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Lexically-independent representation of the monotransitive structure

(Short title: Representation of monotransitives)

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Abstract

Many previous studies have shown that syntactic priming tends to be stronger when the verb is repeated between the prime and target sentences. This phenomenon is known as the lexical boost and has been interpreted as evidence for a direct association between individual verbs and structural information. However, Van Gompel, Arai, and Pearson (2012) found no lexical boost with the monotransitive structure and argued that this structure is not associated with individual lexical items. Their results instead suggested that monotransitive structure information is represented at the category-general level. The current study examined whether this finding generalizes to verbs that can take either a monotransitive structure or a ditransitive structure. Our results demonstrated a lexical boost with double object ditransitive primes but not with monotransitive primes. This suggests that the monotransitive structure is indeed represented at the category-general level across different classes of verbs, whereas other structures are represented at the lexically-specific level.

Keywords

Structural priming; lexical boost; syntax; syntactic representation; verb subcategorization; lexically-specific representation; category-general representation

1. Introduction

Language users possess knowledge about the structures a particular verb can appear in. It has been claimed that this knowledge about verb subcategorization is learnt through experience with the linguistic input and is item-based at the start of language development, meaning that young children store information about syntactic structures in association with specific verbs (Lieven, Pine, & Baldwin, 1997). As evidence that this knowledge is experience-based, previous studies have indeed shown that children are more accurate in using frequent verbs in appropriate structures compared to less commonly used verbs (Brooks, Tomasello, Dodson, & Lewis, 1999; Theakston, 2004; Ambridge, Pine, Rowland, & Young, 2008). As linguistic experience accumulates, they gradually develop abstract structural knowledge that can be applied to newly learnt verbs. However, it still remains unclear how the knowledge about argument structures is stored and represented in adult language users. Some researchers assume that argument structure information is all abstract and lexically independent (e.g., Goldberg, 1995), whereas other researchers argue that it is directly associated with individual verbs (e.g., Pickering & Branigan, 1998). It is in fact still unknown whether information about all types of argument structures is represented in the same way or whether some structures are represented differently from others. The current study addresses this question by exploring syntactic priming of monotransitive and ditransitive structures.

In pioneer work, Pickering and Branigan (1998) tackled the question of how argument structures are represented by using syntactic priming. They tested priming of the two alternative ditransitive structures, double object (DO) and prepositional object (PO)

ditransitives in English. Using a sentence completion task, their participants first completed a prime sentence fragment which was designed to elicit either a DO (1a) or PO (1b).

(1a) The racing driver showed the helpful mechanic...

(1b) The racing driver showed the torn overall....

They next completed a target fragment which included either the same or a different ditransitive verb (e.g., *The patient showed/gave ...*). Their interest was in whether the choice of syntactic structure was influenced by the structure of the prime sentence and the repetition of the verb between the prime and target sentences. Their results showed a robust priming effect: Their participants produced more PO completions following PO primes than DO primes and also more DO completions following DO primes than PO primes. What is more, they also found a *lexical boost effect*: The priming effect was stronger when the verb was the same as in the prime sentence than when it was not. Based on their results, Pickering and Branigan proposed the psychological model of argument structure representation shown in Figure 1, which has subsequently often been referred to as the *residual activation model*.

(Figure 1 about here)

In their model, syntactic information is represented by so-called *combinatorial nodes*, showing which types of argument structures each verb can take (NP NP being a DO

structure and NP PP a PO structure). The verb lemmas are connected to a syntactic category node, signifying that it belongs to the verb category. Importantly, the model assumes that syntactic information of subcategorization frames is directly associated with individual verbs, as indicated by the links between the combinatorial nodes and the verb lemma nodes. The notion of lexically associated argument structure information is consistent with many linguistic theories such as government and binding theory (Chomsky, 1981) and lexical-functional grammar (Kaplan & Bresnan, 1982) although there are theories that make different assumptions, such as constructionist theory (Goldberg, 1995). In Pickering and Branigan's residual activation model, lexically-independent structural priming, i.e., priming in the absence of verb repetition, occurs due to residual activation of a combinatorial node (DO or PO) following a prime sentence. The lexical boost is caused by the activation of the link between the prime verb (e.g., *give* or *show*) and the combinatorial node; when the verb is the same in the prime and target, residual activation of this link enhances priming.

Since Pickering and Branigan's residual activation model, several other explanations of the lexical boost have been proposed. These models differ in the mechanisms involved in the lexical boost as well as in abstract structural priming (Chang, Dell, & Bock, 2006; Jaeger & Snider, 2013; Reitter, Keller, & Moore, 2011). In the explicit memory account proposed by Chang et al. (2006), abstract structural priming is due to implicit learning that occurs when language users incorrectly predict the structure of a prime sentence, whereas the lexical boost occurs because a repeated word acts as an explicit memory retrieval cue for the prime structure. In Reitter et al.'s (2011) model, abstract structural priming is caused by base-level learning, whereas the additional priming

when a word is repeated comes from associative learning associations between word meanings and syntactic structures. According to Jaeger and Snider (2013), structural priming occurs because language users employ structural information in the prime to minimize prediction error in future sentences, which affects the structure they produce in the target; the lexical boost arises because the prime is more informative for the structure of future sentences with the same verb than a different verb.

Because the models by Chang et al. (2006) and Reitter et al. (2011) assume fundamentally different mechanisms for abstract structural priming and the lexical boost, they fit well with findings that the time course of the two types of priming is different. In particular, research by Hartsuiker, Bernolet, Schoonbaert, Speybroeck, and Vanderelst (2008) suggests that abstract structural priming lasts across several intervening trials between prime and target, whereas the lexical boost decays much more rapidly (but see Bernolet, Collina, & Hartsuiker (2016) for evidence that abstract priming also decays). However, Malhotra, Pickering, Branigan, and Bednar (2008) showed that the different time course of abstract priming and the lexical boost can also be explained by a spreading activation model similar to that of Pickering and Branigan (1998). Like Pickering and Branigan's model, Malhotra et al.'s computational model has a syntactic and a lexical layer, as well as a layer of binding nodes between these two layers (corresponding to the connections between the syntactic and lexical nodes in Pickering and Branigan's model). The nodes in the syntactic and the lexical layers are mutually inhibitory ensuring that a selected node receives maximum activation, whereas the binding nodes between the syntactic and lexical layer consist of excitatory connections, which is conceptually

equivalent to activation-based short-term memory. This results in a slower memory decay in the syntactic layer than in the binding nodes and explains why abstract structural priming decays less rapidly than the lexical boost.

Importantly, all these previous models assume that the processes that result in a lexical boost are unaffected by the particular syntactic structure in the prime sentence; they all predict a lexical boost effect regardless of the type of syntactic structure that is being primed. However, Van Gompel, Arai, and Pearson (2012) demonstrated that not all argument structures cause a lexical boost effect. They investigated structural priming from monotransitive and intransitive structures. Monotransitive structures contain a verb that subcategorizes for a single (direct) object whereas intransitive structures do not have an object. In their study, they used mono/intransitive verbs such as in (2-3), verbs that can be used either in a monotransitive or intransitive structure. Their participants first read aloud a prime sentence, which had either an intransitive structure (2a) where the direct object was implicit or a monotransitive structure (2b). They next completed a target fragment such as (3).

(2a) The ambulance driver and the policewoman were following.

(2b) The ambulance driver was following the policewoman.

(3) While the boy scout was following/helping.....

Their results showed a priming effect with both monotransitive and intransitive structures and the priming effect with intransitive verbs was larger when the verb was

repeated than when it was not, demonstrating a lexical boost effect. However, the magnitude of priming from the monotransitive structure was the same regardless of whether the verb in the target sentence was repeated (*follow*) or not (*help*). The finding of an asymmetry in the lexical boost effect between monotransitive and intransitive structures is not unique to this study. Van Gompel, Pickering, Pearson, and Jacob (2006) investigated prime sentences that were temporarily ambiguous between a monotransitive and an intransitive structure such as *when the teenager was eating the pizza that had been ordered well over an hour ago arrived*. In this sentence, *was eating* can initially be interpreted as a monotransitive verb followed by the direct object *the pizza that had been ordered well over an hour ago*, until *arrived* disambiguates the sentence such that *was eating* is intransitive. Van Gompel et al. found that structural priming from the ultimately correct intransitive analysis was stronger when the verb (e.g., *was eating*) in the temporarily ambiguous prime was the same in the target fragment than when it was different. However, priming of the initial monotransitive interpretation was equally large (compared to a completely unambiguous control condition) regardless of whether the verb was repeated (Experiment 3, Van Gompel et al., 2006).

Furthermore, studies that have examined the priming of monotransitive active and passive structures also suggest no lexical boost from monotransitive active primes, although they often do not report statistical tests comparing the difference between the repeated and not repeated verb conditions with active primes. For example, Segaert, Wheeldon, and Hagoort (2016) found that the likelihood of producing a monotransitive active structure following an active prime did not differ significantly from a baseline

condition either when the verb was repeated or not, indicating that there was neither a structural priming effect nor a lexical boost effect with monotransitive active primes. The prime structure did affect production latencies for active structures, with faster latencies after active than passive primes, but importantly, the priming effect of the active structure on production latencies for active target sentences was no larger when the verb in prime and target was the same than when it was different. Similarly, Hardy, Messenger, and Maylor (2017) also found no evidence for a lexical boost with monotransitive active primes with either younger or older adults. In fact, the older adults showed a numerically smaller number of active target responses following active primes when the verb was repeated than when it was not. Finally, Branigan and McLean (2016) reported a slightly higher number of active target responses with verb repetition than without it, but they did not test the statistical significance of this contrast and the difference with active primes was much smaller compared to that with passive primes: Adults produced 91% active targets (out of all actives and passives) after active primes when the verb was repeated and 84% when it was not, whereas they produced 35% active targets after passive primes when the verb was repeated and 61% when it was not (in conditions where no sentence intervened between prime and target). In sum, a lexical boost with the monotransitive active structure has not reliably been observed.

