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Syntactic priming in illiterate and literate older Chinese adults

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Abstract Does life-long literacy experience modulate syntactic priming in spoken language processing? Such a postulated influence is compatible with usage-based theories of language processing that propose that all linguistic skills are a function of accumulated experience with language across life. Here we investigated the effect of literacy experience on syntactic priming in Mandarin in sixty Chinese older adults from Hebei province. Thirty participants were completely illiterate and thirty were literate Mandarin speakers of similar age and socioeconomic background. We first observed usage differences: literates produced robustly more prepositional object (PO) constructions than illiterates. This replicates, with a different sample, language, and cultural background, previous findings that literacy experience affects (baseline) usage of PO and DO transitive alternates. We also observed robust syntactic priming for double-object (DO), but not prepositional-object (PO) dative alternations for both groups. The magnitude of this DO priming however was higher in literates than in illiterates. We also observed that cumulative adaptation in syntactic priming differed as a function of literacy. Cumulative syntactic priming in literates appears to be related mostly to comprehending others, whereas in illiterates it is also associated with repeating self-productions. Further research is needed to confirm this interpretation.

Keywords Priming · Literacy · Transitive alternates · Mandarin · Cumulative adaptation · Self-productions

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Introduction

Literacy substantially changes mind and brain (Dehaene et al., 2015; Huettig et al., 2018). Learning to read and write improves mirror image discrimination (Fernandes et al., 2021; Kolinsky et al., 2011; Pegado et al., 2014), face recognition (Van Paridon et al., 2021), visual search (Olivers et al., 2014), verbal memory (Demoulin & Kolinsky, 2016; Smalle et al.,

2019), phonological awareness (Lukatela, et al., 1995; Morais et al., 1979, 1986; Prakash et al., 1993), prediction during spoken language processing (Favier, Meyer, & Huettig 2021 in press; Huettig & Pickering, 2019; Mani & Huettig, 2014; Mishra et al., 2012), and even the perception of facial emotions (Eviatar, 1997) and non-verbal intelligence as measured by Raven's progressive matrices (Hervais-Adelman et al., 2019; Olivers et al., 2014; Skeide et al., 2017). Research on the effect of literacy is thus a powerful tool to investigate how the human mind works. More specifically, investigating how reading experience affects spoken language processing offers a tool to understand fundamental mechanisms of language processing.

The present study investigates how life-long literacy experience modulates syntactic priming in spoken language processing. Syntactic priming is one of the most robust phenomena in language processing. Kay Bock (1986) first showed that after hearing and repeating a sentence like 'The corrupt inspector offered a deal to the bar owner', participants are more likely to use the same sentence structure, i.e., a prepositional-object (PO) dative, to describe an unrelated pictured event (e.g., 'The boy is handing a valentine to the girl'), compared to the alternative double-object (DO) dative structure (e.g., 'The boy is handing the girl a valentine') and vice versa. The effect of recent syntactic experience on subsequent production is very strong and has been replicated in a variety of tasks, sentence structures, and languages (see Mahowald et al., 2016, for a meta-analysis). A particularly interesting and potentially revealing observation is that syntactic priming effects are greatly increased when the verb is repeated between prime and target sentences (i.e., the lexical boost effect, e.g., Pickering & Branigan, 1998).

Since the first demonstration of syntactic priming 35 years ago, different theoretical accounts have been proposed. An important distinction has been made between error-based learning theories and activation-based accounts. According to error-based learning accounts syntactic priming reflects implicit learning and a processing system that, contingent on the input it receives, continuously updates the weighting of mappings between message-level and syntactic representations (Chang, 2002; Chang et al., 2000, 2006). In line with error-based learning notions it has been found that syntactic priming can persist over multiple intervening sentences (Bock & Griffin, 2000; Bock et al., 2007) or even over a week (Branigan & Messenger, 2016).

Activation-based accounts of syntactic priming on the other hand fit more with short-term activation. Pickering and Branigan (1998) for instance proposed a model in which verb lemmas and associated combinatorial nodes, which specify structure such as DOs and POs, become activated during comprehension. Residual activation of DO or PO combinatorial nodes are assumed to increase the probability of re-using the recently encountered structure. Residual activation is thought to decay rapidly, resulting in relatively short-lasting syntactic priming.

Developmental research has shown that syntactic priming can occur without reading experience in pre-literate children (e.g., Branigan & McLean, 2016). Nevertheless, the fact that syntactic priming has been described as a long-term (e.g., Chang, 2002; Chang et al., 2000, 2006) and a short-term (e.g., Pickering & Branigan, 1998) phenomenon raises the question whether it is modulated by long-term written language experience. Such an influence is predicted in particular by usage-based theories of language processing, which propose that all linguistic skills are a function of accumulated experience with language across the totality of usage events in life (Abbot-Smith & Tomasello, 2006; Bybee, 1995, 2006; Croft 1995, 2000; Langacker, 1988; Tomasello, 2000).

To our knowledge there is only one previous study that has investigated the effect of life-long literacy experience on syntactic priming. Favier and Huettig (2021, in press) investigated the role of long-term written language experience on syntactic priming in a study with 161 adult native Dutch speakers with varying levels of literacy. They found robust comprehension-to-production syntactic priming (with and without verb repetition) between prime and target. Literacy experience in their study affected the usage of the syntactic alternates but did not modulate their priming. Their findings suggest that literacy can change what structures are used by individuals but that these long-term base level changes do not affect the priming of syntactic structures.

There are (at least) two reasons why further investigations into potential effects of literacy experience on syntactic priming are warranted. First, although Favier and Huettig's (2021, in press) study

was a large-scale one, none of their participants were completely (or close to completely) illiterate. It is possible that a study with complete illiterates has more power to detect an effect of literacy experience on syntactic priming. Second, it is conceivable that a potential effect is modulated by language-specific factors. Mandarin, for example, is different from Dutch (the language used by Favier & Huettig, 2021 in press) in that it has few reliable cues to syntactic structure, does not morphologically mark syntactic category or syntactic features, and does not have a rigid word order (see Huang et al., 2016, for further discussion).

Several previous studies have observed syntactic priming in Mandarin Chinese (Cai et al., 2011, 2012, 2015; Huang et al., 2016). Here we investigated the effect of life-long literacy experience on syntactic priming in Mandarin in sixty Chinese older adults from Hebei province. Thirty participants were completely illiterate, the other thirty were full literate Mandarin speakers of similar age and socioeconomic background. We used the confederate method (described below), first introduced by Branigan et al. (2000). The confederate and participants were native speakers of Mandarin Chinese. In the experiment, the experimenter verbally provided participants with a subject and a verb. Participants were then asked to complete the uttered sentence fragments to describe a target picture.

Method

Participants

Thirty illiterate and thirty literate Chinese women participated in the experiment, against the payment of 50 RMB. All were native Mandarin speakers and residents of Chengde city (Changshanyu county, Hebei province), where Mandarin Chinese originated. The illiterate participants ranged in age from 46 to 72 years (mean=55.10; SD=5.88), while the age of literate participants ranged from 43 to 62 years (mean =53.83, SD=6.10). An independent t-test showed no significant difference between these two age groups (p=0.42). None of the illiterate participants had participated in any formal education or received any training in reading or writing. All literate participants had attended formal education, including training in reading and writing, and they all engaged in reading and writing on a daily basis.

Stimuli

Two sets of 180 cards were prepared for the confederate syntactic priming method (Branigan et al., 2000). The entities were all color photographs downloaded from two freely available Chinese image websites (http://588ku.com/ and https://www.vcg.com/creative). All images were easily recognizable and nameable (e.g., a pregnant woman, a clown, a flower bouquet). Both sets of cards were printed on A4 cardboards.

One set, the naive participant's description set, contained 72 experimental cards (48 dative actions and 24 baseline primes), and 108 filler cards. As for the experimental cards, each of them showed one or three images of entities (three for the PO and DO condition, and one for the baseline). The experimental cards all showed animate agents, animate recipients, and inanimate objects. The objects always appeared in the center, while the agents were displayed on the left (the recipient being on the right) in half of the cards and on the right (the recipient being on the left) in the other half of the cards. As for the filler cards, the beginning of sentences, which contained an animate subject and a transitive verb, were given by the same experimenter. Two entities were shown on the card. The filler cards were administered in order to check whether the participants followed the experiment process and made responses corresponding to the confederate's description.

