verb followed by inanimate noun phrase followed by animate prepositional phrase (i.e., V NP_{INAN} PP_{AN}).

Evidence for autonomous syntactic representations comes from many sources. Some such evidence, such as syntactically well-formed but semantically anomalous exchange errors (e.g., *leave the desk on my briefcase;* Garrett, 1980), and agreement errors that depend on syntax rather than semantics (e.g., Bock & Eberhard, 1993), is consistent with autonomous syntactic representations but

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potentially difficult to interpret (e.g., regarding the precise locus of the effect). But most recent evidence comes from *structural priming* effects, or people's tendency to repeat aspects of linguistic structure (see Pickering & Ferreira, 2008, for a review). Bock (1986) had participants repeat sentences and describe pictures under the guise of a running recognition memory task and found that they were more likely to use a sentence that used a *double object* (DO) structure to describe a picture of a dative event (e.g., *The girl is handing the man a paintbrush*) after repeating an unrelated sentence that also used a DO structure (e.g., *The rock star sold the undercover cop some cocaine*) than after a sentence that used a PO structure (*The rock star sold some cocaine to the undercover cop*). Such priming also occurs during comprehension (Branigan, Pickering, & McLean, 2005; Arai, Van Gompel, & Scheepers, 2007) and between comprehension and production (Branigan, Pickering, & Cleland, 2000). Importantly, very similar priming effects occur in many languages, and Mandarin is no exception (e.g., Cai, Pickering, Yan, & Branigan, 2011; Huang, Pickering, Yang, Wang, & Branigan, 2016; see Branigan & Pickering, 2017; Pickering & Ferreira, 2008).

For Indo-European languages, structural priming provides evidence that speakers construct autonomous syntactic representations (i.e., containing syntactic information but not semantic information). It occurs without repetition of words (Bock, 1989), and when there is no semantic difference between the alternative forms, such as main-auxiliary verb versus auxiliary-main verb order in Dutch subordinate clauses (Hartsuiker & Westenberg, 2000) or presence

versus absence of the complementizer *that* (Ferreira, 2003). Priming based on relational semantics does occur (e.g., priming where the constituent corresponding to the patient occurs in the sentence, or whether it receives emphasis; Bernolet, Hartsuiker, & Pickering, 2009; Chang, Bock, & Goldberg, 2003). But such effects appear to be largely independent of syntactic priming. Bock and Loebell (1990) found that speakers tended to repeat syntactic structure irrespective of whether the two sentences involved different relational semantics (e.g., *The plane was landing by the control tower – The boy was woken by the alarm clock*).

Similarly, Messenger, Branigan, McLean, and Sorace (2012) found that children and adults repeated syntactic structure to the same extent irrespective of whether the sentences involved the same relational semantics (e.g., both sentences involved agent-patient roles: *The witch is being lifted by the bear – The king is getting licked by the cow;* or the prime involved theme-experiencer roles and the target involved agent-patient roles: *The girl is being shocked by the sheep – The king is getting licked by the cow*). Together, these studies suggest that in languages such as English and Dutch, priming occurs over representations that include syntactic information (with respect to grammatical category and construction type, e.g., V NP PP) but not representations that integrate syntax and relational semantics (e.g., V NP PP$_{LOCATION}$).

Most studies of Germanic languages lead to similar conclusions about non-relational semantics – in other words, that priming occurs over representations that include syntactic information but not non-relational semantic information.

Priming is not dependent on repetition of animacy in the production of English and Dutch transitive sentences, German dative sentences, and English locatives (Bernolet et al., 2009; Bock, Loebell, & Morey, 1992; Köhne, Pickering, & Branigan, 2014; Ziegler & Snedeker, 2018), or the comprehension of English datives (Carminati, van Gompel, Scheepers, & Arai, 2008).