Following the finding that there is no lexical boost with monotransitive primes (whereas there is with intransitives), Van Gompel et al. (2012) proposed that the information regarding the monotransitive structure is not associated with individual verbs. Instead, they argued that monotransitivity information is represented at the category-

general level. The information regarding the intransitive structure, in contrast, is associated with individual verbs, i.e., represented at the lexically specific level. Figure 2 illustrates the modified residual activation model that Van Gompel et al. (2012) proposed for monotransitive and intransitive structures.

(Figure 2 about here)

Importantly, the combinatorial node for the intransitive structure in this model is directly linked to individual verb lemmas, whereas the node for the monotransitive structure is not. The category-general representation of the monotransitive structure is symbolized by the connection between the verb category node and the monotransitive node. Van Gompel et al. (2012) pointed out two possible reasons why the monotransitive and intransitive structures are represented differently. First, the monotransitive structure occurs more frequently than the intransitive structure. This is illustrated by a large corpus study by Roland, Dick, and Elman (2007) as well as a smaller-scale analysis of the British National Corpus (Burnard, 2000) by Van Gompel et al. (2012), who showed that 52% percent of all verb tokens occurred in a monotransitive structure, 23% occurred in an intransitive structure, and only 2% occurred in ditransitive structures (either PO or DO). In fact, most verbs can appear in the monotransitive structure in English. [To test this, we conducted an additional analysis of 300 randomly selected verb *types* in the British National Corpus. The Oxford Advanced Learner's Dictionary \(2005, 7th edition\) indicated that 270 of these 300 verb types could be used in a monotransitive structure. However, even many of the verbs for which the](#)

dictionary did not indicate a monotransitive use could arguably also be used as monotransitives (*weep tears of joy, lie your way out of something, go the whole way, etc.*) Since the monotransitive structure most frequently occurs across all verbs and most verbs can be used with the monotransitive structure, the information about the monotransitive structure may not need to be specified for individual verbs. It would suffice to postulate that any verb can be used in the monotransitive structure. On the other hand, many verbs cannot be used intransitively. Thus, the information about the intransitive structure needs to be specified for individual verbs. Second, it is perhaps not necessary to specify the monotransitive structure for individual verbs because semantics usually functions as a useful clue to determine whether a monotransitive sentence is acceptable with a particular verb or not. It is usually quite easy to reject ungrammatical monotransitive sentences on the basis of semantics (e.g., **the boy sneezed the girl*), whereas it is far more difficult to reject ungrammatical intransitive sentences (e.g., **the boy congratulated*) on the basis of semantics.

The idea that the monotransitive and intransitive structures are represented differently also offers a plausible explanation for children's erroneous use of argument structure information. Many studies have demonstrated that children produce far more transitive overgeneralization errors with intransitive verbs (e.g., **Peter giggled me* or **she cried her*) than intransitive overgeneralization errors with transitive verbs (e.g., **John hits*) (e.g., Bowerman, 1982; Braine & Brooks, 1995; Pinker, 1989). Even more intriguingly, with age, children make fewer intransitive overgeneralizations of transitive verbs but more transitive overgeneralizations of intransitive verbs before they ultimately start using

transitive and intransitive verbs correctly (e.g., Braine, Brody, Fisch, Weisberger, & Blum, 1990; Brooks & Tomasello, 1999; Maratsos, Gudeman, Gerard-Ngo, & Dettart, 1987). Compatible with this, Brooks et al. (1999) reported that by the age of four or five, most children no longer produced intransitive overgeneralizations of transitive verbs but they still produced transitive overgeneralizations of intransitive verbs. These observations fit well with our proposal that monotransitivity information is represented at a category-general level for adult language users. The finding that children produce more monotransitive overgeneralizations when they get older suggests that they gradually start developing abstract grammatical knowledge and assume that any verb can be monotransitive. In contrast, the finding that children produce fewer intransitive overgeneralizations with age suggests that they develop lexically specific knowledge about the intransitive structure. Although they eventually stop producing monotransitive overgeneralizations, [the knowledge about](#) the monotransitive structure remains category general; at this final developmental stage, ungrammatical monotransitive sentences can easily be rejected based on semantics and the knowledge of precise semantic classes of verbs (cf. Pinker, 1984, 1989).

If the above explanations are correct, we expect that information about all structures except the monotransitive structure is specified for individual verbs and only the monotransitive structure is represented as category-general information. It is, however, possible that Van Gompel et al.'s (2012) finding is limited to the mono/intransitive verbs tested in their study and does not generalize to other types of verbs. One reason to believe this is that the majority of their mono/intransitive verbs were most frequently used in the

monotransitive structure. It is perhaps most economical if language users leave out lexically-specific connections with a very frequently used structure and only have connections between a verb and structures that occur infrequently with it. The activation of the most frequent structure could be deduced from the total activation of all other structures in combination with information about the overall use of the verb. Such a syntactic representation would save the cost of specifying the most frequent structure. If this is the case, the absence of a lexical boost with the monotransitive structure should only be observed with verbs that are very frequently used with this structure. For verbs with which the monotransitive structure is a less frequent structure, a lexical boost effect *should* occur. Another reason is that there are relatively many verbs that can be used in either a monotransitive or intransitive structure, so if, for economical reasons, language users do not store monotransitive information for all verbs, then it may be most likely they do not store it for this particular class of verbs because this would result in the largest savings. This may suggest that monotransitive information is stored for verbs from other verb classes that are not as common as mono/intransitive verbs.

The reasons mentioned above cast some doubt on the generalizability of Van Gompel et al.'s (2012) findings. It is therefore crucial to test other types of verbs and determine whether Van Gompel et al.'s (2012) claim that the monotransitive structure is represented as category-general information holds for other types of verbs. For this purpose, the current study tested verbs that can be used either in a monotransitive structure as in (4a) or in a ditransitive DO structure as in (4b).

(4a) The girl sent a postcard.

(4b) The girl sent her mother a postcard.

Van Gompel et al.'s account of monotransitive representations predicts that, as with mono/intransitive verbs, the monotransitive structure with mono/ditransitive verbs is represented as category-general information. In contrast, like the intransitive structure, the ditransitive structure should be represented as lexically-specific information. We should note that the above-mentioned explanations for why the intransitive structure is represented as lexically-specific information also hold for the DO ditransitive structure: It is less frequent than the monotransitive structure and just like it is difficult to reject ungrammatical intransitive sentences on a semantic basis, it is also difficult to reject ungrammatical ditransitive DO sentences such as **the man donated the church \$100,000* on the basis of semantics.

However, there are also reasons to believe that syntactic representations for mono/ditransitive verbs may be different from those for mono/intransitive verbs. First, ditransitive structures are less common than both mono- and intransitives (Roland, Dick, & Elman, 2007; Van Gompel et al., 2012), and so mono/ditransitive verbs are likely to be used less frequently than mono/intransitive verbs. In order to get an impression of whether mono/ditransitive verbs are indeed less frequent, we randomly sampled 300 different verbs from the British National Corpus (Burnard, 2000) and used the verb frame information in the Oxford Advanced Learner's Dictionary (2005, 7th edition) to code whether each verb could be used in an intransitive, monotransitive or DO ditransitive frame. Of all verbs, 145

(48.3%) could be used in either an intransitive or monotransitive frame (but not in a DO frame), whereas only 8 (2.7%) could be used either in a monotransitive or DO ditransitive frame (but not in an intransitive frame). This difference was significant: $X^2 = 122.67$, $df = 1$, $p < .001$. Given that mono/ditransitive verbs are infrequent, the saving cost for storing monotransitive information at the category-general level with mono/ditransitive verbs would be small, raising the possibility that it may instead be stored as lexically specific information. Furthermore, by using mono/ditransitive verbs, we may also be able to test verbs that are less frequently used in the monotransitive structure than the mono/intransitive verbs in Van Gompel et al. (2012). As noted earlier, [the less frequently a structure occurs with a particular verb, the more likely it may be that language users represent it as lexically-specific information.](#)

We conducted two structural priming experiments with mono/ditransitive verbs. In Experiment 1, we tested whether the monotransitive and the DO dative structures cause significant priming with these verbs, which has not been investigated in previous studies. If the monotransitive structure primes, this would replicate the findings in Van Gompel et al. (2012), who showed priming of the monotransitive structure (in their Experiment 2) but with a different type of verb (mono/intransitive verbs). Previous research has shown that DO ditransitives prime their constituent structure (DO vs. PO ditransitive, e.g., Bock, 1986; Pickering & Branigan, 1998), but it has so far not been demonstrated whether the monotransitive structure with mono/ditransitive verbs can be primed. To examine this, a baseline condition was included. We also repeated the verb between prime and target to maximize the chance of observing monotransitive priming (if we cannot find priming in

this case, then in Experiment 2, the priming effect could not be smaller when the verb is not repeated). Furthermore, the baseline condition allowed us to determine the biases of individual verbs such as *send* and *offer* for either the mono- or DO ditransitive structure in the absence of priming. These verb biases were used in the analyses of Experiment 2.