The confederate's description set also contained 180 cards. Seventy-two of them were experimental cards, consisting of 24 PO prime sentences (12 of them with the same verb and 12 different verbs), 24 DO prime sentences (12 of them with the same verb and 12 different verbs), and 24 baseline sentences. All verbs were used repeatedly between two and seven times. The baseline sentences were sentences with intransitive verbs. There were other 108 cards for filler sentences, all of which were transitive sentences with non-alternative verbs, containing one animate subject and one animate or inanimate entity.

Examples of such sentences are:

1. 男人 抱了 篮球 给 那个 男孩。(PO structure)
   Nanren baole lanqiu gei nage nanhai
   'The man handed. the basketball to the boy.'
2. 家长交 给 老师 一些 学费。 (DO structure)
   Jiazhang gei laoshi yixie xuefei.
   'The parents gave the teacher the tuition fee.'
3. 小宝宝 哭了。 (baseline, intransitive)
   Xiaobaobao ku le
   'The little baby cried.'
4. 老爷爷 称赞了 这个 女孩。 (filler, transitive with non-alternative verbs)
   Laoyeye chengzanle zhege nvhai
   'The old man praised the girl.'

In line with the confederate method, the beginning of the sentences, i.e., a subject and a verb (a dative verb for PO and DO prime sentences, and an intransitive verb for baseline sentences), were provided orally by the confederate experimenter.

The sentences in the confederate's description set were paired with the pictures in the naive participants' description set, so that each prime sentence spoken by the confederate would be immediately followed by an experimental card with target pictures to be described by the participants. The confederate's set was ordered in such a way that half of the prime sentences uttered by the confederate had the same verb as the verb supposed to be used by the naïve participants to describe the experimental card immediately following the specific prime sentence. The other half of the prime sentences contained different verbs in the prime sentence and the target sentence. In addition, all cards were distributed according to the same pseudo-random order, ensuring that each experimental card was separated from other experimental cards by two to four filler cards.

Procedure

The experiment took place in a quiet room. The room contained one desk, with each participant seated at one end, separated by two straight white cardboards, so that the two 'participants' could not see each other. The naive participants were literate and illiterate native Mandarin speakers. The confederate, a young college teacher, was also a native Mandarin speaker. The experimenter sat between the confederate and the participant and provided orally the beginnings of the sentences to both the naïve participants and the confederate. Participants were not informed about the actual objective of the experiment beforehand, and they were instead told that the ability of recognizing pictures between elderly and young individuals was being tested. The desk contained one description set of cards, one selection set of cards, and two response boxes, with a green label standing for 'yes' and a red label standing for 'no' (see Fig. 1).

During each trial, first, the experimenter orally provided a subject and a verb for the sentence to be completed. The confederate then pretended to describe the pictures on her cards to the participant, and read aloud the pre-prepared sentences. After the confederate finished speaking, the participant took the topmost card from her selection set and determined whether it did or did not match the description uttered by the confederate. The task was to place the cards in a green (indicating 'yes') or red (indicating 'no') box accordingly. Afterwards, the participant completed the sentence following the sentence beginnings provided by the experimenter, whereby they described the pictures on the cards. After the participant finished speaking, the confederate pretended to check whether the description matched the card. All sessions were recorded. The naive participant's descriptions of the experimental cards were subsequently transcribed.

Scoring and analysis

In order to examine the magnitude of structural alignment, participants' descriptions of the 72 critical targets (4300 in total) were coded according to whether they used a PO structure or DO structure. Descriptions were categorized as DOs if they involved a dative verb (according to Levin, 1993; Huang et al., 2016) followed by two noun phrases (NP), with one relating to the recipient and another to the theme. Descriptions were categorized as a PO if they involved a dative verb followed by a noun phrase (NP) and a prepositional phrase (PP). All other descriptions that could not be coded as either construction were categorized as 'other'. Such descriptions for instance included a different verb from the one intended (e.g., not a dative verb).

Trials scored as 'other' (PO prime=6.32%, DO prime=7.08%) were excluded from the analysis, creating a binary dependent variable (DO responses were coded as '1', PO responses were coded as '0' and the number of 'other' responses in each prime condition and literacy group was reported in Appendix Table 6). A mixed logit analysis was conducted to predict the log odds of producing a DO target completion. Inferential analyses were based on Generalized Linear Mixed Models (GLMMs) using the lme4 package (Bates et al., 2014) in R (R Core Team 2018). Since the dependent variable was dichotomous (occurrences of DO out of all available responses), a binary logistic model was specified in the family argument of the glmer() function. The fixed effect predictor Prime Type (three levels, i.e., baseline, DO Prime, and PO prime), Subject Type (two levels, i.e., illiterate and literate), and Verb Relatedness (two levels, i.e., related and unrelated) were entered into the model in mean-centered form, using deviation coding. The baseline (BL) condition served as a comparison baseline, and there were two contrast variables indexing, respectively, the effect of the DO prime condition and the effect of the PO prime condition relative to baseline. The model comprised the maximal (by-subjects [N=60] and by-items [N=72]) random effects structure that converged (Barr et al., 2013), including random correlations. However, due to convergence problems, the random effects only included the random by-subject and by-target item intercepts.

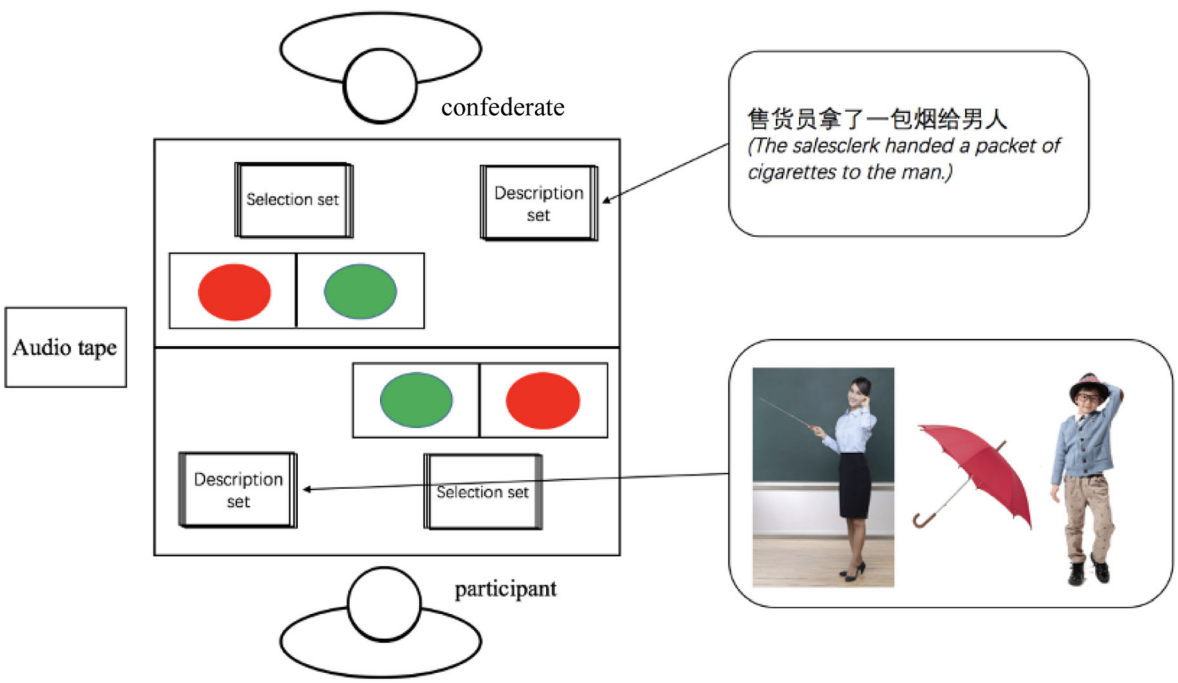

Fig. 1 Experimental setting

Results

Syntactic priming

Table 1 shows the distribution of DO and PO responses by levels of Prime Type. There was large general PO preference (total counts in bottom row and percentages for the BL prime condition). However, in the non-BL conditions, response proportions notably deviated from the BL, showing a less pronounced PO bias after DO primes. Statistical analyses confirmed a reliable main effect of Prime Type on occurrences of DO responses: $_{LR}\chi^2=10.615$; $df=2$; $p<0.005$.

To investigate the effect of lexical relatedness between prime and target (the so-called lexical boost effect), we conducted a logistic linear mixed-effects models using R on responses to target trials that were immediately preceded by a DO and PO prime. Relative to the baseline, DO occurrences statistically robustly increased after DO primes, but not after PO primes (Table 3 and Fig. 2). Figure 2 plots the corresponding model-estimated probabilities (Table 2).

