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Running head: AN INVESTIGATION INTO THE LEXICAL BOOST

An investigation into the lexical boost with nonhead nouns

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Abstract

In five structural-priming experiments, we investigated lexical boost effects in the production of ditransitive sentences. Although the residual activation model of Pickering and Branigan (1998) suggests that a lexical boost should only occur with the repetition of a syntactic licensing head in ditransitive prepositional object (PO)/double object (DO) structures, Scheepers, Raffray, and Myachykov (2017) recently found that it also occurs with the repetition of nouns that are not syntactic heads. We manipulated the repetition of the subject (Experiments 1-3), and the verb phrase (VP) internal arguments (i.e., either theme or recipient, Experiments 4-5) in PO/DO structures. In Experiment 2, the verb was also repeated between prime and target, while in the other experiments it was not. Three different tasks for eliciting the target were employed: picture description via the oral completion of a sentence fragment (Experiments 1-2, and 4), oral completion of a sentence fragment with no visual context (Experiment 3), and oral production of a sentence from a given array of words and no visual context (Experiment 5). Priming occurred in all experiments and was stronger when the verb was repeated (Experiment 2) than when it was not (Experiment 1). However, none of the experiments showed evidence that priming was stronger when either the subject or one of the VP-internal arguments were repeated. These findings support the view that structural information is associated with syntactic heads (i.e., the verb), but not with nonheads such as the subject noun and the VP-internal arguments (Pickering & Branigan, 1998).

Key words: language production; structural priming; lexical boost; syntactic head

Structural priming, the tendency to repeat aspects of sentence structure in successive, unrelated utterances, has been the subject of much investigation over the last twenty years or so. Since the early demonstrations by Bock (1986, 1989), structural priming has been observed with various syntactic structures, in different populations and languages, and with different methods and modalities (see Pickering & Ferreira, 2008, for an overview). One of the reasons why structural priming has attracted so much interest is that it can provide powerful insights into the nature of structural representations and processes involved in language production (Branigan & Pickering, 2016).

One important finding in research on structural priming in production is that priming is stronger when particular words such as the verb are repeated between the prime and the target than when they are not. This finding has been taken as evidence that representations of syntactic structure are associated with these words. Pickering and Branigan (1998) asked participants to complete prime fragments similar to the ones in (1) and then to complete target fragments consisting of a subject and a ditransitive verb. The ditransitive verb in the prime was either repeated in the target or not.

1a. The racing driver showed the torn overall ... (prepositional-object-inducing prime)

1b. The racing driver showed the helpful mechanic ... (double-object-inducing prime)

As in previous studies (e.g., Bock 1986, 1989; Bock, Loebell & Morey, 1992), Pickering and Branigan found priming when the verb in the prime and the target was different; however, priming was significantly enhanced when the verb was repeated. This effect has been termed the *lexical boost effect* and has been replicated in several subsequent studies that have manipulated verb repetition in ditransitive structures (Branigan, Pickering & Cleland, 2000; Corley & Scheepers, 2002; Hartsuiker, Bernolet, Schoonbaert, Speybroeck, & Vanderelst, 2008;

Schoonbaert, Hartsuiker, & Pickering, 2007; Rowland, Chang, Ambridge, Pine, & Lieven, 2012; Segaert, Kempen, Petersson, & Hagoort, 2013; Scheepers, Raffray & Myachykov, 2017; see also Bernolet, Coleman & Hartsuiker, 2014, for evidence that the lexical boost in verb repetition is due to the repetition of the verb form as well as the repetition of the verb's sense).

Pickering and Branigan (1998) provided an account of the lexical boost effect in their residual activation model of structural priming. This model, developed from Roelofs's (1992) computational model of lexical access, assumes that in the mental lexicon, word lemmas are linked to combinatorial nodes that contain information about the structures with which they can co-occur. In articles by proponents of the residual activation model (e.g., Cleland & Pickering, 2003; Pickering & Branigan, 1998; Schoonbaert et al., 2007), the lemmas that are linked to combinatorial nodes are always lemmas of open-class words that are the syntactic head of the structure with which they co-occur, see the diagram in Figure 1.

INSERT FIGURE 1 HERE

As can be seen in Figure 1, the lemma node of a ditransitive verb such as *give* is linked to two combinatorial nodes that specify the syntactic frames with which this verb can co-occur, *NP NP* (the *double object* DO frame, as in *The boy gives the teacher an apple*) and *NP PP* (the *prepositional object* PO frame, as in *The boy gives an apple to the teacher*). When speakers produce sentences, the lemma nodes get activated as well as the relevant combinatorial nodes and the links between the lemma nodes and the combinatorial nodes. For example, when a speaker utters the prime sentence *The boy gives the teacher an apple*, the lemma node for *give*, the combinatorial *NP NP* node and the link between the lemma for *give* and the *NP NP* node get activated (vice versa, if the speaker utters *The boy gives the apple to the teacher* the *NP PP* combinatorial node and the link with the *give* lemma are activated).

The residual activation model accounts for both lexically independent priming (i.e., when the verb is different in prime and target) and the lexical boost effect (i.e., stronger priming when the verb is the same). Specifically, if the target sentence contains the same verb as the prime (e.g., *give*), priming is due to *both* the residual activation of the combinatorial node for the prime structure (e.g., *NP NP*) and the link between the lemma for *give* and the combinatorial node. In contrast, if the verb in the target sentence is different (e.g., *lend*), priming results from the residual activation of the relevant combinatorial node *only* (e.g., the *NP NP* node); because the target verb did not appear in the prime, there is no residual activation of the link between the target verb and the *NP NP* node; this results in a smaller priming effect (i.e., no lexical boost).

Although proponents of the residual activation model do not explicitly rule out that combinatorial nodes can be linked to lemma nodes of words that are not syntactic heads, all instantiations of the model do assume that combinatorial nodes are linked to lemmas of open-class words that are heads. For example, in the diagram in Figure 1 the PO and DO combinatorial nodes are linked to the lemmas of ditransitive verbs (*give* and *send*), but not to other lemmas such as those of the subject noun in ditransitive sentences. This suggests that the lexical boost effect should occur exclusively with the repetition of open-class syntactic heads, but not with the repetition of other words.

The idea that syntactic information is stored with syntactic heads is supported by findings such as those obtained by Melinger and Dobel (2005), where single verb primes were sufficient to bias speakers' preferences for a PO or DO structure in the target, and by findings showing that information about the frequency with which particular structures occur is stored with syntactic heads (e.g., MacDonald, Pearlmutter, & Seidenberg, 1994; Trueswell, Tanenhaus, & Kello, 1993). It is also consistent with assumptions in linguistics (e.g., Pollard & Sag, 1994), where it is generally assumed that the head of a phrase determines the grammaticality of particular structures

(e.g., the fact that the DO structure *The millionaire donated the charity a sum of money* is ungrammatical is determined by the verb *donate*, but not by, for example, *millionaire*).

However, there are other accounts of the lexical boost. One model that is compatible with a boost from the repetition of nonhead words is Chang et al.'s (2006) implicit learning model. In contrast to the residual activation model, the implicit learning model postulates two separate mechanisms for lexically dependent and lexically independent priming. According to this model, lexically independent priming is due to long term implicit learning, an error-based connectionist learning mechanism which learns mappings between conceptual representations and abstract sequences of words. Crucially, the learning of such mappings is not assumed to be directly associated with specific lexical items. Because the implicit learning mechanism is not sensitive to lexical information, it does not predict enhanced priming when a syntactic head, or for that matter, nonheads words, are repeated. Instead, Chang et al. propose that the lexical boost is due to an *explicit* memory mechanism in which the repeated word acts as an explicit cue to the structure of the prime and they hypothesise that "lexical enhancement occurs for verbs and nouns, but not for function morphemes, because the latter are not particularly effective cues" (Chang et. al, 2006, p. 256). Thus, according to this account, the repetition of any open class (i.e., content) word should result in a lexical boost, irrespective of whether this word is a syntactic head or not.

Another account that predicts a lexical boost for both heads and nonheads is Reitter, Keller and Moore's (2011) ACT-R model of structural priming. The model uses two default ACT-R mechanisms, base-level learning and spreading activation. In this model, abstract priming is due to both mechanisms, with spreading activation explaining short term priming (i.e., the priming effect observed for the target sentence immediately following the prime sentence), and with base-level learning explaining long term adaptation. On the other hand, the lexical boost occurs as a result of spreading activation with an additional, associative learning function which temporarily increases the strength of the associations between lexical and syntactic nodes.

Importantly, in this model, spreading activation and associative learning occurs regardless of whether a word is a syntactic head or not.

However, all models agree that the lexical boost is limited to the repetition of *open class* head words and does not occur when function, closed-class words are repeated. Bock (1989) manipulated the repetition of a preposition, that is, a closed class word. She found that such repetition did *not* affect priming: Speakers produced the same number of ditransitive PO target structures containing the preposition *to* irrespective of whether primes contained a prepositional phrase with the preposition *to* (*The girl is handing the paintbrush to the man*) or a prepositional phrase with the preposition *for* (*The secretary is baking a cake for her boss*); in other words, repeating the preposition *to* did not lead to enhanced priming of the PO structure (see also Fox Tree & Meijer, 1999; Pickering & Branigan, 1998; Ferreira, 2003, for further evidence).

As mentioned earlier, there are many studies showing that the lexical boost occurs with the repetition of the verb, an open-class syntactic head. However, only a few studies have tested whether it also occurs with nonheads. Cleland and Pickering (2003), using the confederate scripting priming paradigm, investigated the priming of noun phrase (NP) structures, that is, the adjective-noun structure (e.g., *the red square*) and the noun-relative clause structure (e.g., *the square that's red*) and found a priming effect: Participants were more likely to produce an adjective-noun structure after they had been exposed to a prime containing an adjective-noun than a noun-relative clause structure, whereas they produced more noun-relative clause structures after noun-relative clause primes. In Experiment 1, Cleland and Pickering manipulated the repetition of the noun (the syntactic head of the two NP structures), and of the adjective (a nonhead). They found a reliable lexical boost when the noun was repeated, which is predicted by the residual activation model, as the noun is often considered the syntactic head of the noun phrase structure, but the effect of adjective repetition was statistically not reliable. Thus, this particular result suggests that the lexical boost does not occur with nonheads.

Ivanova, Wardlow, Warker, and Ferreira (2017) showed that the lexical boost also does not occur when a word is used as a head in the target, but as a nonhead in the prime. In their Experiment 2, participants first saw a novel word such as *niss* used as the subject noun in a PO or DO prime (e.g., *the niss passed the apple to the clown*) and subsequently had to use it as a verb in the target (e.g., *the girl nissed the balloon to the cowboy*). Thus, the novel word was the syntactic head of the PO or DO in the target, but not in the prime. Priming in this condition was significantly smaller than in a condition where the novel word was the verb in both the prime and the target and also numerically smaller than when the verbs in the prime and target were different novel words (the latter was a between-experiment manipulation and no statistical comparison was carried out). However, it should be noted that even according to models that predict a lexical boost with nonheads, the lexical boost may not occur when the repeated word has a different category in the prime and target, because structures may be associated separately with nouns and verbs in memory.

McLean, Pickering and Branigan (2004) report the findings of a series of confederate priming experiments manipulating the repetition between prime and target of nonhead arguments in ditransitive sentences. Their numerical results suggested that priming was stronger when all three nonhead nouns were repeated than when they were different. Furthermore, when only the theme was repeated, priming from the PO structure was larger than when there was no repetition (but priming from the DO was not boosted) and when only the recipient was repeated, priming from the DO structure was larger than without repetition (but priming from the PO was not boosted). However, no statistical results were reported and the repetition manipulation was between experiments, which raises the possibility that any differences are due to experiment-general strategies that participants adopt when they notice frequent word repetition in an experiment. Furthermore, repetition of more than one word between the prime and target may also make participants highly aware of the priming manipulation.

More recently, Scheepers, Raffray, and Myachykov (2017) investigated the lexical boost effect in three experiments in which participants first read aloud a PO or DO prime sentence and then saw a random array of words from which they had to construct a sentence (e.g., *bible, evangelist, youngster, sold*). One of the words was marked in a different colour to indicate that they had to start with this word. The words were chosen such that participants generally produced either a PO or DO sentence (e.g., *The evangelist sold the bible to the youngster/the youngster a bible*). In the first experiment, they observed stronger priming (i.e., a lexical boost) when the agent, verb or recipient was repeated (and a non-significant tendency when the theme was repeated). In the other two experiments, they investigated whether the number of words that was repeated (e.g., no word repeated, agent-only repeated, agent+verb repeated, agent+verb+theme repeated, agent+verb+theme+recipient repeated) had an effect. They found that priming increased the more words were shared between prime and target. Thus, Scheepers et al.'s (2017) findings showed a lexical boost not only when the verb was repeated, but also when nonhead words were repeated, either in combination with the verb or not. Scheepers et al.'s (2017) main conclusion from these findings was that the lexical boost is *not* diagnostic of lexically-specific syntactic representation - one should note that the authors stopped short of concluding that syntactic representations are also associated with nonheads, and in doing so they appear to adhere to the standard assumption that such representations can only be associated with heads.