In Experiment 2, we investigated the lexical boost effect with monotransitive and DO ditransitive structures to test whether the lexical boost occurs with DO ditransitive primes but not with monotransitive primes, as predicted by Van Gompel et al.'s (2012) account, or whether the lexical boost occurs with both structures, as suggested by other models in the literature (Chang et al., 2006, Reitter et al., 2011, Jaeger & Snider, 2013; Pickering and Branigan, 1998). In an additional analysis, we included the verb bias information that we obtained from Experiment 1 to examine whether it modulated the lexical boost. Provided that there is no lexical boost with monotransitive primes, we can examine, by including verb bias information, whether this is true only for verbs that were biased towards the monotransitive structure or whether this applies to all verbs we tested, including those that do not have a monotransitive bias. Storing a structure with an individual verb may not be cost-effective if a verb frequently occurs with that structure. If this were the case, [the monotransitive structure should not have lexically-specific links with verbs that are biased towards the monotransitive structure, but those links *should* exist](#) for verbs that are less frequently used with this structure.

2. Experiment 1

Experiment 1 tested mono/ditransitive verbs and examined whether both the DO ditransitive and monotransitive structure prime. In particular, we were interested in the monotransitive structure. One reason why the monotransitive structure might not prime is that across all verbs (not just mono/ditransitive verbs), the monotransitive structure is highly frequent and may therefore already be so strongly activated that the activation level is difficult to boost any further (cf. Reitter et al., 2011). As mentioned earlier, Segaert et al. (2016, Experiment 2) did not find a monotransitive active priming effect on the choice of target structure (active vs. passive) and Hardy et al. (2017) and Branigan and McLean (2016) did not find a lexical boost with active primes. The absence of such priming effects is consistent with studies that showed that priming tends to be weaker or not observed at all with frequent or canonical structures (e.g., Bernolet & Hartsuiker, 2010; Hartsuiker & Westenberg, 2000; Jaeger & Snider, 2013; [Peter, Chang, Pine, Blything, & Rowland, 2015](#); Scheepers & Crocker, 2004). The current study examined this by comparing sentence completions to a target fragment (6) following a baseline condition such as (5c) with completions after a monotransitive prime (5a) or a DO ditransitive prime condition (5b).

(5a) The performer sold the ticket. (monotransitive prime)

(5b) The performer sold the tourist the ticket. (DO ditransitive prime)

(5c) Mercilessly brutal and cruel. (baseline sentence)

(6) The uncle sold.....

The target verb was repeated following (5a, 5b) and the target fragment could be completed either as a monotransitive sentence (e.g., *The uncle sold his car*) or a ditransitive sentence (e.g., *The uncle sold the cousin his car*).

We used a baseline consisting of adverbs and adjectives without verbs nor nouns (cf. van Gompel et al., 2012). Some previous studies have used an intransitive structure as a baseline condition in the investigation of syntactic priming (e.g., Pickering, Branigan, & McLean, 2002; Segaert et al., 2016). The intransitive structure, however, may not be suitable as a baseline in the current experiment, because the number of arguments of the verb in an intransitive structure (the subject) is closer to a monotransitive structure (subject and direct object) than to a ditransitive structure (subject, direct object and indirect object), so an intransitive may prime monotransitives more than ditransitives. Other studies have used trials without a prime sentence as a baseline condition (e.g., Montero-Melis & Jaeger, 2020). However, the lack of a prime sentence means that participants saw the target item following a filler sentence or a previous target trial that was not controlled for its syntax, so it is unclear how it affected priming. In the baseline sentences in the current experiment, we did not use a verb because previous research has shown that the presentation of a verb as a single word can cause syntactic priming (Melinger & Dobel, 2007). We also avoided using nouns since the monotransitive and ditransitive structures differed in the number of arguments and it is possible that the presentation of a particular number of nouns primes either of the structures.

Using the monotransitive completions in the baseline condition as the reference level, we can determine whether priming occurred in the monotransitive and ditransitive

conditions, as well as obtain verb bias information for Experiment 2. In addition, we examined whether the priming effect is, at least partly, driven by semantic information and/or the number of explicitly expressed arguments (i.e., the recipient and theme). We used the DO ditransitive prime condition for this. If priming is due to semantic overlap and/or the number of overt arguments, then DO ditransitive primes should prime PO ditransitive targets relative to monotransitive targets.

Method

Participants

Thirty-three participants recruited from the University of Dundee student community took part in the experiment. All were native speakers of British English. They received either course credit or £4.00 in exchange for their participation. Three participants were excluded from our analyses: one was due to recording failure and two turned out to be non-native speakers of British English.

Materials

We selected twenty commonly used ditransitive verbs that could be used either with a monotransitive or DO ditransitive structure, all of which were used in both the monotransitive and ditransitive structure in the British National corpus (Burnard, 2000). With these verbs, we constructed thirty experimental items such as (5, 6) (See Appendix I). The monotransitive primes consisted of a subject noun phrase, a mono/intransitive verb and a direct object noun phrase. The DO ditransitive primes had the same subject, verb and

direct object, but also included an indirect object immediately following the verb. The baseline sentences consisted of adverbs and adjectives joined with conjunctions such as *and*, *but*, *or*, *rather than* and had no verbs or nouns. The targets consisted of a subject noun phrase followed by a verb that was the same as in the monotransitive and intransitive primes. There was no semantic or contextual relationship between prime and target apart from the repetition of the verb in (5a, 5b). Additionally, 69 complete written sentences and 70 sentence fragments were included as fillers. All the complete fillers contained copular verbs, so they had neither monotransitive nor ditransitive structures. Filler fragments either did not have a verb or contained copular verbs. Those without verbs never immediately preceded experimental items as they may prime monotransitive or intransitive completions.

Design and Procedure

Using a spoken sentence completion method (cf. Branigan, Pickering, Stewart, & McLean, 2000; Van Gompel et al., 2012), participants first read a prime sentence aloud and next completed a target fragment. Participants' speech was recorded during the experiment. We constructed three lists with all 30 experimental items, such that each item appeared in one condition in each list and each condition appeared 10 times in each list. The experimental items and fillers were presented in a fixed quasi-random order with the constraint that at least two fillers intervened between experimental items. To encourage participants to read the materials for comprehension, fourteen comprehension questions were inserted following the complete filler sentences. Six fillers preceded the first experimental item and five fillers followed a break.

Participants were given instructions at the beginning of the experiment. They were asked to read aloud the complete sentences and to produce a grammatical continuation to the sentence fragments whilst completing them quickly and avoiding words that had appeared before. Before the experiment, they completed a practice session, during which they were corrected if they did not follow the instructions. The sentences and fragments were presented on the monitor for 10 seconds and if no response was made during this time period, the next item was presented. They were given a break halfway through and the whole experiment typically took 40 minutes.

Results

We first excluded trials in which participants mistakenly produced a verb that was different from what was displayed on the monitor (e.g., ‘bought’ instead of ‘brought’), which accounted for 1.3% of all data. Target completions were then coded either as monotransitive, DO ditransitive, PO ditransitive or “Other”. They were scored as monotransitive if the verb was followed by a theme noun phrase but not by a recipient; as DO ditransitive if the verb was followed by a recipient noun phrase and then a theme noun phrase; and as PO ditransitive if the verb was followed by a theme noun phrase and then a recipient prepositional phrase. All remaining trials were scored as “Other”. These included trials in which the constituents had different thematic roles such as in *The daughter threw the iron at her mother's head* (recipient and goal) or target fragments that were immediately followed by an infinitival phrase, a prepositional phrase, a sentence complement, or a

conjunction. They also included trials that were incomplete or inaudible. Table 1 shows the number of monotransitive, DO, PO, and other completions for each prime condition.

(Table 1 about here)

We calculated the monotransitive bias of the individual verbs measured in the baseline condition, which will later be used in the analyses in Experiment 2 (See Appendix II). Overall, 35.9% of the target completions in the baseline condition were monotransitive completions. This confirmed that the verbs used in the current study were less frequently used in the monotransitive structure than the verbs in Van Gompel et al.'s (2012) study, where participants produced 59.2% monotransitives in the baseline condition. In our initial analysis, we analyzed the percentages of monotransitive completions out of the total number of monotransitive and DO ditransitive completions as a measure of the activation of the monotransitive structure relative to that of the DO ditransitive structure. We excluded "Other" responses as well as PO ditransitive completions, because they do not represent purely structural priming. After applying this filter, 57.1% of the remaining data were either monotransitive or DO ditransitive structures. We analyzed the [number](#) of excluded completions (PO or Other) [out of all completions that were scored as either monotransitive, DO ditransitive, PO ditransitive or "Other"](#) using a generalized linear mixed-effects model (conducted in the same way as the main analysis below) and found that there was no difference between the baseline condition and the DO ditransitive condition ($\beta=-0.24$,

SE=0.18, $z=-1.30$, $p=0.195$) but the monotransitive condition had fewer exclusions than the baseline condition ($\beta=-0.38$, SE=0.18, $z=-2.08$, $p=0.038$).

We analyzed the **number** of monotransitive completions out of all monotransitive and DO ditransitive completions by fitting a generalized linear mixed-effect model (GLMM, Dixon, 2008; Jaeger, 2008) with prime type (monotransitive, ditransitive, and baseline) as a fixed factor. We used dummy coding, setting the baseline condition as the reference level against which the monotransitive and ditransitive conditions were compared. The intercept value thus corresponds to the proportion of monotransitive completions out of all monotransitive and DO ditransitive completions in the baseline condition in logit scale. We adopted dummy coding because our interest was in the increase/decrease in the likelihood of monotransitive completions following monotransitive or DO ditransitive primes *relative to* the likelihood in the baseline condition. The initial model included a random intercept for participants and items as well as random participant and item slopes for the fixed factor. The optimal random effect structure was explored using backward selection to avoid overparameterization or false convergence (Matuschek, Kliegl, Vasishth, Baayen, & Bates, 2017). Table 2 summarizes the results from the optimal model, which turned out to be the minimal model without a random slope for the two random factors.