Two studies have found evidence for animacy effects on syntactic priming. Gámez and Vasilyeva (2015) found that five-to-six-year-old children were more likely to produce passive sentences after hearing passive sentences when the prime and target sentences had the same configuration of animacy features (e.g., animate patient and inanimate agent) than when they had different configurations (e.g., Prime: animate agent and inanimate patient; Target: inanimate agent and animate patient). These results are consistent with young children using integrated representations. Ziegler and Snedeker (2018) found that animacy matches contributed to the priming of locatives (e.g., *The boy sprayed the cologne on the man* vs. *the man with the cologne*) by locatives and datives by locatives (and indeed the latter occurred only in the context of an animacy match). But these effects demonstrate effects of animacy on thematic roles, rather than animacy on syntactic structure. Thus, the substantial body of adult data suggests that adult speakers of many languages construct syntactic representations (e.g., VP[V NP NP] and VP[V NP PP]) that do not contain non-relational (or indeed relational) semantic information, rather than integrated representations containing non-relational (or indeed relational) semantic information (e.g., VP[V NP_{AN} NP_{IN}] and VP[V NP_{IN} PP_{AN}]).

The representation of syntactic and non-relational semantic information in Mandarin

But what about Mandarin speakers? Given previous claims about the centrality of non-relational semantic information (and specifically animacy) in processing Mandarin sentences, they might show a different pattern. That is, they might use the syntactic and semantic information associated with lexical entries to build representations such as VP[V NP_{IN} PP_{AN}], in which syntactic information about phrasal category is represented alongside non-relational semantic information. If so, participants should tend to repeat syntax when prime and target are matched for animacy, but not when they are not matched for animacy (because different representations would be implicated, e.g., VP[V NP_{IN} PP_{AN}] in one case vs. VP[V NP_{AN} PP_{IN}] in the other).

Huang et al. (2016) investigated dative priming in Mandarin when the target had an animate recipient and the prime had either an animate or an inanimate recipient. Using a recognition memory paradigm (Bock, 1986), participants described target pictures using a PO sentence (e.g., *Qiufan jiao le shouqiang gei jingcha*; 'the prisoner handed the gun to the police') or a DO sentence (*Qiufan jiao gei jingcha shouqiang*; 'the prisoner handed the police the gun'). They tended to repeat the structure of the prime. But more importantly, priming occurred to the same extent 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'). Similar effects

occurred whether the verb was repeated or not, and in an experiment in which the recipient could not be interpreted as incorporating any animacy feature (e.g., *Huanbaozhe song le yixie zhibei gei shamo*; 'the environmentalist gave plants to the desert').

These findings are consistent with priming based on autonomous syntactic representations such as VP[V NP PP] (and non-relational and relational semantic information being specified in purely semantic representations, e.g., Agent$_{AN}$, Theme$_{IN}$, Recipient$_{AN}$). But Huang et al.'s (2016) study does not rule out the possibility of some form of integrated representation. In the mismatched animacy conditions, the prime and target sentences differed with respect to the animacy of the recipient, but the animacy of the theme (and agent) was the same. Priming might therefore have been based on integrated representations whose syntactic features matched between prime and target, and whose non-relational semantic features partially matched (e.g., VP[V NP$_{IN}$ PP$_{IN}$] and VP[V NP$_{IN}$ PP$_{AN}$], with this partial match being sufficient to give rise to priming (see Chang, Baumann, Pappert, & Fitz, 2015, for evidence supporting priming of purely syntactic representations on the basis of partial matching). This possibility is strengthened by evidence that priming effects based on syntax are typically strong (Pickering & Ferreira, 2008) and can override priming effects based on relational semantics (see Chang et al., 2003); matching syntactic features might similarly 'trump' mismatching non-relational semantic features.

To construct the strongest test of whether non-relational semantic information is represented alongside syntactic information, we need to investigate syntactic priming when there is no overlap of non-relational semantic features between prime and target. In the present study, we asked whether participants were primed to use PO and DO structures to describe target events involving inanimate themes and animate recipients after comprehending PO sentences that involved the same (repeated) animacy (Theme$_{IN}$, Recipient$_{AN}$) or reversed animacy (Theme$_{AN}$, Recipient$_{IN}$).