It is possible that the process of sentence generation involved in the random word array task differs from that involved in tasks where speakers are asked to describe a picture. In the random word array task, speakers start with the words given in the array and then have to order them to describe a plausible event that contains these words. When words from the prime are repeated in the array, they may realise that the prime is useful for putting the word array into an order that is meaningful. As a result, they may be primed more strongly when words are repeated between prime and target. In contrast, in picture description (either in combination with a verbal

cue or not), speakers start with the apprehension and conceptualisation of the depicted event; because the pictures make the event easy to conceptualise, speakers may not need word repetition from the prime to find a structure that is meaningful, and therefore, word repetition may not affect structural priming to the same extent as in the random word array task. In sum, during the random array production task, participants may engage in different processes from those involved in other tasks such as picture description, and these processes may have resulted in a lexical boost with words other than the verb.

Some corpus studies also suggest that the lexical boost is not confined to heads. To support their ACT-R model of syntactic priming, which predicts a lexical boost also with the repetition of nonheads, Reitter et al. (2011) investigated the repetition of various syntactic structures, including ditransitive PO and DO structures, in the Switchboard corpus (Godfrey, Holliman, & McDaniel, 1992). They used the lag effect (more structural repetition when two similar structures were closer to each other) as an indication of structural priming. Their mixed regression model showed that the head \times lag interaction was not significant, indicating that the repetition of heads did not cause increased structural repetition. In contrast, the word \times lag interaction was significant, suggesting that the repetition of words in general (heads and nonheads) did enhance structural repetition.

In contrast to Reitter et al. (2011), Snider (2009) did find evidence for a head verb boost when analysing only ditransitives in the Switchboard corpus. In addition, he found that the more similar the prime and target were on a series of features (where these features make up what Snider calls the “similarity metric”), the greater the priming effect. This similarity metric included variables taken from a corpus analysis of ditransitives by Bresnan, Cueni, Nikitina, and Baayen (2007), such as whether the recipient or theme are pronouns, their givenness and definiteness, whether the theme is plural, and the semantic class of the ditransitive verb. Structural priming was modulated by this similarity metric when verb repetition was also

included in the model. This suggests that there are similarity factors other than verb repetition that boost structural priming, but because nonhead repetition was not included in the similarity metric, it does not directly inform us whether their repetition affects priming.

A general concern when relying on corpus evidence to demonstrate syntactic priming is that in a corpus (especially one that is based on oral conversations such as the Switchboard corpus) several non-syntactic factors (e.g., discourse coherence constraints) could lead to repetition. For example, when two structures are more closely connected in the discourse structure, they are more likely to be syntactically primed, but at the same time, it is also more likely that words (in Reitter et al., 2006) or other features (in Snider, 2009) are repeated across them (because they are primed). Examples of sentences that are closely connected in the discourse are question-answer pairs, which presumably occur a lot in the Switchboard corpus. Another variable that may correlate with lexical, featural and syntactic repetition is interlocutor identity: Speakers may be primed more strongly by their own than someone else's production, both syntactically and in terms of word and feature repetition. In sum, when using corpus evidence, one must proceed with caution as there may be confounding variables at work that are correlated with lexical, featural and syntactic repetition. In contrast, controlled psycholinguistic experiments provide a better tool to unequivocally demonstrate priming.

Thus, in this paper, we present the results of five syntactic priming experiments that investigated whether a lexical boost occurs with the repetition of nonheads in ditransitive PO/DO structures, manipulating the repetition of the subject, the verb, the theme, and the recipient. To investigate the effect of priming method, we used three different target elicitation paradigms: Sentence completion with picture description (Experiments 1, 2, and 4), free completion without pictures (Experiment 3), and the random word array task (Experiment 5).

Experiment 1

Experiment 1 tested whether repeating the subject noun in ditransitive PO or DO structures leads to enhancement of priming compared to when it is not repeated. In Experiment 1, the verb in the prime and the target, which is the head of the PO or DO structure, was always different. Participants first read one of the prime sentences exemplified in (2) aloud.

- 2a. The lawyer will hand the celebrity the present. (DO, different subject)
- 2b. The lawyer will hand the present to the celebrity. (PO, different subject)
- 2c. The boy will hand the celebrity the present. (DO, same subject)
- 2d. The boy will hand the present to the celebrity. (PO, same subject)

For the production of the target sentence, we employed a spoken sentence completion method (e.g., Branigan, Pickering, Stewart, & McLean, 2000; Van Gompel, Pickering, Pearson, & Jacob, 2006; Cai, Pickering, Wang & Branigan, 2015). One advantage of this method is that it allowed us to control both the verb and the subject noun that participants produced in the target sentence, so we could manipulate whether they were the same or different from the prime. In order to minimise the number of ‘Other’ responses that occur when participants complete the target, we combined the completion method with a picture description task similar to that employed by Cai et al. (2015) which required participants to complete a sentence fragment presented underneath the picture (Figure 2) by referring to the persons and objects in the picture.

INSERT FIGURE 2 HERE

The primes were either in the DO (2a, 2c) or the PO structure (2b, 2d). Furthermore, the subject noun was either the same in the prime and target (2a-b) or different (2c-d). Previous studies have shown that priming occurs in the absence of any lexical overlap, so we expect more PO target completions following PO than DO primes, both when the subject noun is the same and different in prime and target. The crucial question is whether priming is equally strong when the subject noun is the same as when it is different. If the repetition of any content word functions as a cue for the retrieval of the prime structure, as predicted by Chang et al.'s (2006) implicit learning model, we should observe stronger priming in the conditions where the subject noun is repeated compared to where it is not repeated. A similar prediction is made by Reitter et al.'s (2011) ACT-R model of structural priming; however in this case the lexical boost would be due to spreading activation and heightened associative links between lexical and syntactic nodes. In contrast, if heads are associated with syntactic information but nonheads are not, no enhanced priming should occur.

Method

Participants. Thirty-two students from the University of Dundee, UK, took part in the experiment for course credit. They were all monolingual native speakers of British English and had normal or corrected-to-normal vision.

Materials. We constructed 40 experimental prime-target pairs, containing 15 different ditransitive verbs (see Appendix). The prime sentences were complete written sentences in the four conditions illustrated in (2). Targets were written fragments associated with a picture. The fragments contained a subject noun and a verb (e.g., *A boy will send ...*) and were printed at the bottom of the picture. The subject NP of the target fragment was always indefinite (e.g., in Figure

2: *A boy*), while the subject in the preceding prime was always definite (e.g., in (2): *The lawyer* or *The boy*). This was done so that in the same-subject conditions (2c-d) speakers did not construe the subject of the target fragment as referring to the same entity as the subject of the prime; in other words, to discourage participants from construing the prime and target sentences as being part of the same discourse. Each picture displayed three entities. One of the entities was the subject of the sentence mentioned in the fragment, while the other two entities were selected so that they represented a plausible theme and recipient of a ditransitive sentence with the target verb. The theme was always an inanimate entity and the recipient an animate one. Apart from the repetition of the subject noun in conditions (2c-d), there was no other semantic or lexical overlap between prime and target. To minimize variability in responses which may be due to the position of the pictures, we always displayed the subject agent on the left of the screen, while the theme and recipient entities appeared in different parts to the right and their position was counterbalanced across items.

In addition to the 40 experimental items, we constructed 72 written sentences and 53 pictures with associated sentence fragments, to act as fillers. These filler items contained passives, intransitives and copula-verb constructions. To disguise the repetition manipulation in the experiment, twelve filler sentences were paired with twelve picture fillers such that one of the content words was repeated.

Design. The experimental prime-target items and the filler items were combined and four counterbalanced experimental lists were constructed, each comprising 10 experimental items from each condition, such that one version of each item appeared in each list. This yielded a fully factorial Latin square design. The experimental items were arranged in a fixed pseudo-random order, interspersed with the filler items. Five fillers appeared at the beginning of the experiment

and four fillers followed a short break half way through the experiment. An average of 3.5 filler items separated each experimental prime-target pair, with a minimum of two filler items.

Procedure. The experiment was run with the DMDX software (Forster & Forster, 2003). Participants were seated in front of a computer colour monitor. When they arrived for the experiment, they were told that they would see a sequence of sentences and pictures. They were asked to read the sentences aloud and then click on the mouse to clear the screen. When a picture appeared, they had to describe the picture, using the fragment written under the picture as the start of their sentence. They were told that in their sentence, they should mention all three entities in the picture. In this and all the other experiments in the current study, no time limit was imposed to participants' producing the target sentence, who were instructed to click on the mouse to clear the screen after producing the sentence. A fixation cross was presented before each reading trial and stayed on the screen for 2000 ms. A picture trial immediately followed a reading trial without prior presentation of a fixation cross. In order to make the task more similar to comprehension priming experiments that we have conducted (Arai, Van Gompel, & Scheepers, 2007; Carminati, Van Gompel, Scheepers, & Arai, 2008), participants were asked to 'Continue the description using the picture' after producing the sentence fragment completion in 23 filler items. The experiment was administered in two blocks, with a short break between the two blocks. The whole experimental session was digitally recorded on audiotape with a Mini Disk Recorder. The experiment lasted approximately 45 minutes.

Analyses.

For the inferential analysis of the results of Experiment 1 and the other experiments reported in this paper, we used the package *lme4* (version 1.1.18.1.) within the *R* software (version 3.4.2.) to model the binary choice of target structure (PO = 1 vs. DO = 0) on data that

contained only the PO and DO responses (i.e., on data from which ‘Other’ responses were excluded). We applied the *glmer* function for Generalised Linear Mixed models (GLMM) specifying the binomial option. The predictors were numerically transformed and centered around zero. This coding makes the output of the model interpretable in the same way as the output of an ANOVA, with the intercept representing the overall grand mean and the β coefficients the main effects and interaction(s). For model selection, we followed Barr, Levy, Scheepers, and Tily (2013) in first attempting models that had a maximal random effect structure to take into account all possible individual participant and item differences; that is, in their random part, these models included not only random intercepts for participants and items, but also participants and items random slopes for every main effect and interaction present in the fixed effects part of the models, and the respective correlations. All of the starting models used in our analyses had the above fully specified random structure; however, in some cases because of convergence failures, random correlations were dropped. In the analysis section for each experiment, we will refer to the fully specified model with random correlations as the “full model with correlations” and to the fully specified model without correlations as the “full model without correlations”. After obtaining the best possible maximal random effect model for a specific data set, the significance of the fixed effects and the interactions was assessed with likelihood-ratio χ^2 model comparisons, by comparing the full model to a reduced model in which the effect or interaction of interest was missing in the fixed effects structure (the reduced and full model were always identical in the random part). In addition to the results of the model comparisons, we also report the fixed effects parameter estimates (β coefficients, *SE* and Wald *z*). In all experiments, significance testing of the parameter estimates and the results of the model comparisons were consistent, but because the results of the model comparisons have been argued to be more robust against collinearity in the model (Agresti, 2002), we only report the *p*-values of the latter in the tables.

Results

The recordings of participants' answers were used to produce a written record of the target completions. These descriptions were then scored as PO or DO responses. To qualify as a PO response, a description had to contain a theme following the verb provided in the fragment and a recipient preceded by the preposition *to*. In a DO response, the verb had to be followed by the recipient and by the theme in that order. Responses not meeting these criteria, or responses where participants had made errors in the reading of the prime were classified as 'Other'. Application of these scoring criteria yielded a total of 1174 valid responses where the description was coded as either a PO or a DO response (92% of all responses). Figure 3 shows the proportions of DO, PO and Other responses as a function of prime structure and subject repetition.

INSERT FIGURE 3 HERE

Examination of Figure 3 shows an overall preference for the production of the PO structure, a preference which has been observed in several other syntactic priming studies on English (e.g., Pickering & Branigan, 1998; Scheepers et al., 2017). However, this preference appears to be modulated by the form of the prime structure: There are more DO completions after a DO prime than a PO prime (28% vs. 19%), whereas PO completions are more frequent after a PO than a DO prime (72% vs. 64%). Moreover, the priming effect does not appear to be modulated by the repetition of the subject.

In the mixed effect logistic regression, the fixed predictors were prime structure (PO vs. DO) and subject repetition (subject repeated vs. subject not repeated). The maximal converging model was the full model without correlations. The model summary and the results of the model comparisons are given in Table 1.

INSERT TABLE 1 HERE

The model summary in Table 1 shows a positive and significant intercept (1.669), confirming the observation made earlier that overall, the probability of producing a PO target was significantly higher than that of producing a DO target. More importantly, the model comparisons showed that the effect of prime structure was significant while that of subject repetition was not. Crucially for our research question, the prime structure \times subject repetition interaction was not significant, indicating no lexical boost with subject repetition.

Discussion

Experiment 1 showed that repetition of the subject noun in ditransitive PO/DO structures did not result in a lexical boost. We observed clear structural priming effects, but priming was no stronger when the subject noun was repeated than when it was not. These findings suggest that syntactic representations are not associated with nonheads. Furthermore, they do not support the explicit memory account of the lexical boost suggested by Chang et al. (2006) or Reitter et al.'s (2011) account of spreading activation. According to both accounts, the repetition of any content word should produce a lexical boost. In contrast, the results are consistent with the residual activation model, because current instantiations of the model assume that syntactic, combinatorial information is associated with heads, but not with nonheads.