(Table 2 about here)

The results showed a significant effect in the DO ditransitive prime condition. The negative coefficient means that participants produced *fewer* monotransitive completions (i.e., more

DO ditransitive completions) following DO ditransitive primes than following the baseline. More importantly, there was also a significant effect in the monotransitive condition. The positive coefficient means that participants produced *more* monotransitive completions following monotransitive primes than following the baseline. These results demonstrated a priming effect from ditransitives as well as from monotransitives.

Next, we examined whether DO ditransitive primes primed PO ditransitive targets relative to monotransitive targets, which would be expected if the priming effect is at least partly driven by semantic information and/or the number of explicitly expressed arguments. To test this, we analyzed PO target completions out of all PO and monotransitive completions in each prime condition. We analyzed this using GLMM in the same way as above. Table 3 summarizes the results from the optimal model, which turned out to be the minimal model without random slopes.

(Table 3 about here)

The results showed a significant difference between the monotransitive condition and the baseline condition. Participants produced fewer PO completions, that is, more monotransitive completions following monotransitive primes than following the baseline condition. Most importantly, there was no difference between the DO ditransitive condition and the baseline condition, indicating that DO prime sentences did not prime the PO structure despite their semantic similarity and the equal number of explicit arguments.

Discussion

The results showed evidence for priming of the DO ditransitive structure as well as of the monotransitive structure when we repeated the verb between prime and target. This allows us to explore whether the priming effect is reduced when the verb is not repeated in Experiment 2. Furthermore, the analysis of PO completions showed that DO prime sentences did not increase the likelihood of producing PO completions despite their semantic similarity. This suggests that our experimental method was indeed sensitive to structural rather than semantic similarities between the prime and target sentences. The results also showed that the verbs in the current study were less frequently used in the monotransitive structure than the mono/intransitive verbs in Van Gompel et al. (2012).

3. Experiment 2

Introduction

Experiment 2 investigated a lexical boost with monotransitive and ditransitive structures using prime sentences such as (7) and target fragments such as (8).

(7a) The performer sold the ticket.

(7b) The performer sold the tourist the ticket.

(7c) The performer offered the ticket.

(7d) The performer offered the tourist the ticket.

(8) The uncle sold.....

The prime sentences had either a monotransitive structure (7a, 7c) or DO ditransitive structure (7b, 7d). We also manipulated the repetition of the verb between the prime and target sentences; the verb in (7a, 7b) was repeated whereas in (7c, 7d), it was not.

The experiment had two aims. First, we wanted to test whether a lexical boost occurred with both the DO ditransitive and monotransitive structure. To recap, if syntactic structures are associated with individual verbs for both structures, as assumed by many linguistic theories, we should observe a lexical boost effect with both structures. Namely, participants should be more likely to use the same structure as in the prime when the verb is the same between prime and target than when it is different. Alternatively, if Van Gompel et al.'s (2012) results generalize to other types of verbs and the monotransitive structure is represented as category general information across all verbs, we should observe a lexical boost effect with DO ditransitive primes but not with monotransitive primes. Therefore, priming of the ditransitive structure should be stronger when the verb is repeated than when it is not but priming of the monotransitive structure should not be boosted by the repetition of the verb. Second, if there is no lexical boost with monotransitive primes, we wanted to check whether this was the case only for verbs that were biased towards the monotransitive structure or whether this applied to all verbs we tested. As mentioned in the Introduction, storing a structure with an individual verb may not be cost-effective if a verb frequently occurs with that structure. If this were the case, the monotransitive structure should not be stored as *lexically-specific* information for verbs that are biased towards the monotransitive structure, but *it should be stored* as lexically specific information for verbs that are less

frequently used with this structure. To explore this possibility, we conducted additional analyses to investigate the effect of target verb bias on the lexical boost.

Method

Participants

Forty participants recruited from the same population as in Experiment 1 took part.

Materials

Thirty-two experimental items such as in (7-8) were constructed from the same set of twenty verbs as in Experiment 1 (See Appendix III). The prime sentences were either montransitive (7a, 7c) or ditransitive (7b, 7c). In addition to the structure of the prime, we also manipulated whether the verb in the target was the same as in the prime (7a, 7b) or different (7c, 7d). The fillers were the same as in Experiment 1.

Design and Procedure

The design and procedure were similar to those in Experiment 1. In addition to prime type (montransitive or ditransitive) and verb repetition (verb repeated or not repeated), we counterbalanced the two verbs (e.g., *send* and *offer*) in each item, meaning that we created 4 conditions in addition to (7-8) where the verbs in prime and target were swapped. This counterbalancing factor was not analyzed but was included to avoid the possibility that the verbs in the repeated verb conditions primed more strongly than those in the non-repeated

conditions. Thus, eight versions of each experimental item were created, resulting in eight experimental lists. One version of each item appeared in each list.

Results

Target completions were scored either as monotransitive, DO dative, PO dative or Other following the same criteria as in Experiment 1. After removing trials in which participants failed to use the verb displayed on the monitor (0.5%), 35.7% of the remaining trials were monotransitive completions. Thus, the frequency with which participants produced monotransitives was similar to Experiment 1, and monotransitives were less frequent than in Van Gompel et al. (2012). Table 4 shows the numbers of monotransitive, DO, PO, and Other completions in each condition. As in Experiment 1, we examined the number of excluded trials (PO and Other completions), using Generalized Linear Mixed Models with prime type and verb repetition as fixed factors and participants and items as random factors. We found that neither of the main effects was significant ($\beta=0.01$, $SE=0.06$, $z=0.20$, $p=0.844$ for prime type; $\beta=0.04$, $SE=0.06$, $z=0.70$, $p=0.486$ for verb repetition). There was also no interaction between the two fixed factors ($\beta=0.01$, $SE=0.06$, $z=0.08$, $p=0.937$). In sum, the number of excluded trials did not differ across conditions.

(Table 4 about here)

We analyzed the number of monotransitive completions out of all monotransitive and DO ditransitive completions as a measure of the activation of the monotransitive

structure relative to the DO structure. Of all data points, 64.7% were either monotransitive or DO ditransitive. We report the results of our analyses in two steps. We wanted to examine whether there was a lexical boost effect for both types of structures (monotransitive and DO) and also whether the presence or absence of the lexical boost effect was affected by the structural bias of the target verb. The complete model including verb bias, however, did not converge, so we first conducted analyses without verb bias on all conditions and then conducted analyses with verb bias using separate models for the monotransitive and DO ditransitive prime conditions.

Analyses without verb bias

We analyzed the number of monotransitive structures out of all monotransitive and DO ditransitive completions by fitting a generalized mixed-effect model. Prime type (ditransitive vs. monotransitive) and verb repetition (repeated vs. not repeated) were included as fixed factors, and participants and items as random factors. We used sum-contrasts for the two fixed factors (-1 vs. 1), unlike in Experiment 1. This is because there was no baseline in the current experiment and our interest was in the main effects of the two fixed factors as well as in the interaction between them. The intercept thus corresponds to the overall mean of all four conditions. The initial model included both participant and item random slopes for the fixed factors and their interaction and we explored the optimal model following the same backward selection approach adopted in Experiment 1. Table 5 summarizes the results from the optimal model, which turned out to be the minimal model without random slopes.

(Table 5 about here)

The analysis showed a main effect of prime type, with more monotransitive completions following monotransitive primes than following DO ditransitive primes. There was also a main effect of verb repetition, with fewer monotransitive completions (i.e., more DO ditransitive completions) when the verb was repeated than when it was not, but no interaction between prime structure and verb repetition. Simple effect analyses showed that the effect of verb repetition was significant for the DO ditransitive prime conditions ($\beta = 0.34$, $SE = 0.13$, $z = 2.69$, $p = 0.007$), but not for the monotransitive prime conditions ($\beta = 0.09$, $SE = 0.13$, $z = 0.68$, $p = 0.499$). The results thus confirmed that a lexical boost effect occurs with DO ditransitive primes but not with monotransitive primes. Note that we did not observe a prime structure \times target verb repetition interaction because following monotransitive primes, participants produced slightly *fewer* monotransitives when the verb was repeated than when it was not, the opposite pattern from a lexical boost. When we recoded the target structures into whether they matched (monotransitive completions following monotransitive primes and ditransitive completions following DO ditransitive primes) or mismatched (ditransitive completions following monotransitive primes and monotransitive completions following DO ditransitive primes) the prime structure, we did observe a significant interaction ($\beta = -0.21$, $SE = 0.09$, $z = -2.38$, $p = 0.018$), [justifying the simple effect analyses.](#)

Analysis including verb bias

Although there was no strong overall bias for the monotransitive structure, it is possible that we failed to find a lexical boost effect with the monotransitive structure because a sufficient number of verbs were monotransitive biased. As we have mentioned previously, for economical reasons, it may be most cost-effective if language users form lexically-specific connections only between a verb and structures that occur infrequently with it. To test this, we examined whether the lexical boost effect was modulated by the monotransitive bias of the individual target verbs. We used the biases of the target verbs (rather than the prime verbs) because we were interested in the representations that participants accessed when they produced the target sentence. We obtained the monotransitive bias of the individual target verbs by calculating the odds of monotransitive completions out of all monotransitive and DO completions in the baseline condition in Experiment 1 in log scale (i.e., logit). We included this additional monotransitive bias factor as a continuous variable (centered) in the model that analyzed the [number](#) of monotransitive completions reported above, allowing it to interact with the original fixed predictors (prime structure and verb repetition). Since no model including the three-way interaction between prime type, verb repetition, and monotransitive bias converged, we performed separate analyses for the two prime structures. Table 6 summarizes the results from the optimal models, which turned out to be the minimal models without random slopes for the two random factors.