There was no significant main effect of lexical relatedness (i.e. no overall lexical boost) but we observed a significant interaction between DO prime and verb relatedness. The magnitude of DO structure priming effect robustly increased when the verbs of the prime and target were repeated (Mean=0.377, SD =0.485 for related verb condition and Mean=0.339, SD=0.473, $Z=3.111$, $p=0.002$) (see in Fig. 3). There was no effect of verb relatedness for PO primes.

Effects of literacy

First, we observed robust literacy-related differences in baseline usage (Fig. 4). Illiterates generally produced more DO structures than literate participants. There was a significant main effect in the literacy group (Tukey Contrasts: SE=−1.37, $df=2$, $Z=-3.266$, $p=0.016$).

For both literate and illiterate participant groups, DO structures were produced significantly more often after DO prime ($M=49.6\%$, SD=0.500 for the illiterate group and $M=33.8\%$, SD=0.473 for the literate group) than after the baseline condition ($M=30.4\%$, SD=0.460 for the illiterate group and $M=20.7\%$, SD=0.373 for the literate group), and also significantly more often after PO prime ($M=36.2\%$, SD=0.481 SE=0.740, SE=0.356, $p=0.038$ for the illiterate group, and $M=23.1\%$, SD=0.422, SE=0.193, SE=3.151, $p=0.002$ for the literate group). For both literate and illiterate participant groups, PO structures were not produced significantly more often after DO prime than after the baseline condition, $p>0.05$. There was however a significant interaction between DO prime and literacy groups, reflecting a larger priming effect in the literate than in the illiterate group, $X^2=260$, $df=4$, p value<0.001.

A statistically robust interaction between prime type and subject type revealed that the priming effect differed across illiterate and literate groups. Post-hoc comparisons confirmed a significant difference in the extent of DO priming between illiterate and literate groups (Tukey Contrasts), SE=1.219, $Z=3.151$, $p=0.002$. The likelihood of producing a DO completion after a DO prime than a PO prime was higher in both participant groups, but this effect was larger for literates than for illiterates. The effect of verb relatedness did not robustly differ between literates and illiterates.

Exploratory cumulative priming analyses

To investigate to what extent the two groups differed in the effect of cumulative adaptation, we included the number of DO Prime and DO Target constructions completed by the participants prior to the target trial as factor in our analysis. A logistic linear mixed-effects model on all participants on responses to target trials that were immediately preceded by a DO, PO, or baseline prime was conducted. A table with all results from the analysis is presented in the Appendix (Table 4). Of interest to our research question was that literacy group interacted with the number of prior DO constructions (i.e., the number of DO primes participants comprehended before the present prime, or the number of DO targets produced before the present prime). In addition, there were significant or near-significant triple interactions between literacy group, DO priming (versus baseline), and the number of prior DO prime or target structure. To further explore these effects, we carried out separate analyses for each language group.

We conducted two separate logistic linear mixed-effects models on responses to target trials that were immediately preceded by a DO, PO, or baseline

Table 1 Distribution of responses per prime condition

Prime	Target		
	DO	PO	Others
BL	292 (20.3%)	940 (65.4%)	205
DO	559 (38.8%)	778 (54.0%)	103
PO	402 (27.9%)	947 (65.8%)	91
Total	1253	2665	399

Shown are absolute counts of DO and PO target for trials with all prime conditions

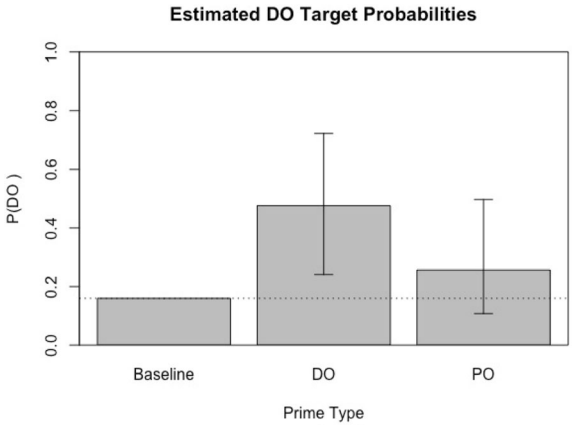

Fig. 2 Probabilities of DO responses in the target trials, as estimated via binary logistic GLMM analyses (see text). Figures are broken down by levels of Prime Type (BL, DO, and PO). Error bars represent 95% CIs for contrasts with the BL prime condition; the latter is indexed by a horizontal dashed line

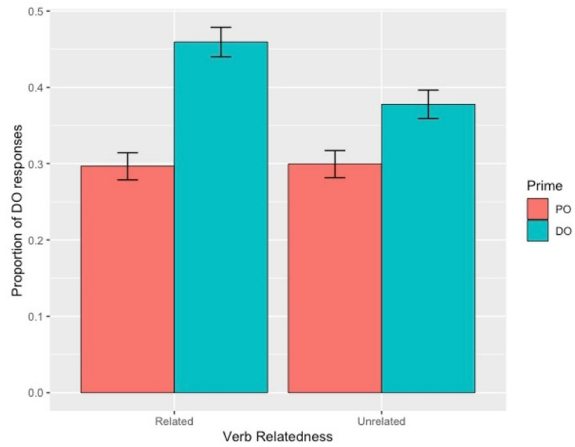

Fig. 3 Proportion of DO responses per verb relatedness condition

sentence on literate and illiterate participants respectively. The data set analyzed (including DO, PO, and Transitive responses only) included 1992 data points for the illiterate participants and 1928 for the literate participants. Fixed effects in the model were: prime condition (PO, DO, baseline), literacy group (illiterate, literate), number of prior DO primes comprehended by the individual, and number of prior DO targets uttered by the participants. All fixed effects, with the exception of prime condition, were centered around the mean. We started with a maximum random effect structure. However, due to convergence problems, the random effects only included the random by-subject and by-target item intercepts, unless noted otherwise. As is shown in

Table 2 Binary logistic GLMM parameter estimates and SEs (in log odds units) for DO occurrences in either verb relatedness condition

	Estimate	Std. error	*z* value	Pr (>|z|)
(Intercept)	1.773	0.334	5.309	<0.001
Prime=DO	0.874	0.425	2.055	0.040
Prime=PO	0.033	0.221	0.147	0.883
SUBJECT_TYPE=Literate	−0.630	0.203	−3.103	0.002
Relatedness=Unrelated	−0.103	0.310	−0.334	0.739
Prime=DO:SUBJECT_TYPE=Literate	−0.111	0.140	−0.788	0.431
Prime=PO:SUBJECT_TYPE=Literate	0.067	0.092	0.730	0.465
Prime=DO:Relatedness=Unrelated	0.307	0.112	2.730	0.006
SUBJECT_TYPE.e1:Relatedness=Unrelated	−0.016	0.081	−0.198	0.843
Prime=DO:SUBJECT_TYPE=Literate:Relatedness=Unrelated	−0.039	0.111	−0.349	0.727

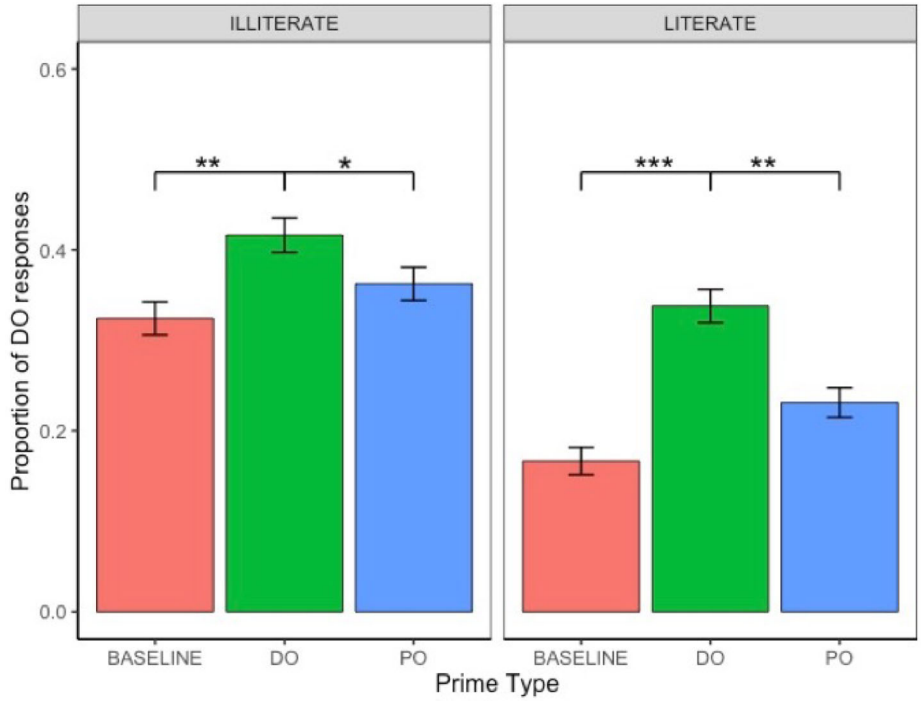

Fig. 4 Distribution of DO responses per prime condition and per literacy condition. Error bars reflect by-subject standard errors

Table 3a and b, both illiterate and literate participants were primed with a DO construction to a certain degree and both groups show a cumulative priming effect (although the cumulative effect for DO structure was not statistically robust in the illiterate group).