Experiment 2

Experiment 2 tested whether repeating the subject noun results in a lexical boost effect in cases where the verb is also repeated, using the same method as in Experiment 1. Thus,

Experiment 2 represents another test of the hypothesis that syntactic information is associated with nonheads. Furthermore, by comparing the size of the priming effect in Experiment 2 (where the verb was repeated) with that of Experiment 1 (where the verb was not repeated) we will be able to determine whether repetition of the verb, the head of the PO and DO structure, results in a lexical boost.

Method

Participants. Twenty-eight new participants from the same population as in Experiment 1 took part in the experiment in exchange for course credit.

Materials. Experiment 2 used exactly the same materials as Experiment 1, with the exception that the verb in the prime was changed so that it was the same as in the target. For example, the four prime sentences in (2), which were associated with the target picture in Figure 2, all had the verb *send* in Experiment 2, the same verb as in the target fragment. As a result of this change, in conditions (2a-b) only the verb was repeated between prime and target, whereas in conditions (2c-d) both verb and subject were repeated.

Design and procedure. The design and procedure were the same as in Experiment 1.

Results

The same scoring procedure as for Experiment 1 was followed. This yielded a total of 1068 valid trials where the description was coded as either a PO or a DO response (95% of all

responses). Figure 4 shows the proportions of DO, PO and Other responses as a function of prime structure and subject repetition.

INSERT FIGURE 4 HERE

Examination of the data in Figure 4 shows a clear priming effect, with the size of the priming effect greater than in Experiment 1, both for PO and DO primes. There was a strong preference for more PO completions after PO than after DO primes (88% vs. 48.5%), and for more DO completions after DO than PO primes (45% vs. 7.5%). Moreover, the priming effect appears to be equally strong in the different-subject as in the same-subject conditions.

The dependent variable and the predictors in the mixed effect logistic regression were the same as for Experiment 1 (prime structure and subject repetition) and the maximal converging model was the full model with the random correlations. The statistical results are given in Table 2. As in Experiment 1, model comparisons were conducted using likelihood-ratio χ^2 tests that compared the full model to a reduced model in which the effect or interaction of interest was missing in the fixed effects structure.

INSERT TABLE 2 HERE

The results of Experiment 2 are completely in line with those of Experiment 1: The model comparisons showed that there was a significant effect of prime structure, no significant effect of subject repetition, and no significant prime structure \times subject repetition interaction.

Combined analysis of Experiments 1 and 2

In order to determine whether priming was stronger when the verb was repeated (Experiment 2) than when it was different (Experiment 1) between prime and target, we also ran a mixed effects logistic regression model on the combined data from Experiments 1 and 2. This also allowed us to perform a more powerful analysis to test whether subject repetition affects structural priming. In this analysis, verb repetition was a between-participants and a within-items variable, therefore it was included in the random effects for items but not for participants (Barr, 2013). The maximal converging model included random correlations. Table 3 reports the model parameters and the results of the model comparisons.

INSERT TABLE 3 HERE

As one can see from Table 3, only the fixed predictor of prime structure achieved significance in the model comparisons. Importantly, the verb repetition \times prime structure interaction was significant, indicating that priming was stronger when the verb was repeated than when it was not. The combined analysis also confirmed the absence of a lexical boost with subject repetition, in that the prime structure \times subject repetition interaction was not significant, and nor was the 3-way interaction.

Discussion

Similar to Experiment 1, Experiment 2 showed that structural priming is unaffected by repetition of the subject noun, which is not the head of the primed structure. In other words, subject noun repetition does not result in a lexical boost effect. This finding was corroborated by

a more powerful analysis of the combined data from Experiments 1 and 2. In contrast, repetition of the verb (the head of the primed structure) clearly did affect the size of the priming effect, as demonstrated by the comparison of Experiments 1 and 2: Priming was stronger when the verb was the same (Experiment 2) than when it was different (Experiment 1).

Experiment 3

Experiments 1 and 2 involved sentence fragment completion in combination with a picture naming task in which participants had to retrieve words for the theme and the recipient entities depicted in the target display. In some cases, finding appropriate words may have been relatively difficult, which raises the possibility that their retrieval interfered with the activation of the prime structure (i.e., it decreased its activation, thus preventing priming). Thus, in Experiment 3, we used the same fragment completion task as in Experiments 1 and 2 (testing the same conditions and using the same materials), but with a free completion method in which participants did not see pictures that they had to refer to. If the picture naming task prevented the lexical boost from occurring in Experiment 1, we should be able to observe a lexical boost in Experiment 3. Furthermore, because there are now no pictures constraining the choice of names for the theme and recipient, we might expect that sometimes participants might repeat the names of the theme and/or the recipient that appeared in the prime (either in addition to repeating the subject or not). If this happens, we should also be able to test whether the repetition of the theme and/or recipient leads to a boost in priming, compared to the repetition of just the subject noun.

Method

Participants. Thirty-six new participants from the same population as in Experiments 1 and 2 took part in the experiment in exchange for course credit.

Materials and procedure.

The materials of Experiment 3 were identical to those of Experiment 1, except that all the pictures were removed from the experimental and filler target trials, leaving only the written sentence fragment (see Figure 2). The instructions were also modified to reflect this change: Participants were instructed to complete the sentence fragment in any way they liked so as to produce a meaningful and grammatical sentence.

Results

We used the same scoring criteria as in the previous experiments. This yielded a total of 688 valid trials where the description was coded as either a PO or a DO response (47.7% of all responses; 38.4% PO, and 9.3% DO responses respectively). The larger proportion of ‘Other’ responses compared to Experiments 1 and 2 is due to the fact that there were no pictures that constrained the completions, so participants often completed the sentence fragments with monotransitive structures (e.g., *the monk will rent ... his cabin out*).

Figure 5 shows the proportions of DO, PO and Other responses as a function of prime structure and subject repetition.

INSERT FIGURE 5 HERE

The dependent variable and the predictors in the mixed effect logistic regression were the same as for Experiment 1 (prime structure and subject repetition). The maximal converging model did not include random correlations. Table 4 reports the model summary and the results of the model comparisons, which were conducted using likelihood-ratio χ^2 tests in the same way as in the previous experiments.

INSERT TABLE 4 HERE

As one can see from Table 4, the model comparisons showed that the only predictor to achieve significance was prime structure. Crucially, the prime structure \times subject repetition interaction was far from significant, indicating that there was no lexical boost when the subject was repeated. Although Figure 5 suggests a numerically larger priming effect when the subject is repeated than when it is not, this is due to the slightly higher proportion of ‘Other’ responses in the different subject conditions; in the mixed effect analyses, which excluded the ‘Other’ responses, the means were in the opposite direction.

As expected, there were responses where participants repeated one or both of the prime’s verb phrase (VP) arguments in the target sentence; these cases were recorded in a separate variable “VP argument repetition” (repeated = 1, not repeated = 0). There were a total of 135 such cases out of 688 valid responses (i.e., 20% of valid responses); Figure 6 shows the proportion of PO and DO responses as a function of prime structure and as a function of whether one or both of the VP arguments from the prime were repeated in the target (we collapsed across the subject repetition variable because there were only 20 VP argument repetitions in the different subject conditions, so it was not meaningful to consider these conditions separately from the same subject conditions).

INSERT FIGURE 6 HERE

Parallel to the previous analyses, we ran a logistic regression model that included the predictor “VP noun repetition” (in addition to prime structure and subject repetition), to assess whether priming was boosted when participants repeated one or both of the VP arguments of the

prime. The maximal converging model was a full model without random correlations. Model comparisons comparing the full model with reduced models from which predictors of interest were absent confirmed a significant main effect of prime structure ($\chi^2 = 6.768, df = 1, p < .001$) and the absence of a prime structure \times subject repetition interaction ($\chi^2 = .559, df = 1, p = .455$). Importantly, the two-way prime structure \times VP repetition interaction was not significant ($\chi^2 = .610, df = 1, p = .435$), indicating that the repetition of the prime's VP arguments did not enhance priming. The three-way prime \times subject repetition \times VP repetition interaction was also not significant ($\chi^2 = 1.135, df = 1, p = .287$).

Discussion

Experiment 3 failed to find a lexical boost with the repetition of the subject using the free completion method. Thus, Experiment 3 provides additional evidence for the view that the lexical boost does not occur with nonhead repetition. Because we did not find a lexical boost in Experiment 3, we conclude that the reason why we did not find a boost in the first two experiments cannot be ascribed to the picture description task involving additional processes (i.e., retrieving the names of the depicted entities) compared to the free sentence completion task. Furthermore, it does not appear to matter whether participants can start with an event representation suggested by pictures (in combination with a sentence fragment) or one based on visually presented words only.

Experiment 3 also showed no evidence that repetition of the theme and/or recipient resulted in a lexical boost. However, because participants did not often repeat the theme or recipient, the analysis was based on few observations where at least one of the VP-internal arguments was repeated. We therefore conducted Experiment 4 for a more powerful analysis of VP noun repetition effects.

Experiment 4

In Experiment 4, we experimentally manipulated the repetition of the VP-internal arguments (theme and recipient), which, together with the subject noun, are also nonheads in ditransitive structures. As mentioned in the introduction, models such as Chang et al.'s (2006) implicit learning and Reitter et al.'s (2011) ACT-R models predict a lexical boost not only with the repetition of the subject noun, but also with the repetition of the two VP-internal theme and recipient arguments. In fact, to uphold these accounts, it could be argued that a lexical boost is more likely to occur with the repetition of the theme and recipient than with the subject. In particular, assuming, as per Chang et al.'s (2006) model, that the lexical boost is due to an explicit memory cue, in order for the repeated word to function as an effective retrieval cue for the PO or DO structure, it should be highly accessible in memory at the *particular point in time* when the choice is made to describe the target picture with a PO or DO structure (e.g., Bock, 1987). This might explain why repeating the subject noun did not result in a lexical boost in Experiments 1-3: The subject noun is produced before the PO or DO structure, so it may no longer be highly accessible when the structural choice is made. In contrast, because the theme and recipient nouns are part of the PO and DO structures, they are likely to be planned close in time to the planning of the structure, so these nouns should be highly accessible at the point of structural planning. In fact, it has been argued that the accessibility of the theme and recipient nouns directly influences the choice of the PO or DO structure (Bock and Irwin, 1980; Brown, Savova, & Gibson, 2012).

Furthermore, it has been assumed in the linguistic literature that VP-internal arguments (i.e., for ditransitive constructions, the theme and recipient) are more closely associated with the verb than the external argument, that is, the subject (cf. Marantz, 1984; Kratzer, 1996) because the verb subcategorises for and directly theta-marks its internal argument(s), whereas it does not

subcategorise for or directly theta mark its external argument. Thus, it can be assumed that nouns that occupy a slot of the verb's internal arguments in the prime might be more effective than external arguments in re-activating the same internal role assignment in the target's VP, causing an increase in priming. Therefore a test of the lexical boost effect with nonhead repetition must also consider cases where the theme and recipient are repeated.

In Experiment 4, we orthogonally manipulated prime structure (2 levels: PO vs. DO) and repetition (3 levels: no repetition vs. theme repetition vs. recipient repetition), thus making a total of 6 conditions. The verb in the prime and target was always different and so was the subject noun. The target eliciting task was similar to that of Experiments 1-2, involving the description of a picture, but with some modification to the written verbal cues presented under the picture (details below).

Method

Participants. Fifty-four new participants from the same population as in Experiments 1-3 took part in the experiment in exchange for course credit.

Materials. The experimental materials for Experiment 4 (see Appendix) were based on those of Experiment 1 with some modifications, as explained below. We also constructed 2 new items (prime + target pairs) to make up a total of 42 items (i.e., a multiple of the 6 conditions). Recall that in Experiments 1-2, the subject noun was presented in the sentence fragment that participants had to complete. In Experiment 4, where the repetition manipulation involved the theme and the recipient nouns, it was not possible to present the manipulated nouns in a sentence fragment without constraining the structure that participants had to produce. Thus, we decided to print only the verb under the pictures (see Figure 7) and instructed participants to use that verb in

their description (this procedure is similar to the one used in confederate priming experiments; see for example Branigan et al., 2000, where the verb is presented under the picture to be described). Like in Experiments 1 and 2, the entity corresponding to the subject agent was always displayed on the left of the display and participants were instructed explicitly to start their description by naming this entity (ensuring that they would indeed produce it as the subject). The theme (inanimate) and recipient (animate) entities were displayed on the right hand side and their position was counterbalanced across items.