(Table 6 about here)

Figure 3 shows the probability of a monotransitive completion as a function of the monotransitive bias of individual target verbs for the verb repeated and non-repeated conditions with monotransitive primes (Figure 3a) and with DO ditransitive primes (Figure 3b).

(Figure 3a about here)

(Figure 3b about here)

The analysis of the monotransitive prime conditions revealed only a main effect of monotransitive bias. The positive coefficient indicates that participants were more likely to produce monotransitive completions with target verbs that had a stronger monotransitive bias. However, there was no main effect of verb repetition nor interaction with monotransitive bias. In other words, there was no evidence of a lexical boost effect, regardless of the magnitude of monotransitive bias (if anything, there were numerically *fewer* monotransitive completions when the verb was repeated). This indicates that the lack of a lexical boost effect for the monotransitive structure was not due to a subset of verbs that had a strong monotransitive bias, but that it was observed for all verbs regardless of their bias. In contrast, the analysis of the DO ditransitive prime conditions revealed significant effects of monotransitive bias, verb repetition and an interaction between the two variables. The effect of verb repetition confirms our earlier analyses showing a lexical boost with DO primes. The positive coefficient of the verb bias effect means that

participants produced *more* monotransitive target completions (and thus, fewer DO ditransitive completions) when the verb was more strongly biased toward the monotransitive structure. Interestingly, we observed an interaction between verb repetition and monotransitive bias. The positive coefficient and Figure 3b show that the lexical boost effect with DO primes was stronger with verbs that occur more frequently in the monotransitive structure. Because a stronger monotransitive bias means a weaker ditransitive bias (the bias was determined using monotransitive and DO completions only), this interaction shows that the lexical boost effect with the ditransitive structure tended to be larger with when the verb was less biased toward the ditransitive structure.

As the prime and target verbs were the same in the repeated DO prime condition, one possibility is that the verb repetition \times verb bias interaction is due to a surprisal effect in this condition: When the prime (and therefore target) verb was more strongly biased towards the monotransitive structure, the DO structure was more surprising and may therefore have caused more priming, resulting in a larger priming effect compared to the non-repeated DO prime condition. To investigate any prime surprisal effects, we analyzed the monotransitive bias of the *prime* verbs in the non-repeated DO and monotransitive prime conditions. (We did not analyze the repeated verb conditions, because this analysis is identical to the target verb bias analyses). Since we already know that the bias of the target verb exerts a strong influence on target completions and might obscure a prime verb bias effect, we first removed the influence of the target verb bias by residualizing for target verb bias using GLMM. Figure 4 shows the relationship between the monotransitive bias of the

prime verb and the proportion of monotransitive completions after residualizing for target verb bias.

<Figure 4 here>

We analyzed the residualized monotransitive completions as a continuous variable using a linear mixed-effects model, including Prime Type and the monotransitive bias of the prime verbs as fixed factors along with the participants and items random factors. The optimal model, which turned out to be the one with the minimal random effect structure, revealed a significant effect of Prime Type ($\beta=-0.32$, $SE=0.09$, $t=-3.75$, $p<0.001$) but no effect of prime verb bias ($p=0.170$) nor interaction between Prime Type and prime verb bias ($p=0.729$). Thus, we did not find any evidence that more surprising structures resulted in stronger priming.

Discussion

The results showed an effect of prime structure. Following monotransitive primes, people produced more monotransitive completions than following DO ditransitive primes. More importantly, we observed a lexical boost effect with the DO ditransitive structure but not with the monotransitive structure. This finding demonstrates that monotransitivity information is not associated with individual verbs and instead suggests that it is specified at the category-general level. In contrast, ditransitivity information is specified for individual verbs, consistent with previous studies.

Our further analysis showed that the absence of the lexical boost with monotransitives is not related to the structural bias of the target verb: There was neither a lexical boost with verbs that occurred frequently in the monotransitive structure nor with those that occurred infrequently in it. This provides evidence against the idea that the monotransitive structure is stored at the lexically specific level for those verbs with which it occurs infrequently and instead suggests that the monotransitive structure is represented at the category general level regardless of verb bias. In contrast, we did observe that the target verb bias affected the lexical boost effect with DO ditransitives: The stronger the bias for the monotransitive structure (i.e., the weaker the bias for the ditransitive structure), the greater the lexical boost effect. In the verb repeated conditions, the prime and target verb were the same, but additional analyses of the verb non-repeated conditions indicated that the bias of the prime verb did not have an effect, so there was no evidence that priming was stronger when the prime structure was more surprising. Instead, the target verb bias results are consistent with the idea that there are lexically-specific connections between the DO ditransitive structure and verbs that infrequently occur with it, but no or weaker connections between this structure and verbs that frequently occur with it. Another possibility is that the results are simply due to a ceiling effect; When the target verb is strongly biased towards the DO structure, the activation of this structure is likely to be high regardless of whether the DO prime has the same verb or not, and therefore, we may not have observed a DO lexical boost with target verbs that are strongly biased towards this structure. We will return to this in the General Discussion.

4. General Discussion

The current study investigated the representations of the monotransitive and DO ditransitive structure using the syntactic priming technique. In Experiment 1, we examined whether priming occurred with both structures. The results showed that participants produced more monotransitive completions following monotransitive prime sentences compared to the baseline condition and also produced more DO ditransitive completions following DO ditransitive prime sentences compared to the baseline condition, confirming that the ditransitive structure as well as the monotransitive structure primed. They also showed that our verbs were less frequently used with the monotransitive structure than in Van Gompel et al. (2012) (35.9% vs. 59.2% **monotransitive** target completions in the baseline condition). In Experiment 2, we again observed an effect of prime structure on target descriptions; more monotransitive completions were produced following monotransitive primes than following DO ditransitive primes. We also observed a lexical boost effect with DO ditransitive primes. This is consistent with results from previous priming studies, which examined syntactic priming of both DO and PO ditransitive structures and found a lexical boost effect with both structures. (e.g., Corley & Scheepers, 2002; Pickering & Branigan, 1998; Schoonbaert, Hartsuiker, & Pickering, 2007). The results from the DO ditransitive primes are also similar to those from intransitive primes, which also showed a lexical boost (Van Gompel et al., 2012). Thus, we argue that ditransitivity information (both DO and PO) as well as intransitivity information is associated with individual verbs. In other words, ditransitivity information is represented at the lexically-specific level. In contrast, and crucially, a lexical boost effect did not occur

with the monotransitive structure, suggesting that monotransitivity information is not associated with individual verbs. In other words, monotransitivity information is represented at the category-general level; it is specified for the whole class of verbs. This finding contradicts an assumption held by many linguistic theories, which assume that information about all argument structures is stored with individual lexical items (e.g., Chomsky, 1981; Pollard & Sag, 1994). Our results regarding monotransitive priming are unlikely to be due to the absence of priming per se because the results in Experiment 1 clearly demonstrated a priming effect of the monotransitive structure when the verb was repeated. Based on our results and those from previous studies on PO and DO structural representations, we propose to extend the network model by Pickering and Branigan (1998) and Van Gompel et al. (2012) to mono/ditransitive verbs as shown in Figure 5.

(Figure 5 about here)

As argued in the introduction, there are two possible reasons for why the monotransitive structure is represented differently from other structures. First, this may be the most economical way of storing argument structure information. Since the monotransitive structure is highly frequent across verbs, it may be costly for language users to keep track of all occurrences of monotransitives associated with particular verbs. *That is, every link and its activation have to be stored in the mental representation, so this places a higher demand on memory representations than if there is only one link between the verb category node and the structure. Furthermore, such lexically-specific representations may*

not be needed because ungrammatical montransitives can generally be ruled out semantically (**the man sneezed blood*). This contrasts with other argument structures such as intransitive and (PO or DO) ditransitive structures, which are less frequent and harder to rule out semantically (e.g., *donate* does not take double objects while *give* does).

Second, if the language processor keeps track of all argument structures other than montransitives, the probability of the montransitive use of a particular verb can be deduced from the total probability of all other argument structures ($p_{\text{montransitive}} = 1 - \sum_{i=1}^n p_i$, where p_i is the probability of each of the other structures). This way, it is not necessary to keep track of occurrences of the montransitive structure for individual verbs.

One may wonder whether the lack of a lexical boost effect with montransitives is due, at least partly, to the high frequency of the montransitive structure. That is, because highly frequent structures tend to prime less strongly than infrequent structures (e.g., Bernolet & Hartsuiker, 2010; Jaeger & Snider, 2013), they may leave less room for a priming boost with lexical repetition. There are two reasons why this is not consistent with our data. First, Experiment 1 showed a very robust priming effect from the montransitive structure. Thus, priming from the montransitive structure is not weak and occurred despite the fact that, across all verbs, the montransitive structure is most frequent. Second, if no lexical boost occurred because frequent structures cause weaker priming, then we should observe that verbs that are used infrequently in the montransitive structure should produce a lexical boost effect. However, the analyses of verb biases in Experiment 2 showed that the lexical boost was unaffected by the verbs' montransitive bias (i.e. the frequency with

which the verb occurred with the monotransitive structure). In other words, there was no lexical boost even with verbs that rarely occur with the monotransitive structure. These results suggest that the lack of a lexical boost with the monotransitive structure is not due to a lack of priming from highly frequent structures, but they instead support our claim that it reflects the lexically independent representation of the structure.