Table 3a and b suggest effects of cumulative adaptation in both groups: more DO targets were produced in the baseline condition when more DO constructions had been encountered (see the fourth and fifth row of Table 3a and b). Thus, a cumulative adaption effect was shown in both participant groups. There was also a significant interaction of DO primes and the number of DO primes observed in both groups, and thus the magnitude of priming effect increased as they heard and comprehended more DO structures as the experiment went on.

However, the cumulative adaption effects appear to be due to (partially) different reasons across literacy groups in the present study. For illiterate and literate participants, there was a significant cumulative DO priming effect with prior DO primes (see the eighth row of Table 3a and b). Thus, they became more likely to produce a DO structure as they comprehended more DO primes. For the illiterate participants only, in contrast, there was a marginally significant interaction effect from DO prime and prior DO target numbers (see the sixth row of Table 3a), which suggests that the illiterate participants were self-primed by their own production of DO structures. Figures 5 and 6 illustrate how participants were affected by the number of prior DO prime structures, and whether they were self-primed by their own production of the DO structure.

Discussion

We conducted a study with sixty older Chinese adults, all native speakers of Mandarin, to examine the effects of literacy experience on syntactic priming. Half of the participants were illiterate, the other half were literate and of similar age and socioeconomic background. In order not to put illiterate participants at an immediate disadvantage, we used the confederate method of spoken picture descriptions (Branigan et al., 2000). The experimenter verbally provided participants with a subject and a

verb, and participants were asked to complete sentence fragments to describe a target picture.

We measured the potential bias associated with literacy experience directly by using a baseline measure of Mandarin transitive sentence usage (PO or DO) in illiterate and literate people. We observed that both illiterate and literate participants showed a strong preference for prepositional object (PO) constructions. This is similar to previous syntactic priming studies with Mandarin Chinese (e.g., Chen et al., 2019; Huang et al., 2016). Literate participants in the present study, however, produced robustly more prepositional object (PO) constructions than illiterate participants. This replicates, with a different sample, language, and cultural background, the finding of Favier and Huettig (2021, in press) that literacy experience affects (baseline) usage of PO and DO transitive alternates.

The response of both participant groups deviated from the general pattern of PO preference after DO prime sentences. Although participants still showed a PO preference, it was much less pronounced after DO primes. In contrast to this DO priming, we observed no PO priming effect. This result may be due to the fact that participants overall showed such a strong PO preference in the baseline condition that a significantly further increase after PO prime sentences was difficult to observe. A lexical boost effect of similar magnitude was observed for DO primes for both

Table 3 a Binary logistic GLMM parameter estimates and SEs (in log odds units) for DO occurrences of illiterate participants per number of DO primes and DO targets, b Binary logistic GLMM parameter estimates and SEs (in log odds units) for DO occurrences of literate participants per number of DO primes and DO targets

(a)	Estimate	Std. error	*z* value	Pr(>|z|)
(Intercept)	−0.68	0.134	−5.076	<0.001
Prime=DO	0.628	0.199	3.153	0.002
Prime=PO	0.181	0.188	0.959	0.338
Nr. of prior DO Target	0.055	0.016	3.379	0.001
Nr. of prior DO Prime	0.057	0.012	4.762	<0.001
Prime=DO:Nr. of prior DO Target	0.047	0.027	1.76	0.078
Prime=PO:Nr. of prior DO Target	−0.02	0.021	−0.97	0.332
Prime=DO:Nr. of prior DO Prime	0.038	0.016	2.314	0.021
Prime=PO:Nr. of prior DO Prime	−0.028	0.017	−1.638	0.101
Nr. of prior DO Target:Nr. of prior DO Prime	0.001	0.001	1.513	0.13
Prime=DO:Nr. of prior DO Target:Nr. of prior DO Prime	0.003	0.001	2.508	0.012
Prime=PO:Nr. of prior DO Target:Nr. of prior DO Prime	−0.001	0.001	−1.006	0.315
(b)	Estimate	Std. error	*z* value	Pr(>|z|)
(Intercept)	1.422	0.162	8.778	<0.001
Prime=DO	0.941	0.264	3.567	<0.001
Prime=PO	−0.306	0.213	−1.435	0.151
Nr. of prior DO Target	0.115	0.028	4.102	0.000
Nr. of prior DO Prime	0.068	0.014	4.927	<0.001
Prime=DO:Nr. of prior DO Target	0.031	0.044	0.693	0.489
Prime=PO:Nr. of prior DO Target	−0.054	0.037	−1.449	0.147
Prime=DO:Nr. of prior DO Prime	0.043	0.021	2.067	0.039
Prime=PO:Nr. of prior DO Prime	−0.017	0.019	−0.892	0.372
Nr. of prior DO Target:Nr. of prior DO Prime	0.001	0.001	0.480	0.631
Prime=DO:Nr. of prior DO Target:Nr. of prior DO Prime	0.002	0.002	1.033	0.302
Prime=PO:Nr. of prior DO Target:Nr. of prior DO Prime	−0.002	0.002	−1.243	0.214

groups, suggesting that literacy may not modulate the lexical boost (Favier & Huettig, 2021 in press).

In contrast to Favier and Huettig (2021, in press), however, in the present study we observed some evidence that literacy experience can influence syntactic priming. First, the interaction of prime type and literacy (and subsequent post-hoc comparisons) revealed that the likelihood of producing a DO completion after a DO prime (rather than a PO prime or baseline) was higher for literates than for illiterates.

Second, exploratory analyses revealed that literacy affected the cumulative adaptation throughout the priming experiment. We looked at potential cumulative syntactic priming effects in three ways: (a) the main effect of the number of prior DO primes and targets, (b) the interaction of DO prime and number of prior DO targets, and (c) the interaction of DO prime and number of prior DO primes. The main effect of the number of prior DO primes and targets means that more DO targets were produced in the baseline condition as participants comprehended more DO primes and produced more DO targets. This effect is therefore not a consequence of 'immediate' priming but rather an effect of 'accumulating residue' of previous DO structures in the experiment. The interaction of DO prime and number of prior DO targets in illiterates means that the magnitude of the priming effect increased due to self-productions in illiterates (i.e., the number of DO targets produced). The robust interaction of DO prime and number of prior DO primes in literates and illiterates means that their magnitude of priming increased as they comprehended more DO structures.