In adapting the pictorial materials of Experiment 1 for Experiment 4, some of the characters in the picture displays of Experiment 1 were changed (or the subject and recipient arguments exchanged) in such a way that the intended target sentence in the theme and recipient repetition condition would describe an event that was plausible in the context of what was depicted in the visual context. Figure 7 shows the modified version of Figure 2 for Experiment 4. This picture was associated with the prime sentences in (3), which contained the prime structure and repetition manipulation:

- 3a. The acrobat will hand the rod to the colleague. (PO, no repetition)
- 3b. The acrobat will hand the book to the colleague. (PO, theme repetition)
- 3c. The acrobat will hand the rod to the juggler. (PO, recipient repetition)
- 3d. The acrobat will hand the colleague the rod. (DO, no repetition)
- 3e. The acrobat will hand the colleague the book. (DO, theme repetition)
- 3f. The acrobat will hand the juggler the rod. (DO, recipient repetition)

INSERT FIGURE 7 ABOUT HERE

Finally, we constructed a further 21 filler sentences and 4 filler pictures (in total there were 57 filler pictures and 93 filler sentences).

We also constructed a file for a pre-experiment picture naming session that was intended to familiarize participants with the characters depicted in the pictorial displays of the experiment (in both experimental and filler items) and their names. The file consisted of a sequence of pictures, each picture showing only one entity and with the English word commonly used to refer to the entity printed under it (for example, for Figure 2, there was a picture showing only the boy with the word ‘boy’ printed underneath).

Design. The experimental prime-target items and the filler items were combined and six counterbalanced experimental lists were constructed, each comprising 7 experimental items for each of the six conditions and forming a fully factorial Latin square design. An average of 3.5 filler items separated each experimental prime-target pair.

Procedure. The procedure for running Experiment 4 was similar to the procedure for Experiments 1 and 2, but before the actual experiment participants performed a picture naming task by going through the picture naming file. Participants were told that the purpose of this preliminary session was to introduce them to the pictures of objects and people that they would see in the experiment proper, and that the words under the pictures were the usual name used to refer to these entities in English. They were told to look at the pictures and read the words aloud. The purpose of the preliminary picture naming session was to increase the likelihood that participants indeed repeated the theme and recipient nouns in the theme and recipient repetition conditions. Note that the pictures showed enough detail as to warrant a description with a specific word; for example, the picture of a butcher showed a man wearing an apron with a steak in one hand and a cleaver in the other.

After the picture naming session, the experiment proper began. The instructions for this part were the same as for Experiments 1 and 2, except that participants were told that, when a picture appeared, they had to describe it by first mentioning the entity on the left and they had to complete the description using the verb given under the picture by mentioning the other two entities. The experiment lasted approximately one hour.

Results

We followed the same scoring procedure as for the previous experiments. In particular, in the conditions where theme and recipient were repeated, only responses containing the same word as in the prime (i.e., responses in which the prime word was repeated in the target, and with the appropriate thematic role) were considered valid; if they contained a different word, including one that would have been acceptable as a general description of the target, the responses were classified as 'Other'. This procedure yielded 1904 valid responses out of a total of 2268 responses (84% of the total number of responses). Figure 8 shows the proportions of DO, PO and Other responses as a function of prime structure and VP noun repetition.

INSERT FIGURE 8 HERE

INSERT TABLE 5 HERE

The results of the statistical analysis are presented in Table 5. For ease of interpretation, we ran separate logistic regression models on the data of Experiment 4 to compare (1) the no repetition primes (the baseline) with the theme repetition primes and (2) no repetition (the baseline) with recipient repetition. Both analyses contained the two-level variable of prime structure (PO vs. DO) and repetition (theme/recipient repeated vs. theme/recipient not repeated).

The models are reported in Table 5 as Model A (full model without random correlations) and Model B (full model with random correlations) respectively. As in the previous experiments, we then carried out likelihood-ratio χ^2 tests to compare these models containing all fixed variables with reduced models without the effect or interaction of interest to determine significance values.

As can be seen from Table 5, the model comparisons showed that the main effect of prime structure achieved significance in both models. There was also a marginal main effect of repetition in the model comparison of the no repetition with the theme repetition conditions (Model A), with the positive coefficient (.175) indicating that PO responses increased when the theme was repeated. However, the prime structure \times repetition interaction, testing whether priming was stronger with theme repetition relative to no repetition (Model A), and whether priming was stronger with recipient repetition relative to no repetition (Model B), was far from significant. Thus there was no lexical boost when the theme or the recipient were repeated in prime and target compared to when no word was repeated.

Discussion

Experiment 4 investigated whether a lexical boost occurs with the repetition of the VP-internal arguments in PO/DO structures, that is, the theme and the recipient, neither of which is the head of the PO or DO structure. As we have seen, these VP-internal argument words are assumed by some linguists to be syntactically more closely associated with the verb than the subject argument; furthermore, because the time of their planning in speech is presumably close to the time of planning the PO or the DO structure, they may be more accessible when the selection of the structure is made; thus, when repeated between prime and target they may act as a better explicit cue to the prime structure than when the subject noun is repeated. The results of Experiment 4 show that the repetition of the theme or recipient did not result in enhanced priming compared with when no argument was repeated. Together with the findings from Experiments 1-

3, they support the view that the repetition of nonhead words does not cause a lexical boost, and consequently that syntactic information is only associated with syntactic heads.

Experiment 5

So far, none of the experiments in this article has found any evidence for a lexical boost when the nonheads of ditransitive sentences (subject, theme and recipient) were repeated between prime and target. On the other hand, we did replicate the lexical boost found in many other syntactic priming experiments when the head (i.e., the verb) was repeated. Thus, up to now, all our evidence supports the residual activation model of Pickering and Branigan (1998), which suggests that structural information is linked to syntactic heads but not to nonheads.

However, our findings are in striking contrast with those of Scheepers et al. (2017), who found a lexical boost with nonheads in ditransitive sentences that were very similar to those we used. In their Experiments 2 and 3, they included conditions where several words were repeated between the prime and target, which may have made participants aware that in cases where there was word repetition, they could use the prime structure to construct a target sentence. But in their Experiment 1, they manipulated the repetition of only one word between prime and target (either the subject, verb, recipient, or theme), so this experiment is more directly comparable to the experiments in our current study.

The most obvious difference between Scheepers et al.'s (2017) Experiment 1 and our experiments is the method: Scheepers et al. used a random word array task in which participants had to construct a target sentence from visually presented words, whereas we used a fragment completion task either with or without picture description. As mentioned in the introduction, the random word array task may involve different processes from the tasks we have used. In order to investigate whether the difference in results between Scheepers et al.'s (2017) and our

experiments is due to the method, Experiment 5 used the same materials as in Experiment 4, but using Scheepers et al.'s method. This will allow us to compare the results from the two methods directly. If we find that the random word array task produces different results from our previous experiments, then we can conclude that the presence of a lexical boost with nonheads is dependent on a specific method. If it produces similar results, then we need to conclude that a lexical boost with nonheads is very difficult to replicate, even with the same task as in Scheepers et al.

Method

Participants. Fifty-four new participants from the same population as in Experiments 1-4 participated in the experiment in exchange for course credit.

Materials. We adapted the target materials of Experiment 4 for use in the random array task. Instead of showing the pictures with the verb underneath, the adapted target displays for Experiment 5 showed an array of 4 words arranged in a quadrant around the centre of the screen and on a white background. Following Scheepers et al. (2017), one of the words appeared in red font, and the other three in black. The word in red was the intended subject of the to-be-produced target utterance. The other three words corresponded to the verb in the future tense (e.g., “will send”, same as in Experiment 4), and the theme and recipient respectively. For any given experimental item, the words in the array were the same words that had been used in the pre-experiment picture naming task in Experiment 4 to name the entities depicted in the target display of that item. Figure 9 shows the target word array for the experimental item that in Experiment 4 was associated with the target display in Figure 7.

INSERT FIGURE 9 HERE

Filler items from Experiment 4 that contained pictures were changed so that they also consisted of arrays of four words, one of which was in red. The displays that showed text only in Experiment 4, i.e., displays showing experimental prime sentences or filler sentences, were kept unchanged in Experiment 5.

Design and Procedure. The design of Experiment 5 was identical to that of Experiment 4: PO and DO prime sentences for each item of Experiment 4 were combined with target word arrays in which, (a) no words from the prime were repeated (no repetition condition), (b) the theme word was repeated (theme repetition condition) and (c) the recipient word was repeated (recipient repetition condition). This yielded 6 prime-target pairs for each experimental item; these were allocated to 6 different lists following the same Latin square design as Experiment 4. The arrangement of the words in the array varied randomly from item to item, but was the same across lists. The relative order of fillers and experimental items was the same as in Experiment 4.

The instructions for Experiment 4 were also modified. Participants were told that, when they saw a sentence, they should read it aloud, then click on the mouse to clear the screen. When they saw an array of words, they should produce a sentence starting with the word printed in red and complete the sentence using the other three words in any order they wished. When they finished uttering the sentence, they should click on the mouse to clear the screen and proceed to the next trial. The experiment lasted approximately 45 minutes.

Results

The scoring procedure was the same as for the earlier experiments. Out of a total of 2268 responses, 2072 (91%) were considered valid. Out of these, 49% were classified as PO responses,

41% as DO responses and 9% as ‘Other’. Figure 10 shows the proportions of DO, PO and Other responses as a function of prime structure and repetition.

INSERT FIGURE 10 HERE

The data were analysed in the same way as in Experiment 4, using separate mixed effects logistic regression models to compare the no repetition conditions with the theme conditions and with the recipient conditions. The results of the statistical analyses are reported in Table 6.

INSERT TABLE 6 HERE

As one can see from the results of the model comparisons in Table 6, Experiment 5 replicated the crucial statistical results of Experiment 4, that is, the significant main effect of prime structure and the lack of a prime structure \times repetition interaction. The non-significant intercept in both models (see Table 6) indicates that overall, participants had no clear preference for either PO or DO targets, unlike in the previous experiments, where they showed a clear PO preference. One possible explanation for this is that the PO structure was relatively hard to construct from the word array because it did not contain the word “to”, whereas the DO structure did not require “to”.

Discussion

Using the random word array task, Experiment 5 showed no evidence for a lexical boost with the repetition of either the theme or recipient. In fact, the results were very similar to those of Experiment 4, where we used fragment completion in combination with picture description. From this we can conclude that the task does not appear to play a critical role in causing a lexical

boost with nonhead repetition; regardless of whether speakers start with an array of words or with pictures, we do not observe a lexical boost with nonheads. We return to this in the general discussion.

Combined analysis of Experiments 1-5

In order to perform a more powerful analysis to test whether nonhead repetition affects structural priming, we analysed the combined the data of Experiments 1-5. The fixed predictors in the combined analysis were prime structure (PO vs. DO), repetition (no repetition vs. repetition of a nonhead word), and experiment (5 levels: Experiments 1-5). Prime structure and repetition were within-participants and items (and therefore added to the random effects structure), while experiment was between participants and between items¹ (and was excluded from the random effects structure; Barr, 2013). The parameter estimates for the full model without random correlations and the results of the model comparisons are presented in Table 7.

INSERT TABLE 7 HERE

The results of the model comparisons confirmed the significant effect of prime structure and, most crucially, the lack of a prime structure \times word repetition interaction observed in the analyses for the individual experiments. Thus, even when combining the data from 204 participants and 6906 trials, we did not find any evidence for a lexical boost with nonheads.

¹ We considered experiment to be between items, because a few of the items used in Experiments 4-5 were not exactly the same as those in Experiments 1-3. Moreover, Experiments 4-5 had two additional items compared to Experiments 1-3 (42 vs. 40, see Materials section for Experiment 4). We also ran a model where experiment was a within-items variable, and it gave the same results.

Furthermore, the combined analysis showed a main effect of experiment, as well as a prime structure \times experiment interaction. The experiment effect is primarily due to a lower proportion of PO responses in Experiment 5 compared to the other experiments, and the interaction is due to the size of the priming effect varying across experiments (e.g., relatively large in Experiment 2, and quite modest in Experiment 3). However, there was no three-way interaction between prime structure, word repetition and experiment, indicating that the absence of a lexical boost was consistent across experiments. All in all, this combined analysis confirms and strengthens the results of the individual experiments.

General Discussion

Five structural priming experiments investigated the lexical boost effect to test whether syntactic information is associated with open class words that are not the head of the syntactic structure. Across three different tasks (sentence fragment completion with picture description, sentence fragment completion without pictures and the random word array task), we found no evidence that the repetition of the subject, the theme or recipient nouns enhanced priming of ditransitive PO or DO structures, either when the verb was different (Experiments 1, 3, 4 and 5) or the same (Experiment 2). This evidence was corroborated by the more powerful combined analysis of the data from all the 5 experiments which, in line with the analyses of the individual experiments, failed to find a prime structure \times repetition interaction. This supports the conclusion that structural information is not associated with nonheads. In contrast, and in line with previous findings, a comparison of Experiments 1 and 2 showed enhanced priming when the verb was repeated, indicating that heads *are* associated with structural information.

Our results contrast with those from Scheepers et al. (2017), who observed a lexical boost due to the repetition of nonhead nouns using the random word array task. In our experiments, we

repeated no more than a single word between prime and target, whereas in Experiments 2 and 3 of Scheepers et al., several conditions repeated multiple words. As mentioned previously, this may explain the difference in results with our experiments, as the repetition of multiple words may have made participants aware that repeated words might help them produce a sentence. More critically, we did not replicate the nonhead boost effect in Scheepers et al.'s Experiment 1, where they only ever repeated a single word. In particular, Experiment 5 in the current study, which used the random word array task that Scheepers et al. used, showed no evidence for a nonhead boost either with repetition of the theme or recipient.