In contrast, the lexical boost effect with the DO ditransitive structure *was* dependent on the structural bias of the individual target verbs: The weaker the bias for the ditransitive structure, the stronger the lexical boost effect. One possibility we considered is that this finding was not due to the bias of the target verb, but due to the prime verb bias in the DO repeated verb prime condition. Because the prime and target verb were the same in this condition, priming may have been stronger when the DO prime structure was more surprising/less frequent with the verb in the prime (Chang et al., 2006; Jaeger & Snider, 2013). Such a finding would be consistent with evidence that priming from infrequent structures is stronger than from frequent structures, a finding often referred to as the inverse frequency effect (Scheepers, 2003; Bernolet & Hartsuiker, 2010; Jaeger & Snider, 2013; Peter et al., 2015). However, the analysis of prime verb bias in Experiment 2 showed no evidence for a surprisal effect on priming: In the conditions where the prime and target verbs were different (and therefore prime and target verb bias were not confounded), structural priming was unaffected by the surprisal of either the monotransitive or ditransitive prime structure given the prime verb.

An alternative explanation for the interaction between target verb bias and the lexical boost with DO primes may be that language users only store structural information

with verbs that occur infrequently with the DO structure. This may be most cost-effective, because in that way, they do not need to keep track of how often the DO structure occurs with verbs that occur frequently with this structure. But this raises the question of how language users represent the activation of the DO structure for these verbs; given our finding that monotransitive information is not stored with individual verbs either, there appears to be no way to deduce the activation of the DO structure. Ditransitive verbs vary in their DO bias (Bresnan, Cueni, Nikitina, & Baayen, 2007), and it is unclear how this information would be stored.

It is perhaps most plausible that the interaction is simply due to a ceiling effect such that DO biased target verbs cannot show as much of a DO lexical boost effect (compared to monotransitive biased verbs) because the percentage of the DO target completions for DO biased target verbs is already very high. This would imply that the DO structure is represented at the lexically-specific level for all verbs regardless of their bias, but it is harder to find a lexical boost with DO biased verbs because their DO activation is high regardless of whether a preceding DO prime contained the same or a different verb. Note that other studies examining the lexical boost (e.g., Corley & Scheepers, 2002; Hartsuiker et al., 2008; Pickering & Branigan, 1998; Segal et al., 2016; Van Gompel et al., 2012) did not analyze verb bias effects, so it is possible that an interaction with verb bias is a general characteristic of the lexical boost.

The most critical finding of the current study concerns the monotransitive prime conditions. In contrast to the DO prime conditions, these conditions showed no lexical boost effect, regardless of the structural bias of the verb, indicating that the monotransitive

structure is represented as category general information. As mentioned in Introduction, this may not only be the most economical way of representing argument structures but also provide a plausible account of children's overgeneralization errors with the monotransitive structure (e.g., Braine et al., 1990; Brooks et al., 1999; Maratsos et al., 1987): Children gradually learn to acquire the lexically independent representation of the monotransitive structure while entrenching the lexically specific representations of other structures.

One possible criticism is that the monotransitives we tested are not “true” monotransitives but are instead PO ditransitives with an implied recipient. Previous studies have shown that structures with an implied argument can prime the full structure. Messenger, Branigan, and McLean (2011) showed that short passives without a *by*-phrase primed full passives with a *by*-phrase and Cai, Pickering, Wang, & Branigan (2015) showed that Chinese monotransitive sentences with an implied theme that was either a NP or PP primed respectively full DO or full PO targets. It should be noted, however, that this does not necessarily imply that these implied arguments are syntactically represented as in the full structure; instead, a “short” structure may prime a full structure that it is most similar to (e.g., a truncated passive prime is more similar to a full passive than an active structure).

Critically, our results showed that the representation of a monotransitive structure *with an implied recipient* is different from a full PO structure *with an explicit recipient*; the representation of the monotransitive structure is category general as it showed no lexical boost in Experiment 2, whereas previous research has shown that the representation of the PO is lexically specific as it does show a lexical boost (e.g., Pickering & Branigan, 1998).

Furthermore, the results from Van Gompel et al. (2012) show that our current findings for monotransitives are not specific to monotransitive verbs with an implied recipient. They tested mono/intransitive verbs where the intransitive structure had an implied direct object, but where the monotransitive structure did not (e.g., *The ambulance driver was following the policewoman*). Nevertheless, consistent with the current findings, they found no lexical boost with monotransitive primes (but they did with intransitive primes). These results suggest that the monotransitive structure with mono/ditransitive verbs is represented as a true monotransitive, not as a PO ditransitive structure with an implied argument.

Our results also shed new light on the question of whether the lexical boost occurs with the repetition of *any* content word, as predicted by several models in the literature (e.g., Chang et al., 2006; Reitter et al., 2011). Recently, Scheepers, Raffray, and Myachykov (2017) and Carminati, Van Gompel, and Wakeford (2019) have obtained different results regarding this question. Scheepers et al. conducted three experiments in which participants read aloud a PO or DO prime and then had to construct a target sentence from a list of words (e.g., *manuscript, sent, editor, critic*). They found that structural priming was larger when the verb was repeated, but also when the argument nouns (in particular, the agent and recipient) were. In contrast, Carminati et al. conducted five experiments using a range of different structural priming methods (including Scheepers et al.'s "word list" method) and found a verb boost effect, but no evidence for a lexical boost effect with the argument nouns of PO or DO ditransitives. Carminati et al.'s results suggest that PO/DO argument structures are associated with their syntactic licensing head, the verb, but not with other content words in the sentence. It is not entirely clear why the results of these two studies

differ, but together, they suggest that the lexical boost from non-head nouns is less robust than the boost from the head verb, which has been observed in many studies using a variety of different structural priming methods.

Our results from the monotransitive primes in Experiment 2 show that even head verb repetition does not always result in a lexical boost. And strikingly, the same verb within the same experiment can either cause a lexical boost (with DO ditransitives) or not (with monotransitives). This finding is difficult to explain for models that assume that the boost occurs with the repetition of any content word. For example, if the lexical boost occurs because a repeated content word functions as a retrieval cue for the structure in the prime (Chang et al., 2006), then verb repetition should function as a retrieval cue for both the DO ditransitive structure and the monotransitive structure. One possibility would be to assume that the verb functions as a better cue if it occurs infrequently with the prime structure, but this makes it hard to explain the findings from the monotransitive primes, which were unaffected by verb bias. Similarly, if the additional priming when the verb is repeated is due to associative learning (Reitter et al., 2011), then it is unclear why there are associations between the verb and the DO ditransitive structure, but not between the verb and the monotransitive structure. And finally, if the lexical boost occurs because a prime is more predictive of the structure in future sentences that have the same verb than those that have a different verb, as argued by Jaeger and Snider (2013), then one would expect this to be the case regardless of whether the prime is DO ditransitive or monotransitive. Instead, our results are more compatible with the proposal that the asymmetry in the lexical boost arises because the monotransitive structure is represented differently, at the category-

general level, from other structures such as the ditransitive and the intransitive structures, which are stored at the lexically specific level.

5. Conclusions

The current study investigated whether the lexically-independent representation of the monotransitive structure is unique to a specific class of verbs or generalizes to a different class of verbs by testing verbs that can occur either in a monotransitive or ditransitive structure. The results demonstrated that the lexical boost does not occur with the monotransitive structure, whereas it does occur with the DO ditransitive structure. Furthermore, the absence of a lexical boost with the monotransitive structure was observed regardless of verb bias. Based on these findings, we argue that the monotransitive structure is, across different types of the verbs, represented at a lexically independent level while other structures are represented at a lexically specific level.

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Table 1. Numbers of monotransitive, DO, PO, and Other completions for each prime condition in Experiment 1 (percentages in brackets).

	Mono	DO	PO	Other
Monotransitive prime	134 (45.3)	43 (14.5)	111 (37.5)	8 (2.7)
DO ditransitive prime	84 (28.3)	85 (28.6)	112 (37.7)	16 (5.4)
Baseline	95 (32.2)	51 (19.7)	124 (42.0)	18 (6.1)

Table 2. GLMM analysis of monotransitive completions out of monotransitive and DO ditransitive completions in Experiment 1 (baseline condition is the reference level).

	β	SE	z	p
Intercept	0.78	0.47	1.67	0.094
Monotransitive prime	1.18	0.35	3.37	<0.001
DO ditransitive prime	-0.66	0.32	-2.07	0.038

Table 3. GLMM analysis of PO completions out of PO ditransitive and monotransitive completions in Experiment 1 (baseline condition is the reference level).

	β	SE	z	p
Intercept	0.39	0.32	1.24	0.215
Monotransitive prime	-0.61	0.22	-2.74	0.006
DO ditransitive prime	0.03	0.24	0.14	0.889

Table 4. Numbers of monotransitive, DO, PO, and Other completions for each condition in Experiment 2 (percentages in brackets).

	Mono	DO	PO	Others
Monotransitive prime + Verb repeated	131 (41.2)	78 (24.5)	83 (26.1)	26 (8.2)
DO ditransitive prime + Verb repeated	86 (27.0)	122 (38.2)	91 (28.5)	20 (6.3)
Monotransitive prime + Verb non-repeated	134 (42.3)	70 (22.1)	84 (26.5)	29 (9.1)
DO ditransitive prime + Verb non-repeated	104 (32.6)	97 (30.4)	81 (25.4)	37 (11.6)

Table 5. GLMM analysis of monotransitive completions out of monotransitive and DO ditransitive completions in Experiment 2.

	β	SE	Z	p
Intercept	0.46	0.32	1.45	0.146
Prime Type	-0.55	0.09	-5.87	<.001
Verb Repetition	0.21	0.09	2.37	0.018
Prime Type \times Verb Repetition	0.12	0.09	1.41	0.159

Table 6. GLMM analysis including monotransitive bias of the target verbs in Experiment 2.