What then explains the difference in the present findings and the findings of Favier and Huettig (2021, in press), who also observed literacy-related usage differences but no (literacy-related) differences in syntactic priming? There are some obvious differences in participants. In the Favier and Huettig (2021,

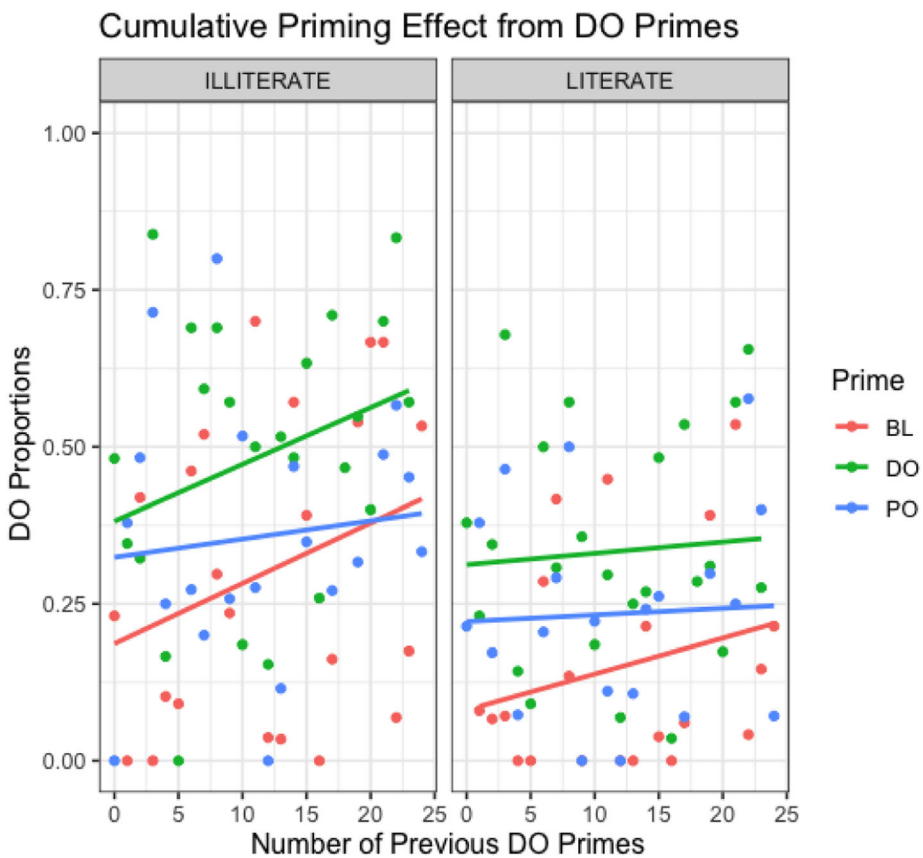

Fig. 5 The cumulative effect of DO structure from the prime

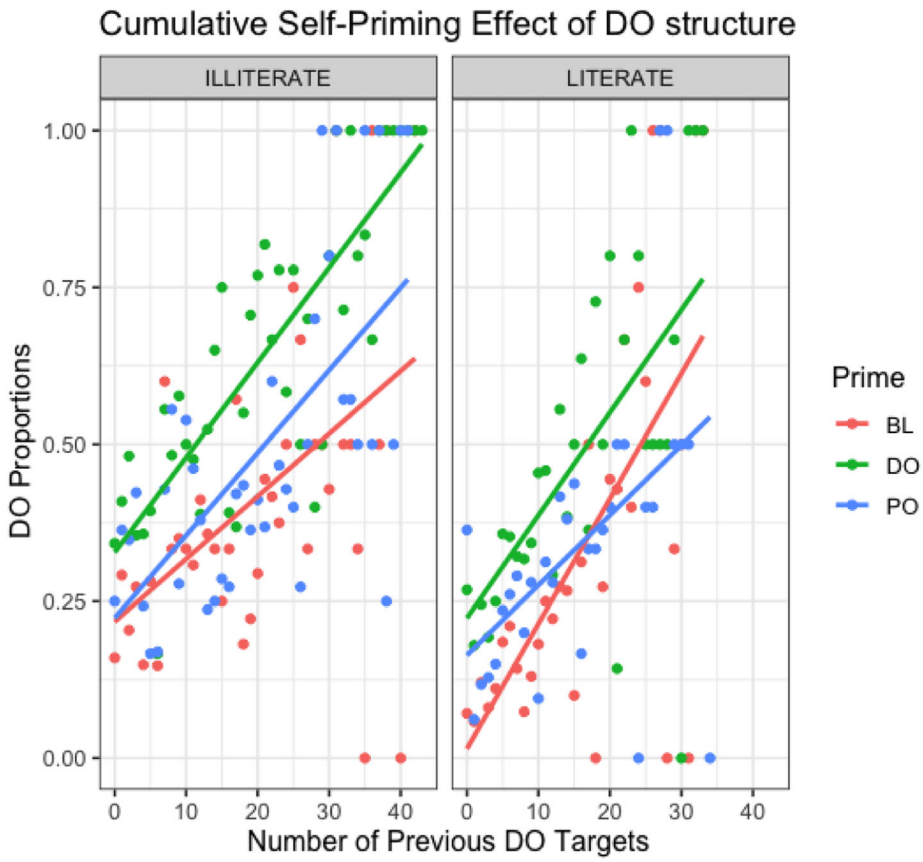

Fig. 6 The cumulative effect of DO structure from the target

in press) study, the Dutch low literate participants were much younger and more literate than the illiterate Chinese older adults in the present study. We also cannot rule out an influence of the linguistic differences between Dutch and Mandarin dative alternates. We conjecture however that the presence of an effect of literacy may be contingent on the (baseline) frequency of the Dutch and Mandarin dative DO and PO alternates. Favier and Huettig (2021, in press) observed that higher literacy scores were associated with a greater tendency to produce PO constructions. In the present study, the Chinese literate also showed a greater tendency to produce PO constructions than the Chinese illiterates. In contrast, to Favier and Huettig (2021, in press), however, Chinese participants in the present study hugely preferred PO constructions even in the baseline condition. A possibility is that literacy-related usage differences only play a role in syntactic priming of low frequent structures (as the Mandarin DO structure used in the present study) and that such influences 'level off' in structures that are frequently used by low and high literates alike. Indeed, some previous research does suggest that infrequent structures prime more reliably (e.g., Scheepers, 2003; Jaeger & Snider, 2013). This possibility is in line with the notion that literacy-related usage differences play a major role in syntactic priming during the stage of language acquisition (compatible with the notion that syntactic priming plays a role as an implicit learning mechanism, Chang et al., 2012). These results therefore raise the intriguing possibility that literates and illiterates differ in their degree of relying on learning from other- and self-production. If future studies replicate the present pattern of findings, then this would suggest that literates show a stronger tendency to learn by comprehending others' utterances than illiterates. Conversely, illiterates may rely more on (and perhaps also benefit from) repeating structures. Future research could usefully

be directed at investigating these possibilities systematically.

In sum, in a study with sixty Chinese older adults we found literacy-related usage differences: literates produced robustly more prepositional object (PO) constructions than illiterate participants. We observed strong syntactic priming for double-object (DO) but not prepositional-object (PO) dative alternations in both participant groups. The magnitude of DO priming in literates was higher than in illiterates. Interestingly, we observed some evidence for cumulative adaptation in both groups: more DO targets were produced in the baseline condition when more DO constructions had been encountered. Literates produced more DO structures as they comprehended more DO primes (but not as they produced more DO targets). Illiterates, on the other hand, produced more DO structures as they produced more DO targets as well as when they comprehended more DO primes). This suggests that cumulative adaptation in syntactic priming may differ as a function of literacy: cumulative syntactic priming in literates appears to be related to comprehending others, whereas in illiterates it is also related to repeating self-productions. Further research, ideally in a pre-registered study with a large-scale sample, is needed to confirm this interpretation.

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Availability of data and material The data and R code used for data analysis can be found at: https://doi.org/10.17605/OSF.IO/BHN2W, https://osf.io/bhn2w/

Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Ethical approval The present research complied with the standards of the Zhejiang University ethics board.

Appendix

Stimuli

Baseline primes.

	Prime sentences	Target sentences (possible description)
1	小宝宝醒了.	男孩抛了一个球给小狗.
	'The newborn baby woke up.'	'The boy threw a ball to the dog.'
2	巫婆走了.	女孩喂了食物给小狗.
	'The witch went away.'	'The girl fed some food to the dog.'
3	妈妈笑了.	厨师盛了一盘菜给女人.
	'The mother smiled.'	'The chef held a dish to the woman.'
4	宝宝饿了.	医生配了药品给病人.
	'The baby was hungry.'	'The doctor prescribed some medicine to the patient.'
5	弟弟醒了.	女孩带了一束捧花给新娘.
	'The brother woke up.'	'The girl brought a flower bouquet to the bride.'
6	男孩跌倒了.	总经理租了一栋房子给一家人.
	'The boy fell down.'	'The manager rent a house to the family.'
7	孩子睡了.	工人搬了一箱水给病人.
	'The child was asleep.'	'The delivery man delivered a case of water to the patient.'
8	工人下岗了.	接待员拿了一条裙子给舞者.
	'The worker was laid-off.'	'The hostess brought a dress to the dancer.'
9	小孩哭了.	商人卖了一个玩具给孕妇.
	'The child cried.'	'The trader sold a toy to the pregnant woman.'
10	小偷上当了.	新郎递了一枚戒指给新娘.
	'The thief was cheated.'	'The groom gave a ring to the bride.'
11	孕妇晕了.	男人赏了一点小费给服务员.
	'The pregnant woman fainted.'	'The man awarded a tip to the waiter.'
12	小丑跑了.	女人买了一个蛋糕给小孩.
	'The clown ran away.'	'The woman bought a cake for the child.'