We conclude that it appears to be difficult to replicate Scheepers et al.'s (2017) results of a lexical boost with nonheads, using either their random word array method or different methods. It is possible that subtle differences in the method and the materials explain the difference between Scheepers et al.'s (2017) and our findings, but any such explanation would have to be very speculative. Given that our combined analysis from five experiments using three different methods failed to uncover a lexical boost effect with nonheads, we conclude that, if the effect exists, it must either be very small or strongly dependent on subtle experimental differences. This contrasts with the lexical boost with verb repetition, which has been demonstrated in many studies and using different priming methods (e.g., Branigan et al., 2000; Corley & Scheepers, 2002; Hartsuiker et al., 2008; Schoonbaert et al., 2007; Rowland et al., 2012; Segart et al., 2013). Furthermore, Mahowald, James, Futrell & Gibson (2016) recently published a meta-analysis of 73 studies of syntactic priming in language production, where, among other things, they compared the magnitude of abstract priming to that of the lexical boost in a subset of 45 studies where verb repetition had been manipulated. They found that "the effect of lexical overlap is actually stronger than the priming effect itself" (Mahowald et al., 2016, p. 12). Thus, it appears that the lexical boost with verb repetition is not only very robust (i.e., easy to detect and replicable across different experimental paradigms), but also tends to be big in size.

Our findings are consistent with the residual activation account of structural priming and with its explanation of the lexical boost (e.g., Pickering & Branigan, 1998). As explained in the introduction, this model assumes that structural information is linked to word lemmas (see Figure 1). It is the activation of these links that results in the lexical boost effect. Specifically, the verb repetition effect in PO/DO priming occurs because during the processing of the prime, the link between the PO or DO structure and its head, the verb, is strengthened. Because the link is verb-specific, it enhances priming when the target verb is the same as in the prime, but it does not when it is different. In the residual activation model, it has so far been assumed that there are no links between structural information and nonheads. Our findings support this assumption: We found no evidence that repetition of the subject, theme or recipient between prime and target enhanced priming, suggesting that there are no links that can be activated between the abstract PO or DO structure and the argument nouns in the sentence.

Our results do not support models that assume that the repetition of any content word results in a lexical boost effect (e.g., Chang et al., 2006; Reitter et al., 2011). Chang et al.'s (2006) explanation of the lexical boost effect as due to an explicit memory mechanism predicts that any open class word, not just the head of the structure, should act as a cue to remembering and reproducing the prime structure in the target. Our results show that only the repetition of the verb leads to a lexical boost, but the repetition of the other argument nouns, including the VP-internal arguments, does not. Thus, to accommodate our findings, Chang et al.'s account of the lexical boost would need to be revised. If the explicit memory mechanism that Chang et al. propose is to be retained in the model, such a mechanism would have to incorporate a distinction between heads and nonheads, with the constraint that only head repetition is an effective cue for the retrieval of the prime structure. Note, though, that this constraint essentially implies that in explicit memory, structural information is associated with heads but not with nonheads, so explicit memory would have to make reference to abstract grammatical information; as such, it

would add a structural component to the explicit memory mechanism. This would constitute a radical extension of the model, because it would imply that abstract syntactic information is implicated not only in implicit learning, as is currently assumed, but also in explicit memory. Alternatively, the lexical boost could be accounted for in Chang et al.'s (2006) model within the same implicit learning mechanism responsible for abstract priming. This possibility has been considered (see in particular Chang et al., 2012); however in its current implementation, the model has met with difficulties in reproducing the high variability and the high magnitude in the size of the lexical boost found in some psycholinguistic experiments (confirmed by the results of Mahowald et al.'s (2016) meta-analysis mentioned earlier). For this reason, Chang et al. (2006) proposed that the lexical boost was due to a separate, explicit memory mechanism that is qualitatively different from the implicit learning mechanism that is responsible for abstract priming.

With regard to Reitter et al.'s (2011) model, in this model the lexical boost arises as a result of a temporary increase in the strength of the links between lexical and syntactic nodes via associative learning. To account for our findings, this model would have to restrict this increase to lexical nodes that are syntactic heads.

It is worth noting though that the mechanisms for abstract structural priming and the lexical boost in Chang et al.'s (2006) and Reitter et al.'s (2011) models were motivated by findings that abstract structural priming persists over time, while the lexical boost decays rapidly (e.g., Bock & Griffin, 2000, Hartsuiker et al., 2008, Branigan & McLean 2016). In particular, in Chang et al.'s model, the lexical boost decays rapidly because short term memory is normally assumed to be transient, while implicit learning is not and consolidates over time, while in Reitter et al.'s model, the fast decay of the lexical boost is due to the fact that spreading activation via associative learning causes only a temporary increase in the link between the syntactic and the lexical nodes. However, the memory mechanisms underlying abstract structural priming and the

lexical boost may not be as different as was originally assumed. Recently, Bernolet, Collina and Hartsuiker (2016) demonstrated that abstract priming, too, decays over time; in particular, they found that priming is stronger when prime and target are adjacent than when they are separated by intervening trials. Yan, Martin and Slevc (2018) found that people with aphasia who have short-term memory deficits showed both the same abstract structural priming and lexical boost effects as control patients, and the size of the lexical boost did not correlate with the patients' performance on short-term memory tests.

Interestingly, although the residual activation model of Pickering and Branigan (1998) in its original postulation could not directly explain the different time courses of abstract priming and the lexical boost, Malhotra, Pickering, Branigan and Bednar (2008) developed an extended computational version of the model that does exactly this. Their connectionist model assumes three layers: a layer consisting of verb lemma nodes, a combinatorial node layer and an intermediate layer of binding nodes between the verb lemma and combinatorial nodes that represent verb-structure connections. Because the binding nodes are of a different type than the verb and combinatorial nodes, their activation decay is different, and this explains the difference in time course between abstract structural priming and the lexical boost. Thus, Malhotra et al.'s modelling shows that it is possible to model the time course difference in a unified residual activation model of structural priming. Critically, the model suggests, along with the results of Bernolet et al. (2016) and Yan et al. (2018), that the lexical boost and structural priming are tightly interwoven.

Finally, one question concerning the lexical boost is what types of syntactic heads should engender it. Some linguistic theories of the generative type (e.g., Chomsky, 1995) make a distinction between functional heads, which do not contain a content word, and lexical heads, which do. For example, the INFL feature, where the grammatical features of the verb are argued to be generated (i.e., the auxiliary, tense, aspect and number), is a functional head, whereas the

main verb in the sentence is a lexical head. However, Pickering and Branigan (1998, Experiments 3-5) did not find any evidence that the repetition of either the verb's tense, aspect or number between prime and target resulted in a lexical boost, so it appears that the lexical boost is limited to lexical syntactic heads. Following Pickering and Branigan (1998), we believe that the lack of a lexical boost with the repetition of features associated with INFL is to be traced to the distinction between open class content words and closed class function words proposed originally by Bock (1989) and to the finding that priming is not sensitive to the repetition of function words, but only of content words. Bock (1989) and Pickering and Branigan's (1998) findings show that syntactic structures are not represented with closed-class elements, such as function words and inflections, even though in linguistics these elements are normally assumed to head a projection. Our current findings confirm that the head-nonhead distinction is critical for open-class words, and that syntactic structures are represented only with content words that are heads.

In sum, our findings from five structural priming experiments using three different comprehension-to-production experimental paradigms showed that the lexical boost in ditransitive sentences does not occur when nonhead words are repeated between prime and target; in contrast it only occurs when the head (i.e., the verb) is repeated. Together, these results support the residual activation model proposed by Pickering and Branigan (1998) and its computational extension and implementation proposed by Malhotra et al. (2008). It does not support models that predict a lexical boost when nonheads are repeated (Chang et al., 2006; Reitter et al. 2011).

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APPENDIX

Only the DO versions of the primes are given.

EXPERIMENTS 1-2

The 40 experimental sentences used in Experiments 1 and 2. The primes from Experiment 1 are in (a). The verbs in parentheses were used in the primes of Experiment 2, where the verb was the same in prime and target. The target fragments displayed under the pictures of Experiments 1 and 2 are in (b).

1a. The magician/actor will mail the agent the video. (show)

1b. A magician will show....

2a. The soldier/visitor will sell the villager the tent. (give)

2b. A soldier will give

3a The diver/sailor will send the engineer the rope. (lend)

3b. A diver will lend....

4a. The artist/geologist will offer the student the camera. (loan)

4b. An artist will loan....

5a. The lawyer/relative will post the inmate the DVD. (bring)

5b. A lawyer will bring...

6a. The doctor/ officer will promise the journalist the report. (post)

6b. A doctor will post...

7a. The vampire/fairy will lend the gnome the coat. (hand)

7b. A vampire will hand....

8a. The priest/gardener will loan the teacher the van. (sell)

8b. A priest will sell..

9a. The wizard/archer will offer the elf the bread. (serve)

9b. A wizard will serve...

10a. The pilot/driver will lend the passenger the newspaper. (offer)

10b. A pilot will offer...

11a. The monk/butcher will offer the farmer the cart. (rent)

11b. A monk will rent....

12a. The actress/director will show the reporter the review . (forward)

12b. An actress will forward...

13a. The warrior/champion will show the king the trophy. (bring)

13b. A warrior will bring...

14a. The butler/ wife will serve the baron the dinner.(bring)

14b. A butler will bring...

15a. The gymnast/ principal will rent the janitor the computer. (lend)

15b. A gymnast will lend...

16a. The scientist/ secretary will forward the writer the journal. (loan)

16b. A scientist will loan...

17a. The pirate/sergeant will mail the captain the drawing. (send)

17b. A pirate will send...

18a. The professor/editor will lend the reviewer the article. (post)

18b. A professor will post...

19a. The astronaut/dancer will forward the interviewer the tape. (hand)

19b. An astronaut will hand...

20a. The chef/porter will give the receptionist the laptop. (sell)

20b. A chef will sell...

21a. The prisoner/ teenager will show the friend the poster. (mail)

21b. A prisoner will mail...

22a. The clown/musician will give the spectator the chocolate. (offer)

22b. A clown will offer...

23a. The guard/spy will send the criminal the gun. (rent)

23b. A guard will rent...

24a. The singer/applicant will hand the manager the contract. (forward)

24b. A singer will forward...

25a. The bride/tailor will post the painter the photograph. (show)

25b. A bride will show...

26a. The acrobat/student will hand the instructor the handkerchief. (give)

26b. An acrobat will give...

27a. The mermaid/witch will promise the child the sweet. (offer)

27b. A mermaid will offer...

28a. The nun/man will sell the schoolgirl the bag. (mail)

28b. A nun will mail...

29a. The ballerina/aristocrat will rent the rockstar the limousine. (lend)

29b. A ballerina will lend...

30a. The Indian/activist will hand the politician the petition. (mail)

30b. An Indian will mail...

31a. The nurse/boy will show the pensioner the magazine. (post)

31b. A nurse will post...

32a. The Eskimo/aboriginal will loan the angler the rod. (mail)

32b. An Eskimo will mail...

33a. The athlete/photographer will loan the novice the equipment. (send)

33b. An athlete will send ...

34a. The angel/lady will send the beggar the money. (give)

34b. An angel will give...

35a. The waitress/mother will promise the child the ice cream. (serve)

35b. A waitress will serve...

36a. The duke/tycoon will give the son the mansion. (promise)

36b. A duke will promise...

37a. The constable/councillor will post the resident the notice. (bring)

37b. A constable will bring...

38a. The boy/lawyer will hand the celebrity the present. (send)

38b. A boy will send...

39a. The spy/millionaire will sell the officer the Rolex. (promise)

39b. A spy will promise...

40a. The stewardess/technician will bring the colleague the whisky. (serve)

40b. A stewardess will serve...

EXPERIMENT 4

The 42 experimental sentences used in Experiment 4. The primes are in (a). No overlap condition (see 1 below): The salesperson will mail the customer the video. Recipient overlap condition: The salesperson will mail the magician the video. Theme overlap condition: The salesperson will mail the customer the card. The verb displayed under the target picture is in (b).

1a. The salesperson will mail the customer/magician the video/card.

1b. will show

2a. The visitor will sell the village/soldier the tent/flag.

2b. will give

3a The sailor will offer the engineer/diver the rope/bike.

3b. will lend

4a. The geologist will give the student/painter the camera/car.

4b. will loan

5a. The supervisor will bring the inmate/referee the DVD/ball.

5b. will pass

6a. The researcher will hand the journalist/boxer the note/medicine.

6b. will post

7a. The fairy will lend the gnome/vampire the coat/spoon.

7b. will hand

8a. The gardener will loan the teacher/priest the van/razor.

8b. will sell

9a. The archer will offer the elf/prince the bread/watermelon.

9b. will serve

10a. The interviewer will give the actress/violinist the handkerchief/drink.

10b. will offer

11a. The butcher will show the farmer/monk the cart/house.

11b. will rent

12a. The shopkeeper will sell the customer/scout the watch/scarf.

12b. will forward

13a. The knight will bring the king/witch the trophy/key.