If the repeated- and animacy-reversed conditions showed similar priming, then it would suggest that syntactic representation in Mandarin is indeed independent of non-relational semantic information. If instead there was priming in the repeated-animacy conditions but not in the reversed-animacy conditions, it would conversely suggest that syntax and non-relational semantics are integrated in Mandarin. A third possibility is that priming might occur in both the repeated-animacy and reversed-animacy conditions, but would be larger in the repeated-animacy conditions. This pattern would suggest that non-relational semantic information plays a more important role than syntactic information in Mandarin processing, and would be consistent with the existence of integrated syntactic-semantic representations.

Note that any effect of animacy order would further imply that Mandarin speakers use representations that specify the order of non-relational semantic features. There is contradictory evidence about whether representations specifying non-relational semantic information can themselves be primed. Bock et al. (1992) found priming based on animacy – <mark>effects that they interpreted in</mark>

terms of bindings between animacy and grammatical relations (e.g., whether the subject is animate), but which could also reflect priming of animacy order (e.g., whether the first mentioned entity is animate). Cai et al. (2012) interpreted a priming effect for Mandarin datives as showing relational priming (of the order of the patient and recipient thematic roles), though their effect could have reflected non-relational priming (since the patient was inanimate and the recipient was animate). But other studies have not found effects of animacy on order or indeed grammatical relations (Bernolet et al., 2009; Köhne et al., 2014). It is therefore unclear whether priming of animacy order takes place, either in Mandarin or indeed other languages.

We therefore conducted two experiments in which Mandarin-speaking participants read prime sentences and produced target descriptions of pictures describing dative events. We manipulated both the syntactic structure of the prime sentence and the order of animate and inanimate arguments. The pattern of results would indicate whether participants were primed to repeat syntactic structure independent of animacy, or whether they repeated the order of animate and inanimate arguments.

Experiment 1

Method

Participants

To estimate the necessary number of participants to achieve high power. in the present study, we used the SIMR package in R (Green & MacLeod, 2016) to calculate the observed power of priming effect in Huang et al.,2016 (Experiment 5) in which the materials, procedure, dependent and independent variables were very similar to the present study. The results showed that to detect a priming effect with 80% power would require 41 participants. Since we had four conditions, forty-four (i.e., a multiple of four) Mandarin speakers from South China Normal University (Guangzhou) were recruited. 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 15RMB after the experiment.

Items

We constructed 28 items, each consisting of prime sentences and a paired target picture (see Appendix). The sentences corresponded to four prime conditions (see Table 1). The Double Object (DO) condition involved the typical form of a double object sentence (i.e., having two noun phrases after the verb), with an animate recipient followed by an inanimate theme (or patient). The Prepositional Object condition involved the typical form of a prepositional object sentence (i.e., having a noun phrase followed by a prepositional phrase after the verb), with an inanimate theme followed by an animate recipient. The Prepositional Object-Animacy Reversed (PO-AR) condition also had a noun

phrase followed by a prepositional phrase after the verb, but in this case had an animate theme followed by an inanimate recipient.[i] In other words, the PO-AR shared syntactic structure with the PO condition, but shared order of animacy with the DO condition. The fourth condition was an intransitive baseline sentence and was therefore not expected to prime either PO or DO structures.

The paired target picture (Figure 1) depicted a ditransitive action that was different from the action in the prime sentence. The name of the agent and the verb were printed below the picture in Chinese characters (here, meaning 'The prisoner handed'). Target pictures involved an animate agent, an animate entity that we assumed would be treated as the recipient, and an inanimate entity that we assumed would be treated as the theme. Different entities and verbs were used in the prime and target in each set of materials. In half the target pictures, the agent was on the left, the presumed theme was in the middle, and the presumed recipient was on the right; in the other half, the presumed recipient was on the left, the presumed theme was in the middle, and the agent was on the right. We also included 84 transitive filler items involving a transitive sentence with agent-verb-theme order (e.g., *The waitress kicked the cowboy*) and a corresponding picture; these involved twenty different transitive verbs. We constructed four lists of items, each containing 7 sentences from each condition and one version of each item, in a Latin Square design.