PO primes.

Num	Prime sentences	Target sentences
1	女人拿了一张纸给画家. 'The woman handed a piece of paper to the painter.'	医生拿{了一支体温计给小女孩}{给小女孩一支体温计}. 'The doctor handed {a thermometer to the girl}{the girl a thermometer}.'
2	画家送了一幅画给男孩. 'The painter gave a painting to the boy.'	小丑送{了一个气球给女孩}{给女孩一个气球}. 'The clown gave {a balloon to the girl}{the girl a balloon}.'
3	男人赠了礼物给女孩. 'The man gave a gift to the girl.'	爷爷赠{了一个棒棒糖给男孩}{给男孩一个棒棒糖}. 'The old man gave {a lollipop to the boy}{the boy a lollipop}.'
4	村民抛了一块石头给孩子. 'The villager threw a stone to the child.'	男人抛{了一个篮球给男孩}{给男孩一个篮球}. 'The man threw {a basketball to the boy}{the boy a basketball}.'
5	修车工还了车给司机. 'The mechanic returned the car to the driver.'	保安还{了一把钥匙给女人}{给女人一把钥匙}. 'The security guard returned {the key to the woman}{the woman the key}.'
6	老奶奶送了一块西瓜给女孩. 'The old woman gave a piece of watermelon to the girl.'	老师送{了一些铅笔给女孩}{给女孩一些铅笔}. 'The teacher gave {some pencils to the girl}{the girl some pencils}.'
7	家长交了学费给老师. 'The parents paid the class fee to the teacher.'	小偷交{了一条项链给警察}{给警察一条项链}. 'The thief handed {a necklace to the policeman}{the policeman a necklace}.'
8	经理留了一把苕帚给清洁工. 'The manager left a broom to the street sweeper.'	舞蹈家留{了一双舞鞋给女孩}{给女孩一双舞鞋}. 'The dancer left {a pair of dancing shoes to the girl}{the girl a pair of dancing shoes}.'
9	邮递员带了一封信给女人. 'The postman brought a letter to the woman.'	护士带{了一些糖给小男孩}{给小男孩一些糖}. 'The nurse brought {some candy to the boy}{the boy some candy}.'
10	服务员递了一道菜给顾客. 'The waiter handed a dish to the customer.'	男人递{了一张车票给乘务员}{给乘务员一张车票}. 'The man handed {the train ticket to the stewardess}{the stewardess the train ticket}.'
11	农民留了一些蔬菜给小兔子. 'The peasant left some vegetable to the rabbit.'	父母留{了一个手镯给女孩}{给女孩一个手镯}. 'The parents left {a bracelet to the girl}{the girl a bracelet}.'
12	侦探交了一份指纹给警察. 'The detectives handed a sample of fingerprints to the police.'	快递员交{了一个箱子给男人}{给男人一个箱子}. 'The postman handed {a box to the man}{the man a box}.'

DO primes.

	Prime sentences	Target sentences
1	男人借给乞丐一个碗. 'The man lent the beggar a bowl.'	老师借{给男孩一把伞}{了一把伞给男孩}. 'The teacher lent {the boy an umbrella}{an umbrella to the boy}.'
2	老爷爷赏给小猫一条鱼. 'The old man awarded the cat a fish.'	老师赏{给男孩一本书}{了一本书给男孩}. 'The teacher awarded {the boy a book}{a book to the boy}.'
3	游客丢给乞丐一些硬币. 'The tourist tossed the beggar some coins.'	女孩丢{给清洁工一个易拉罐}{了一个易拉罐给清洁工}. 'The girl tossed {the street sweeper a can}{a can to the street sweeper}.'
4	老师赠给男孩一本书. 'The teacher gave the boy a book.'	歌手赠{给女孩一把吉他}{了一把吉他给女孩}. 'The singer gave {the girl a guitar}{a guitar to the girl}.'

Appendix continued

	Prime sentences	Target sentences
5	邮差借给商人一辆自行车. 'The postman lent the trader a bicycle.'	农民借{给老爷爷一把镰刀}{了一把镰刀给老爷爷}. 'The peasant lent {the old man a sickle}{a sickle to the old man}.'
6	秘书拿给主任一支笔. 'The secretary gave the director a pen.'	女人拿{给画家一幅画}{了一幅画给画家}. 'The woman gave {the painter a painting}{a painting to the painter}.'
7	老爷爷抛给渔夫一张渔网. 'The old man threw the fisher a fishing net.'	女人抛{给小宝宝一个泰迪熊}{了一个泰迪熊给小宝宝}. 'The woman threw {the toddler a teddy bear}{a teddy bear to the toddler}.'
8	营业员递给男孩一部手机. 'The shop assistant handed the boy a smart phone.'	空姐递{给女孩一杯茶}{了一杯茶给女孩}. 'The stewardess handed {the girl a cup of tea}{a cup of tea to the girl}.'
9	老奶奶留给女孩一串项链. 'The old woman left the girl a necklace.'	宇航员留{给男孩一把国旗}{了一把国旗给男孩}. 'The astronaut gave {the boy a national flag}{a national flag to the boy}.'
10	男孩还给画家一幅画. 'The boy returned the painter the painting.'	女孩还{给清洁工一把苕帚}{了一把苕帚给清洁工}. 'The girl returned {the cleaner the mop}{the mop to the cleaner}.'
11	农夫带给男孩一些牛奶. 'The farmer brought the boy some milk.'	服务员带{给男人一些蘑菇}{了一些蘑菇给男人}. 'The waiter brought {the man some mushrooms}{some mushrooms to the man}.'
12	富翁送给流浪汉一些衣服. 'The rich man gave the tramp some clothes.'	接待员送{给女人一杯饮料}{了一杯饮料给女人}. 'The hostess gave {the woman an orange juice}{an orange juice to the woman}.'

See Fig. 7 and Tables 4, 5, 6.

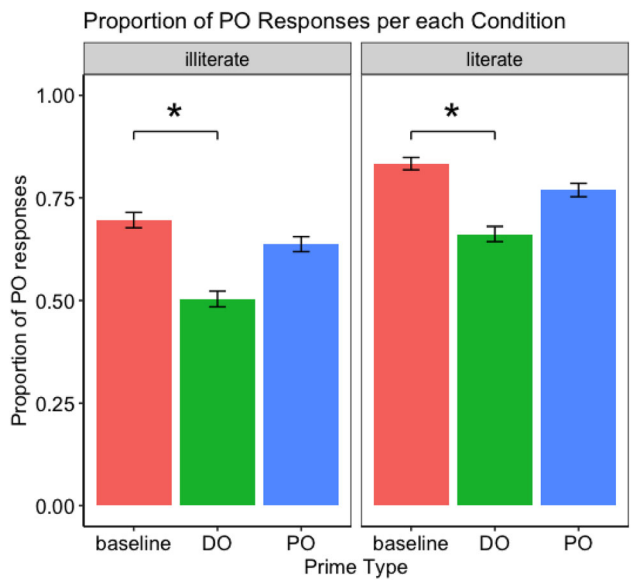

Fig. 7 Proportion of PO responses per each condition

Table 4 Based on 3919 data points; Loglik=−2973; interactions are indicated with ":"