13b. will hand

14a. The official will give the worker/gladiator the award/torch.

14b. will show

15a. The director will hand the cameraman/cowboy the webcam/whistle.

15b. will lend

16a. The assistant will send the writer/beekeeper the journal/microscope.

16b. will loan

17a. The captain will mail the sergeant /princess the drawing/fan.

17b. will send

18a. The youth worker will lend the boy/cyclist the toy/trumpet.

18b. will show

19a. The agent will show the dancer/astronaut the tape/rose.

19b. will hand

20a. The porter will loan the receptionist/chef the laptop/radio.

20b. will sell

21a. The teenager will hand the friend/prisoner the gift/letter.

21b. will mail

22a. The presenter will give the spectator/baby the chocolate/balloon.

22b. will offer

23a. The spy will send the criminal/bricklayer the gun/chainsaw.

23b. will rent

24a. The manager will hand the employee/singer the contract/ticket.

24b. will forward

25a. The tailor will offer the painter/bride the jacket/glass.

25b. will show

26a. The instructor will lend the student/surfer the towel/kite.

26b. will post

27a. The babysitter will give the child/waiter the napkin/violin.

27b. will offer

28a. The man will sell the schoolgirl/nun the bag/comb.

28b. will mail

29a. The aristocrat will rent the rockstar/pope the limousine/painting.

29b. will lend

30a. The activist will forward the politician/Indian the petition/map.

30b. will hand

31a. The boy will show the pensioner/patient the magazine/cassette.

31b. will post

32a. The entertainer will loan the doorman/eskimo the robe/harmonica.

32b. will send

33a. The surveyor will bring the apprentice/photographer the equipment/record.

33b. will loan

34a. The lady will offer the maid/fairy the cloak/pear.

34b. will give

35a. The innkeeper will serve the traveller/hunter the tea/steak.

35b. will bring

36a. The wizard will send the peasant/jester the blanket/candle.

36b. will give

37a. The officer will give the resident/fireman the notice/fire extinguisher.

37b. will bring

38a. The acrobat will hand the colleague/juggler the rod/book.

38b. will send

39a. The millionaire will sell the officer/spy the Rolex/golf club.

39b. will lend

40a. The cashier will hand the client/passenger the leaflet/hamburger.

40b. will serve

41a. The designer will pass the carpenter/tailor the blueprint/umbrella.

41b. will lend

42a. The plumber will show the electrician/welder the pipe/hammer.

42b. will send

Table 1. Fixed effects parameter estimates (in log odds) for the full model without random correlations, and results of the model comparisons, Experiment 1. Fixed factors: prime structure (PO vs. DO) and subject repetition (repeated vs. non repeated). Both factors are within participants. Statistically significant effects ($p < .05$) are shown in bold.

	Parameter estimates			Model comparisons		
	β	<i>SE</i>	Wald <i>z</i>	χ^2	<i>df</i>	<i>p</i>
Intercept	1.669	.319	5.230	23.124	1	< .001
Prime structure	.392	.092	4.239	13.997	1	< .001
Subject repetition	-.052	.081	-.649	.401	1	.526
Prime structure x subject repetition	-.052	.084	-.619	.358	1	.549

Table 2. Fixed effects parameter estimates (in log odds) for full model with random correlations and results of the model comparisons, Experiment 2. Fixed factors: prime structure (PO vs. DO) and subject repetition (repeated vs. non repeated). Both factors are within participants. Statistically significant effects ($p < .05$) are shown in bold.

	Parameter estimates			Model comparisons		
	β	<i>SE</i>	Wald <i>z</i>	χ^2	<i>df</i>	<i>p</i>
Intercept	1.834	.336	5.459	40.410	1	< .001
Prime structure	1.652	.246	6.725	44.077	1	< .001
Subject repetition	-.379	.252	-1.504	2.786	1	.095
Prime structure x subject repetition	-.368	.241	-1.523	2.714	1	.099

Table 3. Fixed effects parameter estimates (in log odds) for full model with random correlations and results of the model comparisons, Experiments 1 and 2 combined. Prime structure (PO vs. DO) and Subject repetition (repeated vs. non repeated) are within-participants, Verb repetition (verb different vs. same) is between participants and within items. Statistically significant effects ($p < .05$) are shown in bold.

	Parameter estimates			Model comparisons		
	β	<i>SE</i>	Wald <i>z</i>	χ^2	<i>df</i>	<i>p</i>
Intercept	1.640	.238	6.869	39.250	1	< .001
Prime structure	.912	.080	11.328	70.572	1	< .001
Subject repetition	-.033	.068	-.486	.239	1	.625
Verb repetition	-.027	.174	-.157	.025	1	.875
Prime x subject repetition	-.039	.064	-.610	.372	1	.542
Prime x verb repetition	-.559	.079	-7.036	35.728	1	< .001
Subject repetition x verb repetition	-.027	.065	-.424	.179	1	.672
Prime x subject repetition x verb repetition	-.015	.065	-.230	.053	1	.818

Table 4. Fixed effects parameter estimates (in log odds) for full model without random correlations and results of the model comparisons, Experiment 3. Fixed factors: prime structure (PO vs. DO) and subject repetition (repeated vs. non repeated). Both factors are within participants. Statistically significant effects ($p < .05$) are shown in bold.

	Parameter estimates			Model comparisons		
	β	<i>SE</i>	Wald <i>z</i>	χ^2	<i>df</i>	<i>p</i>
Intercept	1.692	.221	7.650	40.415	1	< .001
Prime structure	.259	.105	2.474	5.937	1	.015
Subject repetition	-.056	.105	-.531	.269	1	.603
Prime structure x subject repetition	-.059	.105	-.573	.314	1	.575

Table 5. Fixed effects parameter estimates (in log odds) and results of model comparisons for Experiment 4: Comparing no repetition with theme repetition (Model A), and no repetition with recipient repetition (Model B). All factors are within-participants. Statistically significant effects ($p < .05$) are shown in bold.

	Parameter estimates			Model comparisons		
	β	<i>SE</i>	Wald <i>z</i>	χ^2	<i>df</i>	<i>p</i>
Model A. <i>Fixed factors: Prime structure (PO vs. DO) and Repetition (none vs. theme), full model without random correlations</i>						
Intercept	1.754	.262	6.687	38.744	1	< .001
Prime structure	.247	.995	2.487	5.463	1	.019
Repetition	.175	.093	1.878	3.131	1	.077
Prime structure x theme repetition	.022	.122	.180	.032	1	.858
Model B. <i>Fixed factors: Prime structure (PO vs. DO) and Repetition (none vs. recipient), full model with random correlations</i>						
Intercept	1.713	.289	5.926	31.609	1	< .001
Prime structure	.437	.140	3.112	9.105	1	.002
Repetition	.015	.128	.116	.009	1	.924
Prime structure x recipient repetition	.020	.120	.169	.013	1	.907

Table 6. Fixed effects parameter estimates (in log odds) and results of model comparisons for Experiment 5: Comparing no repetition with theme repetition (Model A), and no repetition with recipient repetition (Model B). All factors are within-participants. Statistically significant effects ($p < .05$) are shown in bold.

	Parameter estimates			Model comparisons		
	β	SE	Wald z	χ^2	df	p
Model A. <i>Fixed factors: Prime structure (PO vs. DO) and Repetition (none vs. theme), full model without random correlations</i>						
Intercept	.265	.202	1.313	1.713	1	.190
Prime structure	.231	.071	3.259	9.563	1	.002
Repetition	.085	.059	1.428	1.909	1	.167
Prime structure x theme repetition	.040	.053	.766	.571	1	.449
Model B. <i>Fixed factors: Prime structure (PO vs. DO) and Repetition (none vs. recipient), full model with random correlations</i>						
Intercept	.142	.205	.694	.478	1	.489
Prime structure	.244	.105	2.315	4.981	1	.026
Repetition	-.005	.128	-.038	.001	1	.970
Prime structure x recipient repetition	.061	.115	.531	.275	1	.600

Table 7. Fixed effects parameter estimates (in log odds) for full model without random correlations and results of the model comparisons for Experiments 1-5 combined. The fixed effects of prime structure (PO vs. DO) and repetition (no repetition vs. repetition of an argument) are within-participants. Experiment (5 levels=5 experiments) is between participants and items. Statistically significant effects ($p < .05$) are shown in bold.

	Parameter estimates			Model comparisons		
	β	<i>SE</i>	Wald <i>z</i>	χ^2	<i>df</i>	<i>p</i>
Intercept	1.228	.154	7.982	44.562	1	< .001
Prime structure	.430	.044	9.693	67.252	1	< .001
Repetition	.051	.034	1.627	2.559	1	.109
Experiment	-.461	.091	-5.047	24.060	1	< .001
Prime structure x repetition	.025	.032	.770	.574	1	.449
Prime structure x experiment	.205	.045	-4.567	19.555	1	< .001
Repetition x experiment	.015	.031	.476	.219	1	.640
Prime structure x repetition x experiment	.003	.032	.120	.014	1	.906

Figure Captions

Figure 1. Diagram illustrating the residual activation model of Pickering and Branigan (1998).

Figure 2. Example of a target picture and sentence fragment that followed the primes in (2) in Experiments 1 and 2.

Figure 3. Proportions of PO, DO and Other responses as a function of prime structure and subject repetition in Experiment 1. Error bars indicate standard errors.

Figure 4. Proportions of PO, DO and Other responses as a function of prime structure and subject repetition in Experiment 2. Error bars indicate standard errors.

Figure 5. Proportions of PO, DO and Other responses as a function of prime structure and subject repetition in Experiment 3. Error bars indicate standard errors.

Figure 6. Proportions of PO and DO responses as a function of prime structure and VP noun repetition, Experiment 3.

Figure 7. Example of a target picture and fragment that followed the primes in (3) in Experiment 4.

Figure 8. Proportions of PO, DO and Other responses as a function of prime structure and repetition of the theme or recipient in Experiment 4. Error bars indicate standard errors.

Figure 9. Example of a target display in Experiment 5.

Figure 10. Proportions of PO, DO and Other responses as a function of prime structure and repetition of the theme or recipient in Experiment 5. Error bars indicate standard errors.