Table1

Sample stimuli in Experiment 1:

Prime Condition	Example
a. DO	*Nigu ji le nage dashi yiben jingshu.*
	The nun posted LE that master a scripture.
	("The nun posted the master a scripture.")
b. PO-AR	*Nigu song le haizi gei nage cimiao.*
	The nun gave LE child to that temple. ("The
	nun gave the child to the temple.")
c. PO	*Nigu ji le jingshu gei nage dashi.*
	The nun posted LE scripture to that master.
	("The nun posted the scripture to the
	master.")
d. Baseline	*Nigu shui le.*
	The nun slept LE. ("The nun slept.")

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Fig. 1. Example target picture in Experiment 1. The fragment in the target picture means "The prisoner handed".

Procedure

Eleven participants were randomly assigned to each list. Participants were told that the experiment investigated the relation between language production and memory. At the beginning of the experimental session, participants were familiarised with the entities that would be used in the experiment by being shown a picture of each entity, together with its name (the majority were two-character high frequency words, plus six three-character words). The main experiment used a recognition-memory structural priming paradigm (Bock, 1986; Huang et al., 2016), involving two phases: a study phase and a test phase. The study phase included 30 trials (4 PO,4PO-AR, 4 DO, 3 Baseline, and 15 filler trials). Each trial began with a fixation cross displayed for 500ms, and then the written prime sentence appeared. Participants were instructed to memorise the sentence and then press the space bar to trigger a 200ms blank screen, followed by the associated target picture. Participants were instructed to memorise the picture, and then press the space bar to trigger the next trial. The test phase included an initial ten practice trials, followed by 28 experimental trials and 84

filler trials that appeared in randomised order with the constraint that experimental trials were separated by at least two filler trials. The procedure in the test phase was the same as in the study phase, except that for the prime sentences the participants were instructed to read them aloud and then decide that whether they had appeared in the study phase by answering aloud 'shi' ('yes') or 'fou' ('no'); for the target pictures, the participants described the picture by completing the sentence fragment beneath the picture, and then made a recognition judgment by answering aloud 'shi' or 'fou'.

Scoring

We scored a response as a DO if it consisted of the sentence preamble followed by a noun phrase denoting the recipient followed by a noun phrase denoting the theme, as a PO response if it consisted of the sentence preamble followed by a noun phrase denoting the theme followed by the preposition *gei* and a noun phrase denoting the recipient, or as an Other response otherwise.

Results

Table 2 reports the frequency of DO, PO, and other responses, and the proportion of DO responses (out of all responses), across the four prime conditions. In the data analyses we used Generalised logistic mixed models (glmer) with crossed random effects for participants and items, using the *glmer* program of the *lme4* package (Bates & Maechler, 2010) in *R*. DO responses were coded as 1, and PO were coded as 0 and Other responses were excluded from the analysis.

To test the main effect of prime type, we compared a model that treated prime type as a fixed effect with the null model that excluded prime type as a fixed effect. Following Matuschek, Kliegl, Vasishth, Baayen and Bates (2017), we selected the optimal random effect supported by the data. This included the random intercept and slope for participants and items.

The model comparison was significant (likelihood ratio test: χ^2=4.99, p<.05), demonstrating a main effect of prime type. Hence there was a structural priming effect. We additionally carried out pairwise comparisons (Table 3). To correct for multiple testing, the set of raw p values were converted to false-discovery rates (FDR) according to Benjamini and Hochberg (Benjamini & Hochberg, 1995). Although there were numerically more DO responses in the DO condition than in the PO, PO-AR, and Baseline conditions, these effects were not significant after FDR correction. Critically, there was no difference between the number of DO responses in the PO and PO-AR conditions.

To rule out the possibility of any effects caused by using different verbs in the PO and PO-AR conditions (e.g., different predictability of the verbs' syntactic frames), we asked a further 400 participants to produce picture descriptions for the experimental stimuli using a specified verb (printed beneath the picture). These responses were coded as DO, PO, or other, using the same coding criteria as in the main experiment. There was no difference in the mean proportion of DO responses for verbs used in the PO and PO-AR conditions (0.26 (SD=.21) vs. 0.19 (0.25), p>.1).