	Estimate	Std. error	*z* value	Pr(>|z|)
(Intercept)	1.051	0.105	10.000	<0.001
Prime=DO	0.784	0.165	4.746	<0.001
Prime=PO	−0.243	0.142	−1.711	0.087
SUBJECT_TYPE=Literate	−0.371	0.105	−3.531	<0.001
Nr. of prior DO Target	−0.085	0.016	−5.243	<0.001
Nr. of prior DO Prime	0.062	0.009	6.843	<0.001
Prime=DO:SUBJECT_TYPE=Literate	−0.835	0.269	−3.106	0.002
Prime=PO:SUBJECT_TYPE=Literate	0.063	0.142	0.441	0.659
Prime=DO:Nr. of prior DO Target	−0.039	0.026	−1.504	0.133
Prime=PO:Nr. of prior DO Target	0.037	0.021	1.738	0.082
SUBJECT_TYPE.=Literate:Nr. of prior DO Target	0.030	0.016	1.855	0.064
Prime=DO:Nr. of prior DO Prime	−0.040	0.013	−3.056	0.002
Prime=PO:Nr. of prior DO Prime	0.023	0.013	1.764	0.078
SUBJECT_TYPE=Literate:Nr. of prior DO Prime	−0.005	0.009	−0.594	0.553
Nr. of prior DO Target:Nr. of prior DO Prime	−0.001	0.001	−1.214	0.225
Prime=DO:SUBJECT_TYPE=Literate:Nr. of prior DO Target	−1.693	0.555	−3.049	0.028
Prime=PO:SUBJECT_TYPE=Literate:Nr. of prior DO Target	−0.017	0.021	−0.792	0.429
Prime=DO:SUBJECT_TYPE=Literate:Nr. of prior DO Prime	0.002	0.013	0.187	0.851
Prime=PO:SUBJECT_TYPE=Literate:Nr. of prior DO Prime	0.006	0.013	0.448	0.654
Prime=DO:Nr. of prior DO Target:Nr. of prior DO Prime	0.003	0.001	2.218	0.027
Prime=PO:Nr. of prior DO Target:Nr. of prior DO Prime	−0.002	0.001	−1.587	0.113
SUBJECT_TYPE=Literate:Nr. of prior DO Target:Nr. of prior DO Prime	0.000	0.001	−0.402	0.688
Prime=DO:SUBJECT_TYPE=Literate:Nr. of prior DO Target:Nr. of prior DO Prime	0.001	0.001	0.476	0.634
Prime=PO:SUBJECT_TYPE=Literate:PriorD:Nr. of prior DO Prime	0.001	0.001	0.525	0.600

	Estimate	Std. error	*z* value	Pr(>|z|)
(Intercept)	1.876	0.293	6.416	<0.001
Prime=DO	1.399	0.479	2.920	0.004
Prime=PO	−1.083	0.357	−3.032	0.002
SUBJECT_TYPE=Literate	−0.306	0.293	−1.047	0.295
Nr. of prior DO Target	−0.294	0.088	−3.358	0.001
Nr. of prior PO Target	0.055	0.043	1.281	0.200
Nr. of prior DO Prime	−0.290	0.145	−1.994	0.046
Nr. of prior PO Prime	−0.090	0.150	−0.600	0.548
Prime=DO:SUBJECT_TYPE=Literate	−0.687	0.479	−1.435	0.151
Prime=PO:SUBJECT_TYPE=Literate	0.188	0.357	0.525	0.600
Prime=DO:Nr. of prior DO Target	−0.120	0.133	−0.903	0.367
Prime=PO:Nr. of prior DO Target	0.231	0.122	1.899	0.058
SUBJECT_TYPE=Literate:Nr. of prior DO Target	0.049	0.088	0.555	0.579
Prime=DO:Nr. of prior PO Target	−0.133	0.064	−2.091	0.037
Prime=PO:Nr. of prior PO Target	0.229	0.065	3.526	<0.001
SUBJECT_TYPE=Literate:Nr. of prior PO Target	−0.023	0.043	−0.528	0.597
Nr. of prior DO Target:Nr. of prior PO Target	0.008	0.006	1.282	0.200
Prime=DO:Nr. of prior DO Prime	−0.041	0.192	−0.215	0.829

Table 4 continued

	Estimate	Std. error	z value	Pr(>|z|)
Prime=PO:Nr. of prior DO Prime	−0.615	0.219	−2.804	0.005
SUBJECT_TYPE=Literate:Nr. of prior DO Prime	0.155	0.145	1.067	0.286
Nr. of prior DO Target:Nr. of prior DO Prime	0.061	0.018	3.381	0.001
Nr. of prior PO Target:Nr. of prior DO Prime	0.009	0.007	1.343	0.179
Prime=DO:Nr. of prior PO Prime	0.001	0.202	0.005	0.996
Prime=PO:Nr. of prior PO Prime	0.376	0.229	1.640	0.101
SUBJECT_TYPE=Literate:Nr. of prior PO Prime	−0.065	0.150	−0.430	0.667
Nr. of prior DO Target:Nr. of prior PO Prime	−0.008	0.018	−0.432	0.666
Nr. of prior PO Target:Nr. of prior PO Prime	0.005	0.007	0.709	0.479
Nr. of prior DO Prime:Nr. of prior PO Prime	0.009	0.005	1.844	0.065
Prime=DO:SUBJECT_TYPE=Literate:Nr. of prior DO Target	0.103	0.133	0.775	0.438
Prime=PO:SUBJECT_TYPE=Literate:Nr. of prior DO Target	−0.186	0.122	−1.534	0.125
Prime=DO:SUBJECT_TYPE=Literate:Nr. of prior PO Target	0.054	0.064	0.846	0.398
Prime=PO:SUBJECT_TYPE=Literate:Nr. of prior PO Target	−0.105	0.065	−1.615	0.106
Prime=DO:Nr. of prior DO Target:Nr. of prior PO Target	0.023	0.010	2.228	0.026
Prime=PO:Nr. of prior DO Target:Nr. of prior PO Target	−0.027	0.008	−3.354	0.001
SUBJECT_TYPE=Literate:Nr. of prior DO Target:Nr. of prior PO Target	0.000	0.006	−0.040	0.968
Prime=DO:SUBJECT_TYPE=Literate:Nr. of prior DO Prime	0.098	0.192	0.511	0.610
Prime=PO:SUBJECT_TYPE=Literate:Nr. of prior DO Prime	−0.190	0.219	−0.867	0.386
Prime=DO:Nr. of prior DO Target:Nr. of prior DO Prime	−0.011	0.025	−0.448	0.654
Prime=PO:Nr. of prior DO Target:Nr. of prior DO Prime	0.040	0.026	1.533	0.125
SUBJECT_TYPE=Literate:Nr. of prior DO Target:Nr. of prior DO Prime	−0.029	0.018	−1.638	0.101
Prime=DO:Nr. of prior PO Target:Nr. of prior DO Prime	0.007	0.010	0.688	0.491
Prime=PO:Nr. of prior PO Target:Nr. of prior DO Prime	0.012	0.010	1.224	0.221
SUBJECT_TYPE=Literate:Nr. of prior PO Target:Nr. of prior DO Prime	0.000	0.007	−0.053	0.958
Nr. of prior DO Target:Nr. of prior PO Target:Nr. of prior DO Prime	−0.002	0.001	−2.876	0.004
Prime=DO:SUBJECT_TYPE=Literate:Nr. of prior PO Prime	−0.022	0.202	−0.112	0.911
Prime=PO:SUBJECT_TYPE=Literate:Nr. of prior PO Prime	0.277	0.229	1.208	0.227
Prime=DO:Nr. of prior DO Target:Nr. of prior PO Prime	0.011	0.025	0.432	0.666
Prime=PO:Nr. of prior DO Target:Nr. of prior PO Prime	−0.039	0.026	−1.536	0.125
SUBJECT_TYPE=Literate:Nr. of prior DO Target:Nr. of prior PO Prime	0.011	0.018	0.635	0.526
Prime=DO:Nr. of prior PO Target:Nr. of prior PO Prime	0.002	0.010	0.177	0.859
Prime=PO:Nr. of prior PO Target:Nr. of prior PO Prime	−0.023	0.010	−2.203	0.028
SUBJECT_TYPE=Literate:Nr. of prior PO Target:Nr. of prior PO Prime	0.000	0.007	0.010	0.992
Nr. of prior DO Target:Nr. of prior PO Target:Nr. of prior PO Prime	0.000	0.001	−0.075	0.940
Prime=DO:Nr. of prior DO Prime:Nr. of prior PO Prime	0.005	0.006	0.884	0.377
Prime=PO:Nr. of prior DO Prime:Nr. of prior PO Prime	0.008	0.008	0.968	0.333
SUBJECT_TYPE=Literate:Nr. of prior DO Prime:Nr. of prior PO Prime	−0.002	0.005	−0.423	0.673
Nr. of prior DO Target:Nr. of prior DO Prime:Nr. of prior PO Prime	−0.002	0.000	−4.396	0.000
Nr. of prior PO Target:Nr. of prior DO Prime:Nr. of prior PO Prime	−0.001	0.000	−3.880	0.000
Prime=DO:SUBJECT_TYPE=Literate:Nr. of prior DO Target:Nr. of prior PO Target	−0.014	0.010	−1.298	0.194
Prime=PO:SUBJECT_TYPE=Literate:Nr. of prior DO Target:Nr. of prior PO Target	0.016	0.008	1.910	0.056
Prime=DO:SUBJECT_TYPE=Literate:Nr. of prior DO Target:Nr. of prior DO Prime	0.013	0.025	0.532	0.595
Prime=PO:SUBJECT_TYPE=Literate:Nr. of prior DO Target:Nr. of prior DO Prime	−0.003	0.026	−0.127	0.899
Prime=DO:SUBJECT_TYPE=Literate:Nr. of prior PO Target:Nr. of prior DO Prime	−0.009	0.010	−0.930	0.352