Figure 1

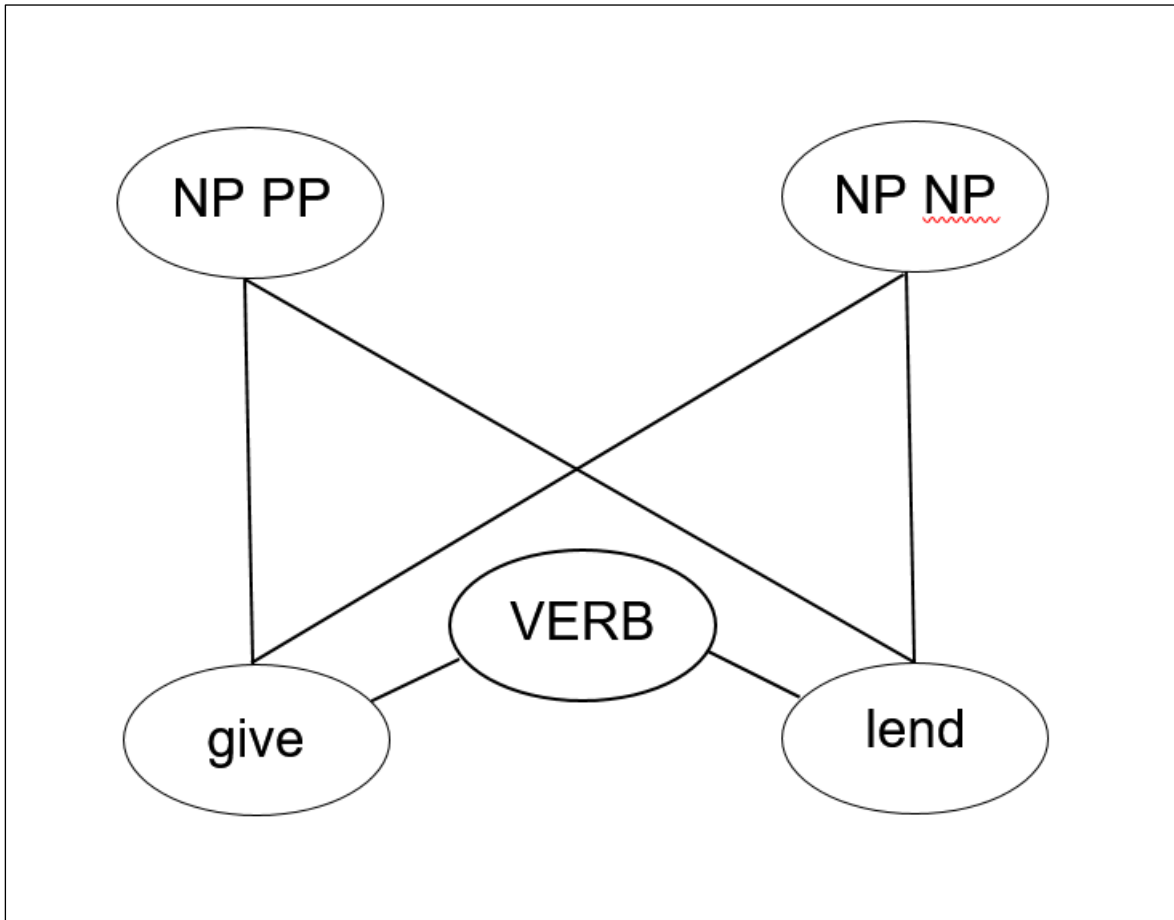


Figure 2

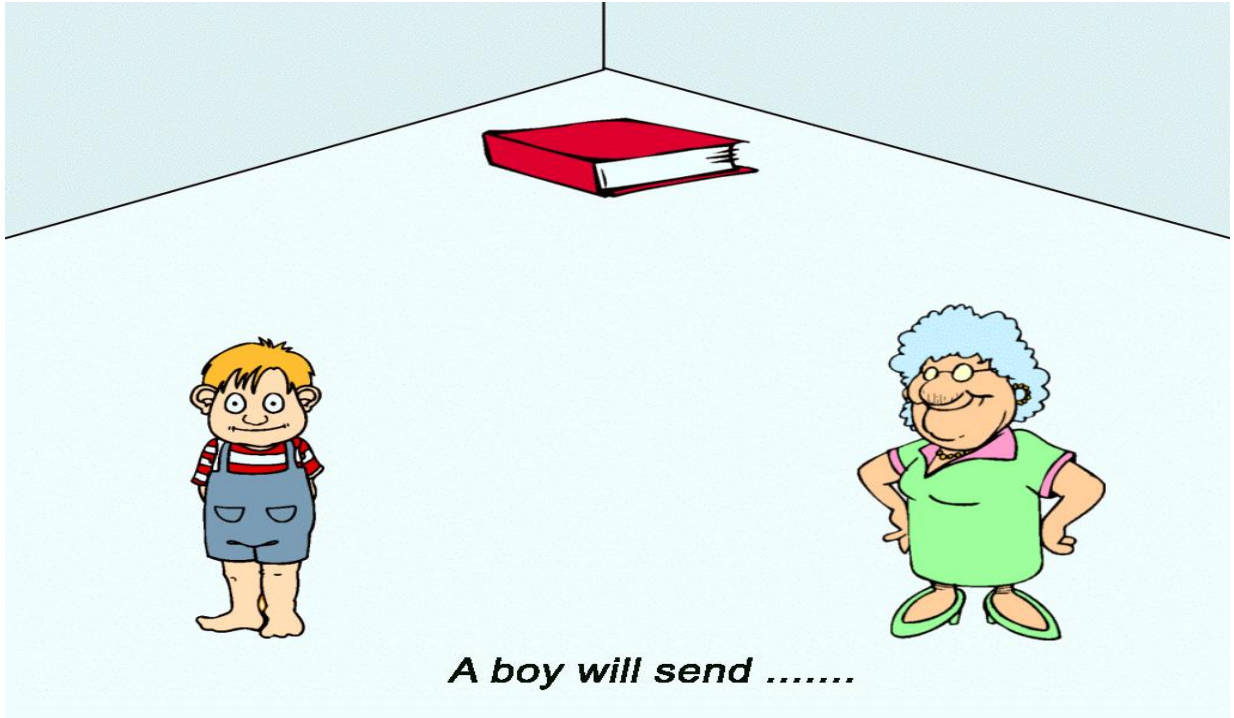


Figure 3

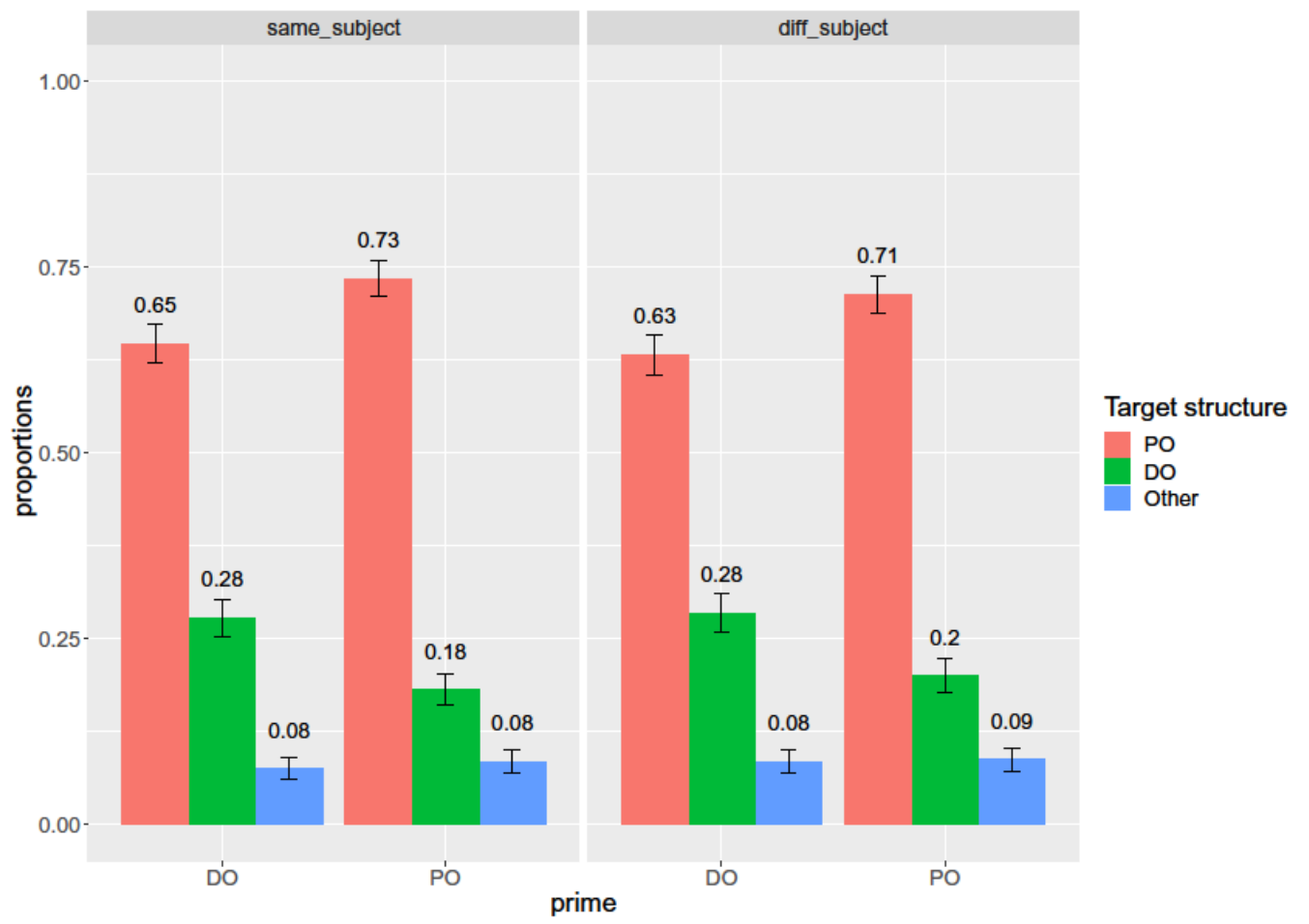


Figure 4

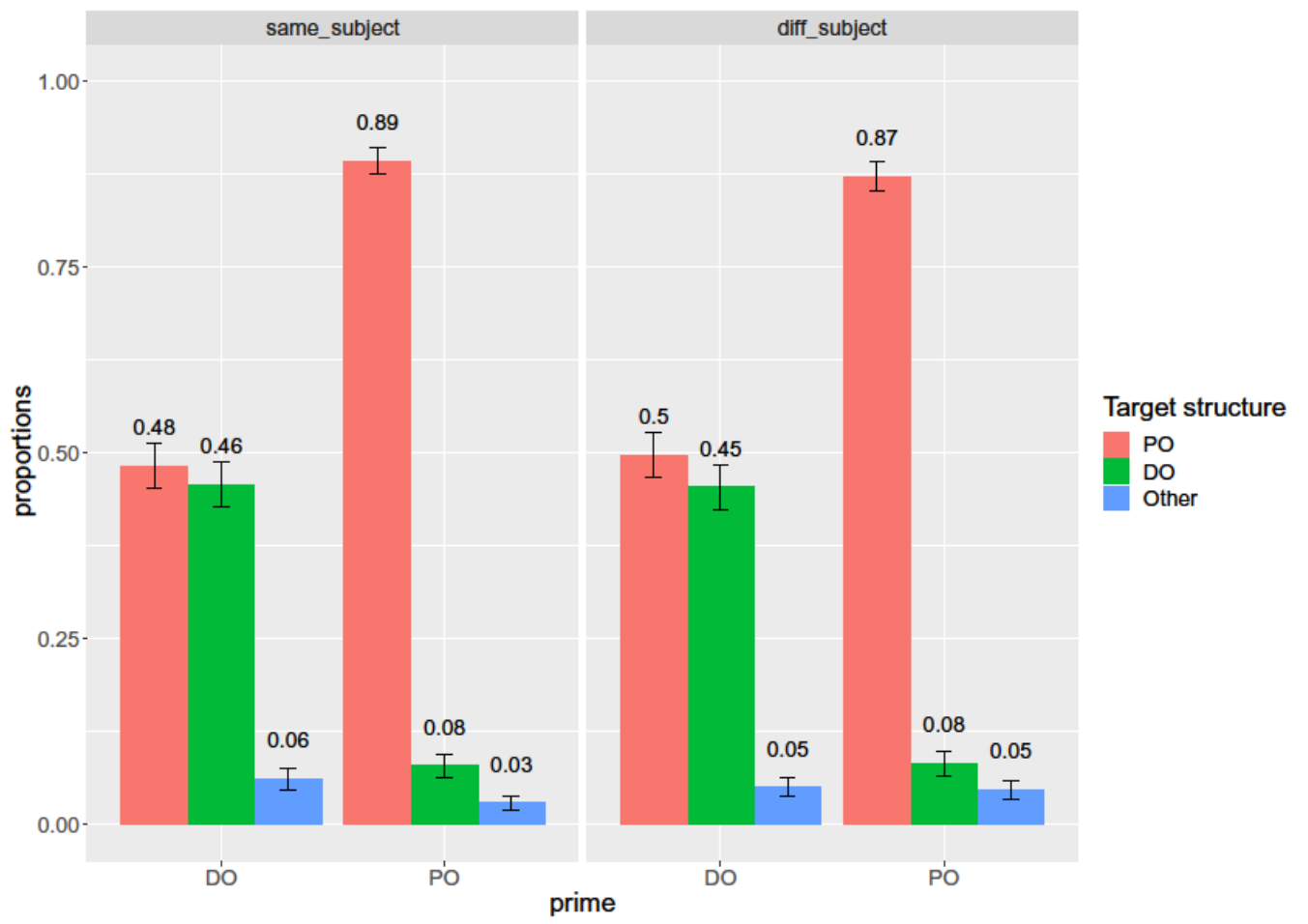


Figure 5

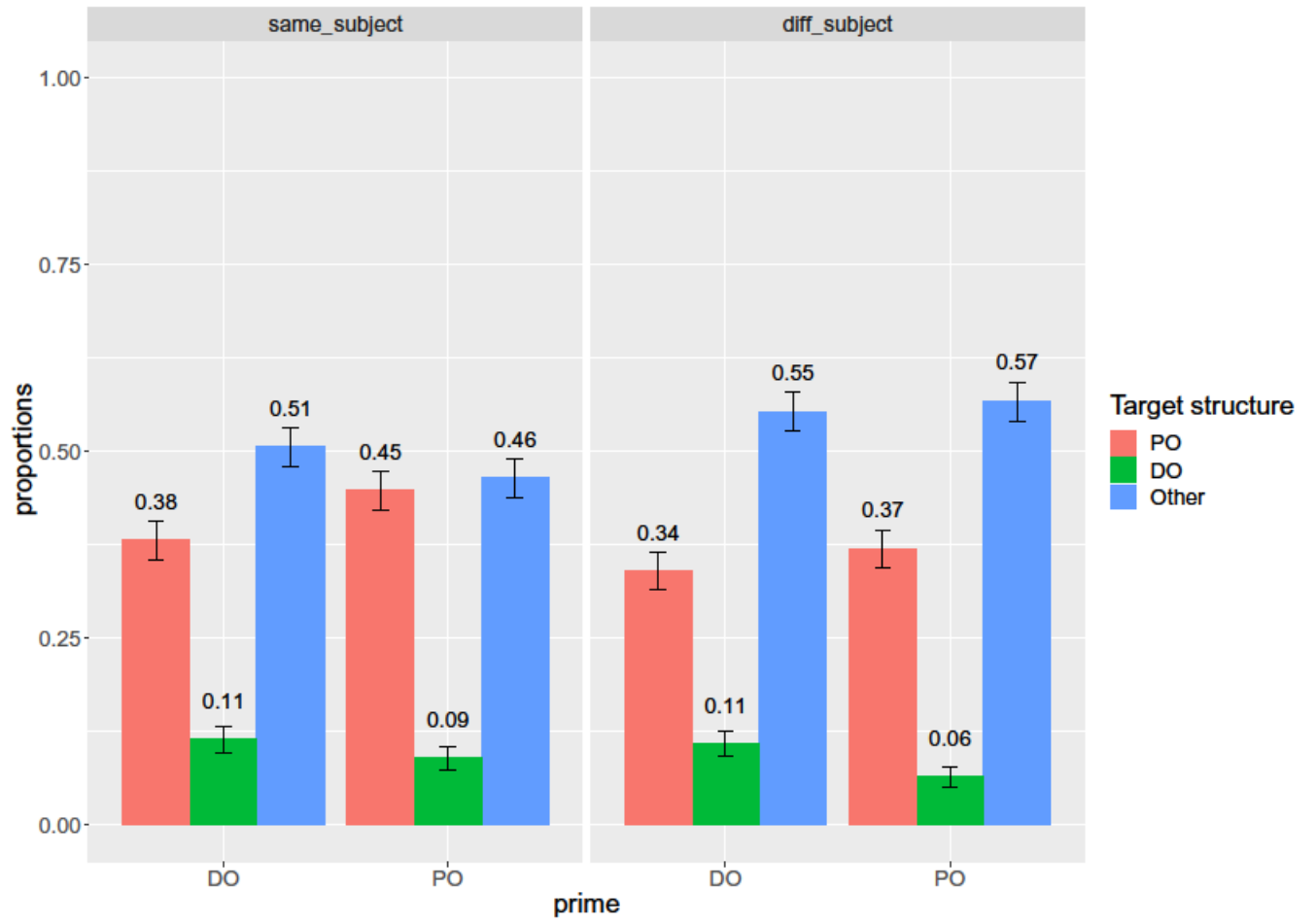