		β	SE	z	p
Monotransitive prime	Intercept	-1.36	0.33	4.14	<0.001
	Verb repetition	0.26	0.17	1.53	0.137
	Monotransitive bias	2.24	0.33	6.80	<0.001
	Verb repetition \times Monotransitive bias	0.24	0.21	1.11	0.266
DO ditransitive prime	Intercept	-0.15	0.29	-0.53	0.596
	Verb repetition	0.39	0.15	2.68	0.007
	Monotransitive bias	1.63	0.22	7.56	<0.001
	Verb repetition \times Monotransitive bias	0.48	0.18	2.72	0.007

Figure 1. Residual activation model proposed by Pickering and Branigan (1998).

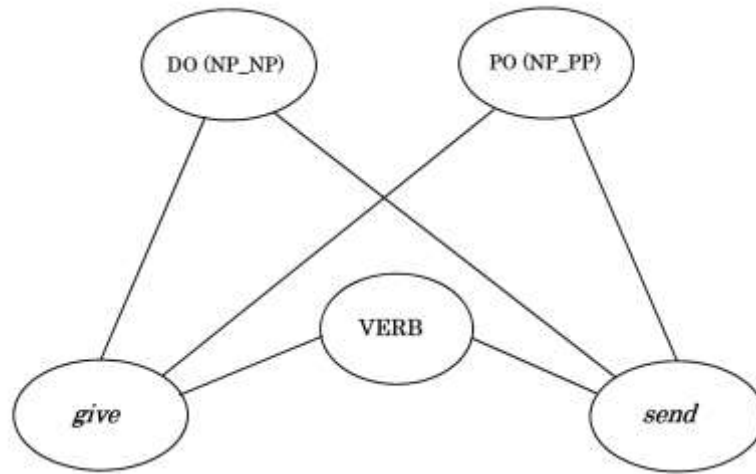


Figure 2. Modified residual activation model proposed by Van Gompel et al. (2012).

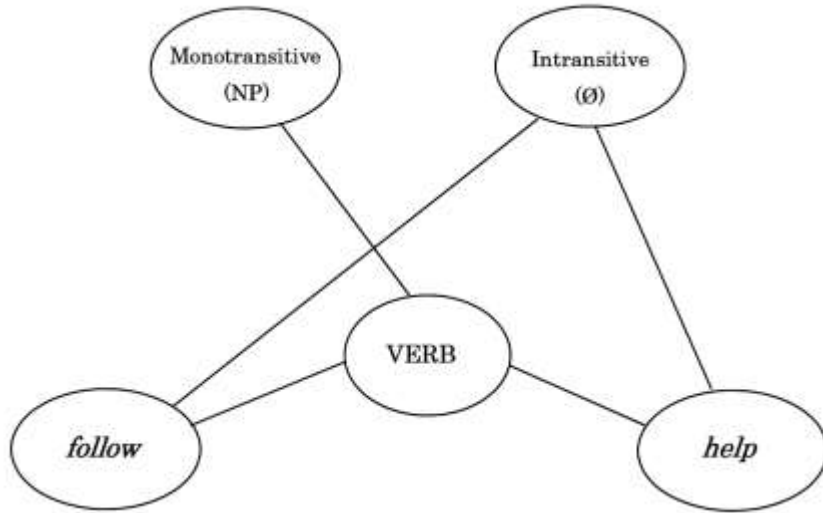


Figure 3a. Effect of monotransitive bias of the target verb on the lexical boost with monotransitive primes in Experiment 2.

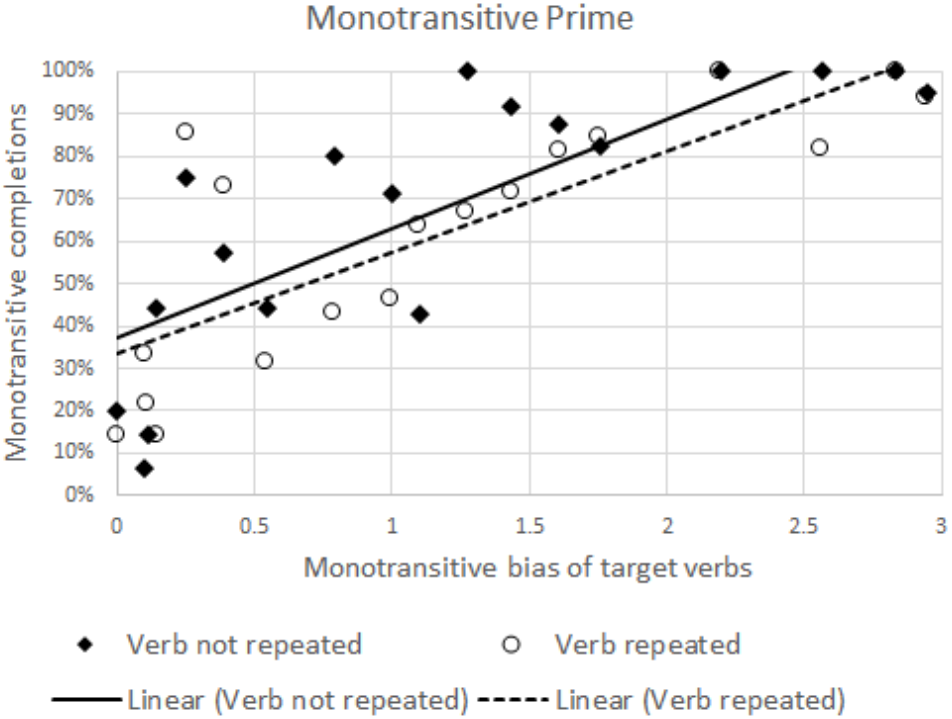


Figure 3b. Effect of monotransitive bias of the target verb on the lexical boost with DO ditransitive primes in Experiment 2.

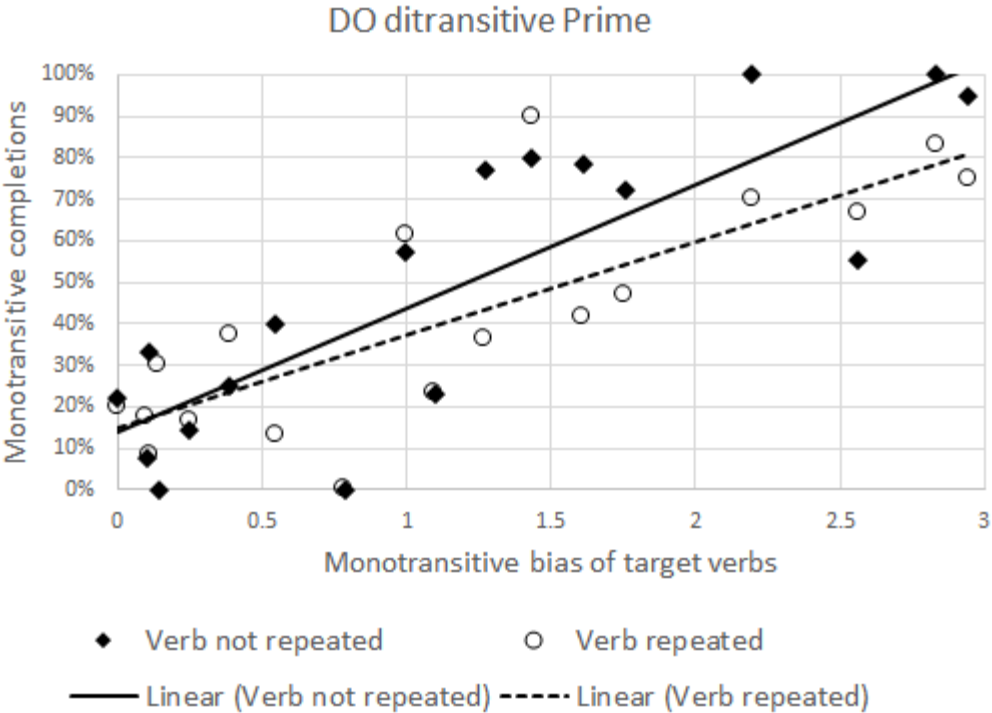


Figure 4. Effect of monotransitive bias of the prime verb on the lexical boost for the verb non repeated conditions after residualizing for the target verb bias (Experiment 2).