Table 4 continued

	Estimate	Std. error	*z* value	Pr(>|z|)
Prime=PO:SUBJECT_TYPE=Literate:Nr. of prior PO Target:Nr. of prior DO Prime	0.018	0.010	1.778	0.075
Prime=DO:Nr. of prior DO Target:Nr. of prior PO Target:Nr. of prior DO Prime	−0.001	0.001	−0.884	0.376
Prime=PO:Nr. of prior DO Target:Nr. of prior PO Target:Nr. of prior DO Prime	−0.001	0.001	−0.974	0.330
SUBJECT_TYPE=Literate:Nr. of prior DO Target:Nr. of prior PO Target:Nr. of prior DO Prime	0.001	0.001	0.806	0.420
Prime=DO:SUBJECT_TYPE=Literate:Nr. of prior DO Target:Nr. of prior PO Prime	−0.022	0.025	−0.887	0.375
Prime=PO:SUBJECT_TYPE=Literate:Nr. of prior DO Target:Nr. of prior PO Prime	0.015	0.026	0.588	0.557
Prime=DO:SUBJECT_TYPE=Literate:Nr. of prior PO Target:Nr. of prior PO Prime	0.004	0.010	0.358	0.721
Prime=PO:SUBJECT_TYPE=Literate:Nr. of prior PO Target:Nr. of prior PO Prime	−0.008	0.010	−0.806	0.420
Prime=DO:Nr. of prior DO Target:Nr. of prior PO Target:Nr. of prior PO Prime	−0.001	0.001	−1.191	0.233
Prime=PO:Nr. of prior DO Target:Nr. of prior PO Target:Nr. of prior PO Prime	0.003	0.001	3.158	0.002
SUBJECT_TYPE=Literate:Nr. of prior DO Target:Nr. of prior PO Target:Nr. of prior PO Prime	0.000	0.001	−0.095	0.924
Prime=DO:SUBJECT_TYPE=Literate:Nr. of prior DO Prime:Nr. of prior PO Prime	−0.004	0.006	−0.625	0.532
Prime=PO:SUBJECT_TYPE=Literate:Nr. of prior DO Prime:Nr. of prior PO Prime	−0.002	0.008	−0.235	0.814
Prime=DO:Nr. of prior DO Target:Nr. of prior DO Prime:Nr. of prior PO Prime	0.000	0.001	0.215	0.830
Prime=PO:Nr. of prior DO Target:Nr. of prior DO Prime:Nr. of prior PO Prime	0.000	0.001	−0.682	0.495
SUBJECT_TYPE=Literate:Nr. of prior DO Target:Nr. of prior DO Prime:Nr. of prior PO Prime	0.001	0.000	1.557	0.120
Prime=DO:Nr. of prior PO Target:Nr. of prior DO Prime:Nr. of prior PO Prime	0.000	0.000	−0.844	0.399
Prime=PO:Nr. of prior PO Target:Nr. of prior DO Prime:Nr. of prior PO Prime	0.000	0.000	0.403	0.687
SUBJECT_TYPE=Literate:Nr. of prior PO Target:Nr. of prior DO Prime:Nr. of prior PO Prime	0.000	0.000	0.210	0.833
Nr. of prior DO Target:Nr. of prior PO Target:Nr. of prior DO Prime:Nr. of prior PO Prime	0.000	0.000	4.770	0.000
Prime=DO:SUBJECT_TYPE=Literate:Nr. of prior DO Target:Nr. of prior PO Target:Nr. of prior DO Prime	0.000	0.001	0.408	0.683
Prime=PO:SUBJECT_TYPE=Literate:Nr. of prior DO Target:Nr. of prior PO Target:Nr. of prior DO Prime	−0.001	0.001	−0.889	0.374
Prime=DO:SUBJECT_TYPE=Literate:Nr. of prior DO Target:Nr. of prior PO Target:Nr. of prior PO Prime	0.001	0.001	0.947	0.344
Prime=PO:SUBJECT_TYPE=Literate:Nr. of prior DO Target:Nr. of prior PO Target:Nr. of prior PO Prime	−0.001	0.001	−0.663	0.508
Prime=DO:SUBJECT_TYPE=Literate:Nr. of prior DO Target:Nr. of prior DO Prime:Nr. of prior PO Prime	0.000	0.001	0.567	0.570
Prime=PO:SUBJECT_TYPE=Literate:Nr. of prior DO Target:Nr. of prior DO Prime:Nr. of prior PO Prime	0.000	0.001	−0.566	0.572
Prime=DO:SUBJECT_TYPE=Literate:Nr. of prior PO Target:Nr. of prior DO Prime:Nr. of prior PO Prime	0.000	0.000	0.692	0.489
Prime=PO:SUBJECT_TYPE=Literate:Nr. of prior PO Target:Nr. of prior DO Prime:Nr. of prior PO Prime	0.000	0.000	−1.339	0.181
Prime=DO:Nr. of prior DO Target:Nr. of prior PO Target:Nr. of prior DO Prime:Nr. of prior PO Prime	0.000	0.000	1.793	0.073
Prime=PO:Nr. of prior DO Target:Nr. of prior PO Target:Nr. of prior DO Prime:Nr. of prior PO Prime	0.000	0.000	−2.085	0.037
SUBJECT_TYPE=Literate:Nr. of prior DO Target:Nr. of prior PO Target:Nr. of prior DO Prime:Nr. of prior PO Prime	0.000	0.000	−1.275	0.202

Table 4 continued

	Estimate	Std. error	*z* value	Pr(>|z|)
Prime=DO:SUBJECT_TYPE=Literate:Nr. of prior DO Target:Nr. of prior PO Target:Nr. of prior DO Prime:Nr. of prior PO Prime	0.000	0.000	−1.384	0.166
Prime=PO:SUBJECT_TYPE=Literate:Nr. of prior DO Target:Nr. of prior PO Target:Nr. of prior DO Prime:Nr. of prior PO Prime	0.000	0.000	2.127	0.033

Random effects include by-subject and by-item intercepts

Table 5 Results from the logistic mixed-effects model on the DO productions, investigating the effects of immediate priming, cumulative adaptation and literacy group

	Estimate	Std. error	*z* value	Pr(>|z|)
(Intercept)	0.113	0.510	0.222	0.825
Prime=PO	−1.228	0.209	−5.887	<0.001
SUBJECT_TYPE=Literate	−1.125	0.425	−2.647	0.008
Relatedness=Unrelated	−0.778	0.627	−1.241	0.215
Prime=PO:SUBJECT_TYPE=Literate	−0.032	0.303	−0.106	0.915
Prime=PO:Relatedness=Unrelated	0.537	0.302	1.776	0.076
SUBJECT_TYPE=Literate:Relatedness=Unrelated	−0.096	0.307	−0.314	0.753
Prime=PO:SUBJECT_TYPE=Literate:Relatedness=Unrelated	0.168	0.444	0.379	0.705
	Estimate	Std. error	*z* value	Pr(>|z|)
(Intercept)	1.773	0.334	5.309	<0.001
Prime=DO	0.874	0.425	2.055	0.040
Prime=PO	0.033	0.221	0.147	0.883
SUBJECT_TYPE=Literate	−0.630	0.203	−3.103	0.002
Relatedness=Unrelated	−0.103	0.310	−0.334	0.739
Prime=DO:SUBJECT_TYPE=Literate	−0.111	0.140	−0.788	0.431
Prime=PO:SUBJECT_TYPE=Literate	0.067	0.092	0.730	0.465
Prime=DO:Relatedness=Unrelated	0.307	0.112	2.730	0.006
SUBJECT_TYPE.e1:Relatedness=Unrelated	−0.016	0.081	−0.198	0.843
Prime=DO:SUBJECT_TYPE=Literate:Relatedness=Unrelated	−0.039	0.111	−0.349	0.727

Table 6 The number of other responses per each prime condition and literacy group

	Illiterate	Literate
Baseline	116	90
DO	67	36
PO	57	34
Total	240	160

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