Figure 6

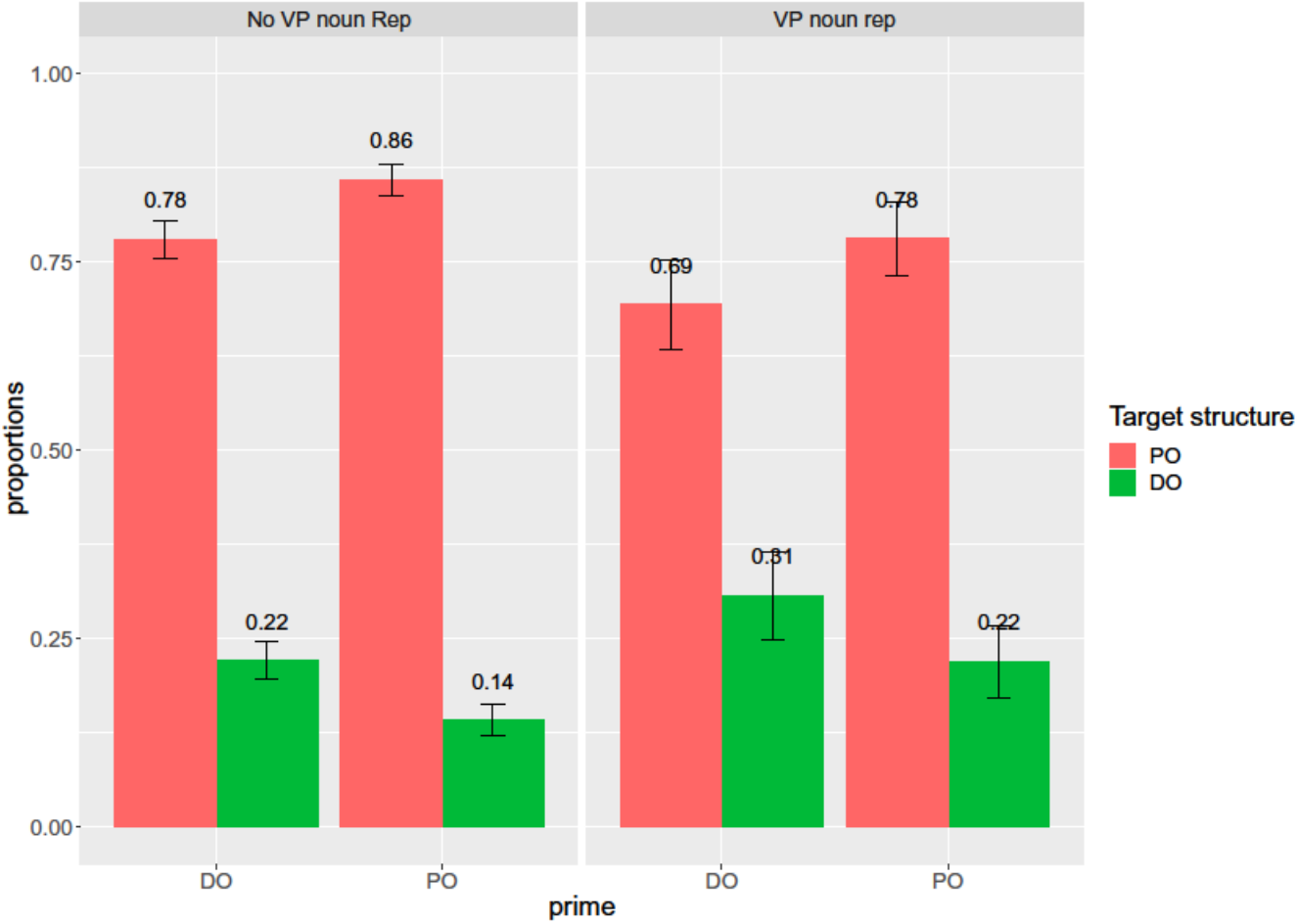


Figure 7

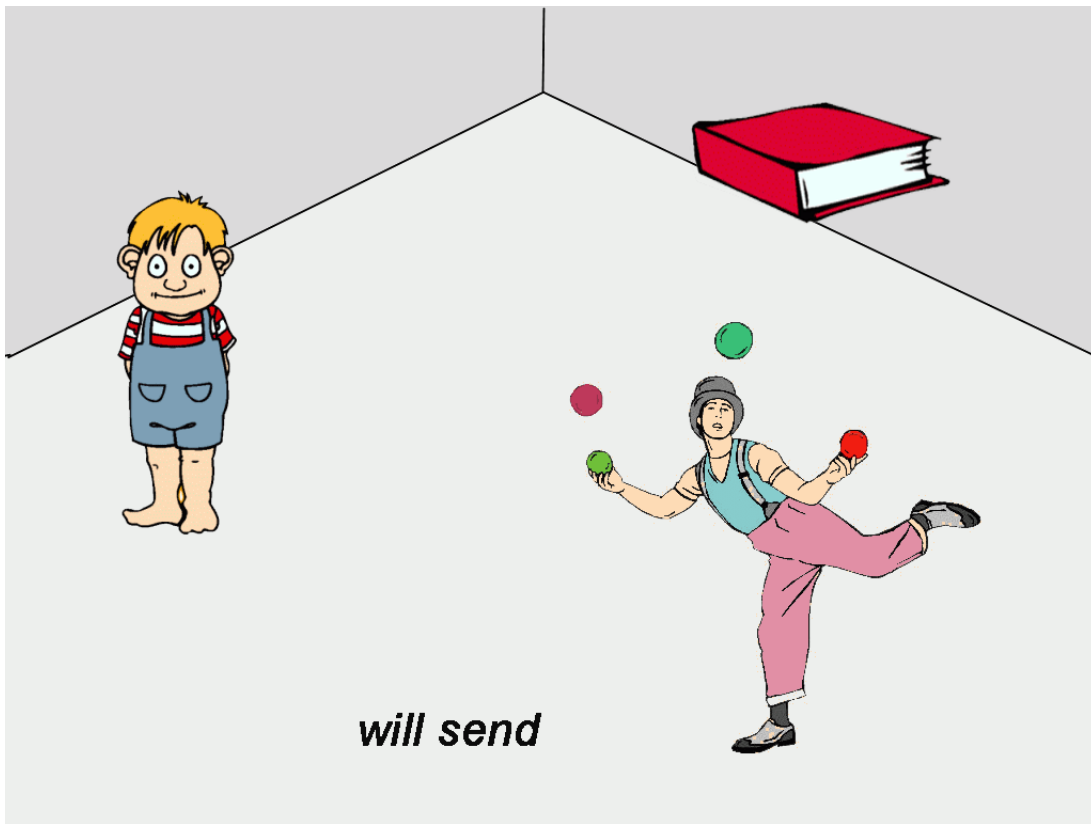


Figure 8

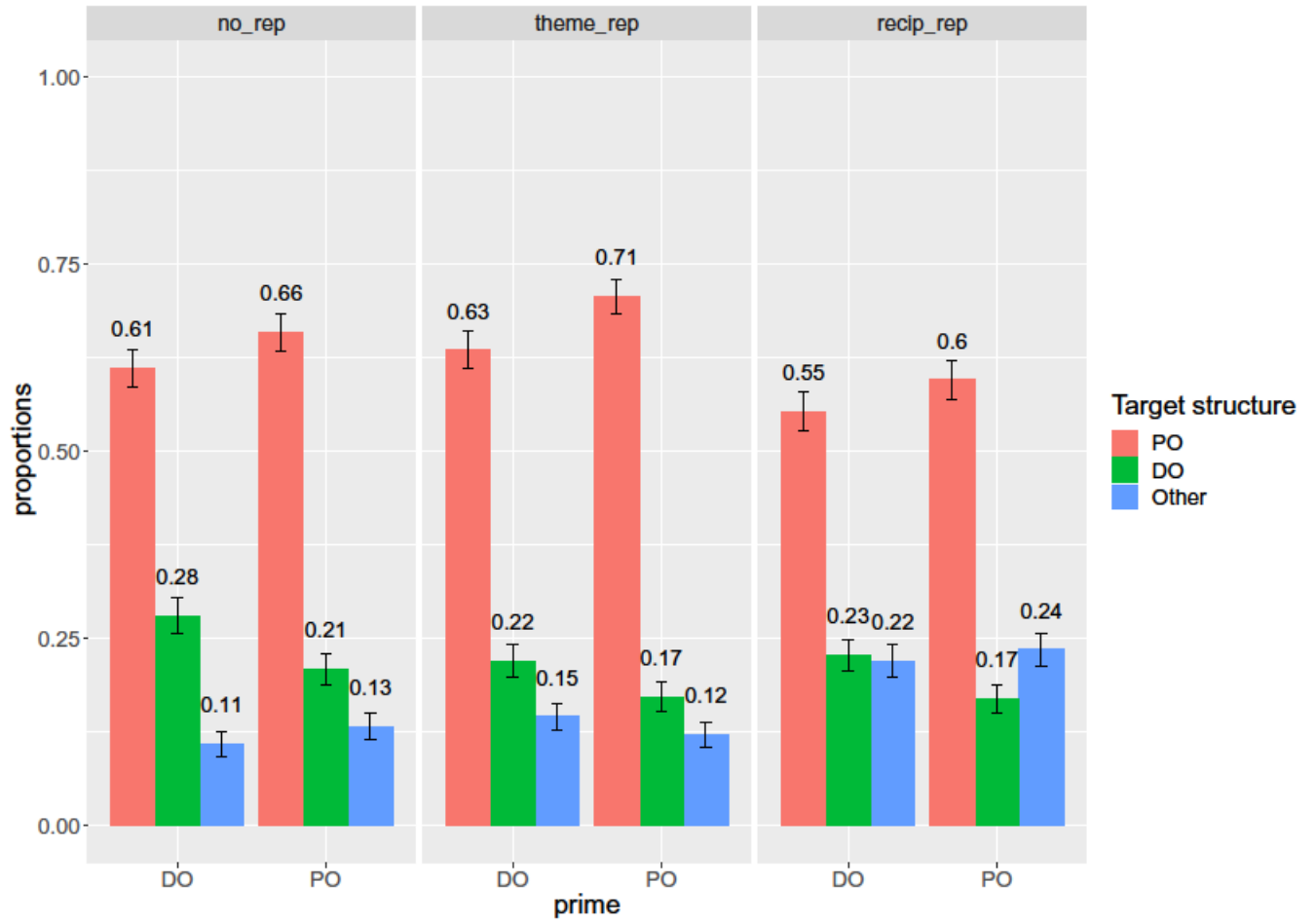


Figure 9

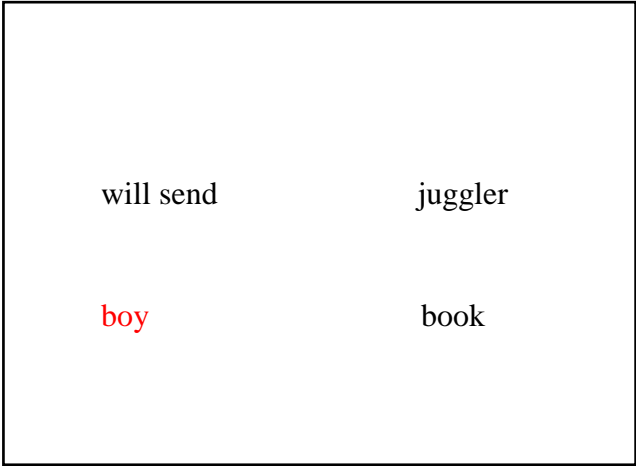


Figure 10