Table 2

Experiment 1: Frequency of DO, PO and Other Responses, and proportion of DO responses, by condition.

Prime	DO	PO-AR	PO	baseline
DO	76	45	43	51
PO	232	258	264	256
Others	0	5	1	1
Proportion DO	0.25	0.15	0.14	0.17

Table 3

Experiment 1: Pairwise comparisons among prime conditions.

	Estimate	*SE*	*Z*	*p-corrected*
PO-AR vs. DO	-1.21	0.51	-2.37	.1
PO vs. DO	-1.14	0.49	-2.33	.06
Baseline vs. DO	-1.05	0.52	-2.02	.09
PO vs. PO-AR	0.07	0.50	0.14	>.1
Baseline vs. PO-AR	0.16	0.50	0.32	>.1
Baseline vs. PO	0.09	0.48	0.19	>.1

Discussion

In Experiment 1, there was an overall syntactic priming effect, but participants were no more likely to produce DO responses following a PO-AR prime than following a PO prime. In other words, there was no evidence that they tended to repeat the order of animacy across prime and target.

However, participants did not produce significantly more DO responses following a baseline prime than following a PO prime, so the lack of a difference between the PO-AR and PO prime conditions might reflect a failure to detect an effect of the PO condition. In fact, the overall proportion of DO responses was low, which in turn may have weakened priming effects (e.g., PO vs. DO, Baseline vs. DO). This may in part reflect a preference to produce PO responses in Mandarin (Cai et al., 2011, 2012, 2015; Huang et al., 2016). But it may also have occurred because the experiment included a comparatively small number of DO prime sentences (i.e., 7 out of 28 experimental sentences and 84 fillers), as DO primes constituted only one out of four experimental conditions. To address this concern, Experiment 2 increased the proportion of DO sentences by including DO sentences among the fillers. At the same time, it provided a replication of Experiment 1, not only allowing us to investigate the lack of a difference between the PO and PO-AR conditions, but also to investigate the other priming effects.

Experiment 2

Method

Participants

Forty-four further Mandarin speakers from the same subject pool were paid to participate in this experiment.

Items

The experimental items were the same as those used in Experiment 1. We replaced 21 filler transitive prime sentences with DO sentences (i.e., one-quarter of the fillers), thereby increasing the number of DO prime sentences from 7 to 28.

Procedure and Scoring

These were the same as in Experiment 1.

Results

Table 4 reports the frequency of DO, PO, and Other responses, and the proportion of DO responses, across conditions. As in Experiment 1, we compared a model that treated prime type as a fixed effect with the null model that excluded prime type as a fixed effect. The optimal random effect model supported by the data included the random intercept for participants and items. The results showed that the effect of prime type was significant (likelihood ratio test: $\chi^2=4.67$, $p<.05$), thus demonstrating a structural priming effect. Pairwise comparisons corrected for multiple comparisons (Table 5) showed that

participants produced more DO responses in the DO condition than in the PO, PO-AR, and Baseline conditions (confirming the numerical pattern found in Experiment 1). Critically, we again found that the participants produced equivalent numbers of DO responses across the PO and PO-AR conditions. Additionally, participants produced more DO responses after Baseline primes than after PO or after PO-AR primes (in contrast to Experiment 1).

Table 4

Experiment 2: Frequency of DO, PO and Other Responses, and proportion of DO responses, by condition.

Prime	DO	PO-AR	PO	baseline
DO	114	64	70	90
PO	192	236	231	213
Others	2	8	7	5
Proportion DO	0.37	0.21	0.23	0.29

Table 5

Experiment 2: Pairwise comparisons among prime conditions.

	Estimate	*SE*	*Z*	*p-corrected*
PO-AR vs. DO	-1.06	0.22	-4.85	<.001
PO vs. DO	-0.98	0.21	-4.58	<.001
Baseline vs. DO	-0.48	0.20	-2.35	.028
PO vs. PO-AR	0.08	0.23	0.35	>.1
Baseline vs. PO-AR	0.58	0.22	2.65	.016

Baseline vs. PO	0.50	0.22	2.30	.026

General Discussion

In two structural priming experiments, we considered whether speakers of Mandarin construct independent syntactic representations, or whether they construct representations that integrate syntactic and non-relational semantic information. Both experiments showed a significant priming effect, such that their likelihood of producing a DO response was influenced by the structure of the prime sentence that they had heard. In both experiments, participants produced more DO responses following a DO prime than in the other conditions (though in Experiment 1 these pairwise comparisons were not statistically significant after correction for multiple comparisons). But in neither experiment were they more likely to produce DO responses following a PO-AR prime than following a PO prime. In other words, there was no evidence that they tended to repeat the order of animacy across prime and target. In Experiment 2, they were more likely to produce DO responses following Baseline primes than following PO or PO-AR primes.

Specifically, the experiments suggest that participants were primed to choose between responses with a V NP NP structure or responses with a V NP PP structure. They were not primed to choose between responses with a V NP$_{AN}$ NP$_{INAN}$ structure or responses with a V NP$_{INAN}$ PP$_{AN}$ structure. In other words, the priming took place over representations that involved syntactic

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information but not information about animacy – that is, non-relational semantic information. These results therefore suggest that speakers of Mandarin compute autonomous syntactic representations.[ii]

The experiments involved conditions (PO and PO-AR) that included prime sentences with equivalent syntax in which animacy was reversed (inanimate-animate versus animate-inanimate order). However, there was no indication that this manipulation affected priming at all. Apart from supporting the autonomous account over the integrated account, these results therefore give us no reason to assume any role of animacy in the computation of word order in Mandarin.

We also noted that Cai et al. (2012) found (relational semantic) priming of the order of the patient and recipient thematic roles in Mandarin datives, but that their pattern of results could instead have arisen from (non-relational semantic) priming of the order of animate and inanimate arguments. Our results suggest that such animacy priming does not occur, and therefore support the occurrence of relational semantic priming effects in Mandarin.

As discussed above, there is strong evidence that speakers of English and related languages compute autonomous syntactic representations, with semantic information being involved in a separate stage (or stages) of production (see Pickering & Ferreira, 2008). Our findings suggest that this is also the case for Mandarin.

Pickering and Branigan (1998) interpreted syntactic priming in English in terms of the activation of representations at the lemma stratum (following Levelt, Roelofs, & Meyer, 1999). In their account, processing a sentence involving a particular syntactic structure (e.g., a prepositional-object dative) leads to activation of the verb lemma and an associated combinatorial node corresponding to the syntactic structure (in this case, V NP PP). Importantly, the combinatorial node incorporates categorical information but not semantic information (such as animacy), which is represented elsewhere (in the conceptual stratum). The theory therefore predicts syntactic priming independent of semantics. Semantic structural priming is an independent phenomenon and provides evidence for the separation of syntax and semantics (see Branigan & Pickering, 2017).

Our results are therefore compatible with a similar representational structure for Mandarin. In other words, we propose the existence of verb lemmas that are linked to combinatorial nodes specifying syntactic information but not information about animacy. For example, there are nodes corresponding to the PO, DO, and PO-AR constructions, but these nodes are independent of animacy.

In conclusion, our findings therefore provide some evidence that the separation of syntactic and semantic representations may be universal – though clearly research into other languages unrelated to English or Mandarin is needed. These conclusions are of course relevant both when considering the

mechanisms of language production (and comprehension), but also when

considering the nature of linguistic representation (Branigan & Pickering, 2017).

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[i] In a small number of items, the inanimate noun could also be interpreted with a non-recipient role, e.g., location.

[ii] The fact that priming occurred to the same extent following PO and PO-AR primes also indicates that any relational semantic differences between the PO and PO-AR primes (see note i) did not contribute to priming, and hence that the primed representations did not involve relational semantic information.