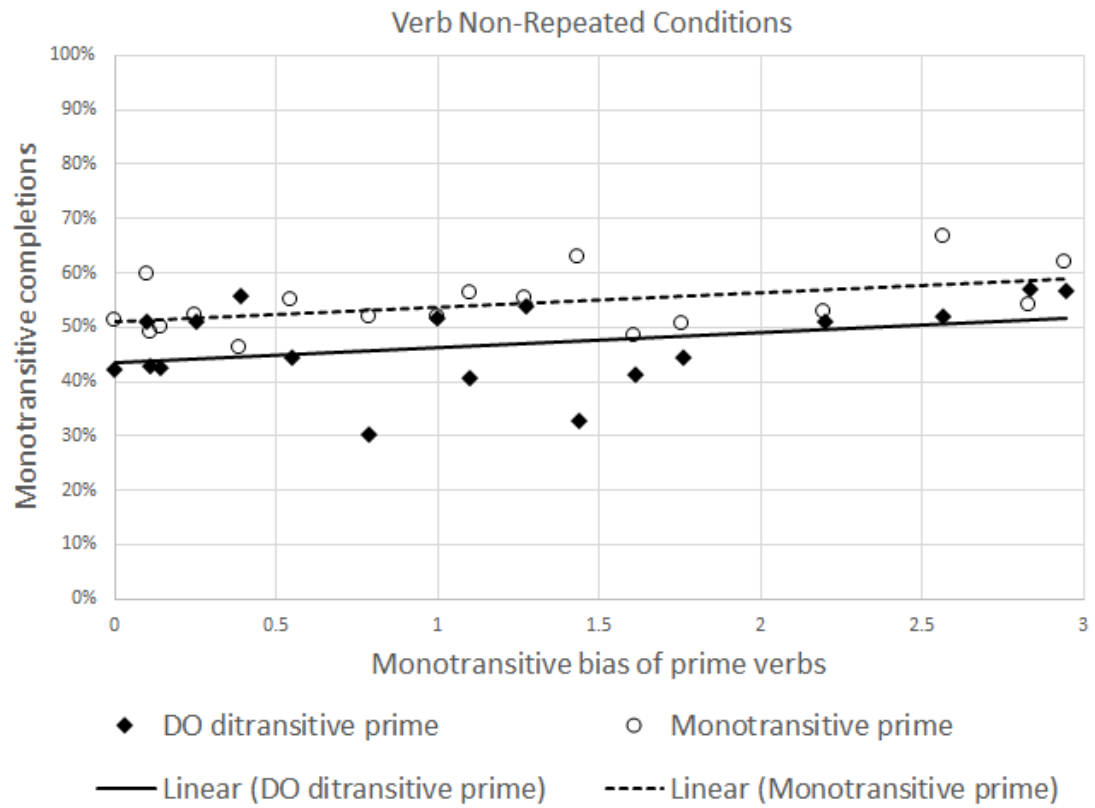
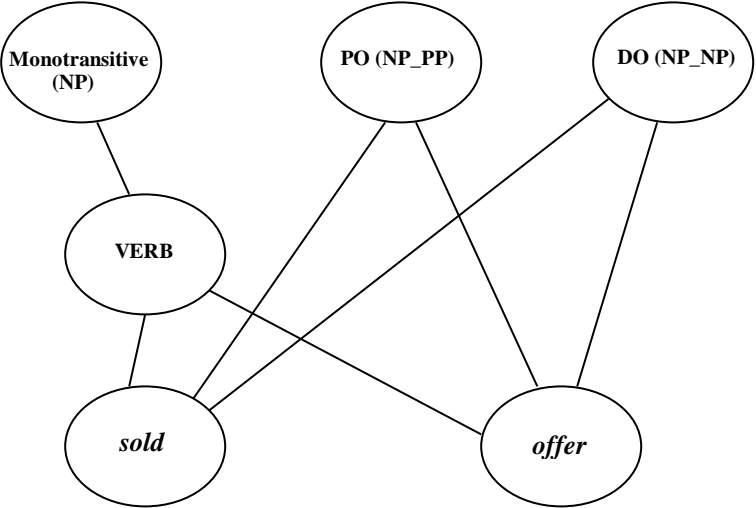


Figure 5. Residual activation model of the monotransitive and ditransitive structures with mono/ditransitive verbs.



Appendix

I. Materials from Experiment 1

(a) monotransitive prime (without the argument in brackets); (b) DO ditransitive prime (with the argument in brackets); (c) baseline condition; (d) target fragment.

1a,b. The schoolboy wrote (the woman) the letter.

1c. Very vague and rather incomprehensible.

1d. The divorcee wrote.....

2a,b. The performer sold (the tourist) the ticket.

2c. Mercilessly brutal and cruel.

2d. The uncle sold.....

3a,b. The officer issued (the refugee) the document.

3c. Awfully immature and mischievous.

3d. The landlord issued.....

4a,b. The applicant brought (the receptionist) the form.

4c. Dreadfully miserable and sorrowful.

4d. The granny brought.....

5a,b. The sergeant allotted (the soldiers) the rations.

5c. Unbearably dull and laborious.

5d. The parents allotted.....

6a,b. The Queen awarded (the athlete) the medal.

6c. Terribly disrespectful and ignorant.

6d. The supervisor awarded.....

7a,b. The deputy loaned (the employee) the computer.

7c. Deeply distraught but still hopeful.

7d. The father loaned.....

8a,b. The accountant lent (the man) the car.

8c. Surprisingly straightforward and offensive.

8d. The co-worker lent.....

9a,b. The teenager threw (the girl) the hat.

9c. Extremely exquisite and divine.

9d. The daughter threw.....

10a,b. The colleague bought (the lady) the book.

10c. Merely imaginary but very hideous.

10d. The boyfriend bought.....

11a,b. The management allocated (the workers) the budget.

11c. Astonishingly flawless and perfect.

11d. The schoolteacher allocated.....

12a,b. The gentleman sent (the fiancée) the watch.

12c. Untraditional but surprisingly popular.

12d. The girlfriend sent.....

13a,b. The gymnast tossed (the novice) the ball.

13c. Intelligent, profound, and most of all truthful.

13d. The flatmate tossed.....

14a,b. The chairman wrote (the secretary) the note.

14c. Quite tasty but a little too buttery.

14d. The advisor wrote.....

15a,b. The company posted (the recruit) the brochure.

15c. Not sincere at all and rather hypocritical.

15d. The landlady posted.....

16a,b. The schoolmaster promised (the child) the sweets.

16c. Helpless but nevertheless very courageous.

16d. The acquaintance promised.....

17a,b. The principal offered (the student) the scholarship.

17c. Highly charming and graceful.

17d. The commander offered.....

18a,b. The council granted (the pensioner) the payment.

18c. Very masculine but also very skinny.

18d. The mother granted.....

19a,b. The boy brought (the bride) the card.

19c. Seemingly luxurious but actually very cheap.

19d. The grandchild brought.....

20a,b. The shopkeeper posted (the client) the catalogue.

20c. Extremely stubborn and narrow-minded.

20d. The friend posted.....

21a,b. The proprietor lent (the visitor) the room.

21c. Wonderfully tranquil and peaceful.

21d. The boss lent.....

22a,b. The registrar sent (the student) the certificate.

22c. Quite erratic but highly stylish.

22d. The executive sent.....

23a,b. The mafia forwarded (the assassin) the cash.

23c. Eccentric rather than awkward or neurotic.

23d. The foreman forwarded.....

24a,b. The schoolgirl loaned (the boy) the Frisbee.

24c. Extraordinarily zealous and powerful.

24d. The teammate loaned.....

25a,b. The teacher assigned (the children) the textbooks.

25c. Always passionate and very creative.

25d. The employer assigned.....

26a,b. The merchant sold (the customer) the goods.

26c. Not prudent at all and rather reckless.

26d. The classmate sold.....

27a,b. The solicitor owed (the lawyer) the fee.

27c. Extremely anxious but still cheerful.

27d. The schoolmate owed.....

28a,b. The sailor promised (the tourist) the motorboat.

28c. Very ludicrous but quite funny.

28d. The manager promised.....

29a,b. The superintendent offered (the newcomer) the contract.

29c. Exceptionally precious and very fragile.

29d. The king offered.....

30a,b. The man bought (the student) the camera.

30c. Really eloquent and persuasive.

30d. The mistress bought.....

II. List of the mono/ditransitive verbs used in Experiments 1 and 2 and their logit bias for the monotransitive structure, estimated by taking the monotransitive completions out of all the monotransitive and DO ditransitive completions (proportions in brackets).

verb	Bias for monotransitive
allocate	0.79 (0.60)
allot	1.10 (0.75)
assign	0.25 (0.25)
award	1.10 (0.75)
buy	0.39 (0.33)
bring	1.27 (0.75)
forward	2.20 (1.00)
grant	0.14 (0.14)
issue	2.56 (1.00)
lend	0.11 (0.11)
loan	0.10 (0.10)
offer	0.55 (0.44)
owe	0.00 (0.00)
post	1.44 (0.80)
promise	1.76 (0.86)
send	1.00 (0.67)
sell	1.61 (0.86)
throw	2.94 (1.00)
toss	2.83 (1.00)
write	2.94 (1.00)

III. Materials from Experiment 2

(a) monotransitive prime verb repeated (without the argument in brackets and with the verb before the slash); (b) DO ditransitive prime verb repeated (with the argument in brackets and with the verb before the slash); (c) monotransitive prime verb not repeated (without the argument in brackets and with the verb after the slash); (d) DO ditransitive prime (with the argument in brackets and with the verb after the slash); (e) target fragment. We also created 4 additional conditions to counterbalance for potential verb effects, in which the two verbs in each item were swapped.

1a,b,c,d. The janitor tossed/brought (the guest) the key.

1e. The playmate tossed.....

2a,b,c,d. The solicitor lent/owed (the lawyer) the fee.

2e. The schoolmate lent.....

3a,b,c,d. The performer sold/offered (the tourist) the ticket.

3e. The uncle sold.....

4a,b,c,d. The officer issued/forwarded (the refugee) the document.

4e. The landlord issued.....

5a,b,c,d. The applicant sent/brought (the receptionist) the form.

5e. The granny sent.....

6a,b,c,d. The sergeant allotted/promised (the soldiers) the rations.

6e. The parents allotted.....

7a,b,c,d. The Queen granted/awarded (the athlete) the medal.

7e. The supervisor granted.....

8a,b,c,d. The deputy sold/loaned (the employee) the computer.

8e. The father sold.....

9a,b,c,d. The accountant lent/offered (the man) the car.

9e. The co-worker lent.....

10a,b,c,d. The teenager brought/threw (the girl) the hat.

10e. The daughter brought.....

11a,b,c,d. The schoolboy posted/wrote (the woman) the letter.

11e. The divorcee posted.....

12a,b,c,d. The management allocated/assigned (the workers) the budget.

12e. The schoolteacher allocated.....

13a,b,c,d. The gentleman sent/bought (the fiancée) the watch.

13e. The girlfriend sent.....

14a,b,c,d. The gymnast loaned/tossed (the novice) the ball.

14e. The flatmate loaned.....

15a,b,c,d. The chairman forwarded/wrote (the secretary) the note.

15e. The advisor forwarded.....

16a,b,c,d. The company issued/posted (the recruit) the brochure.

16e. The landlady issued.....

17a,b,c,d. The schoolmaster bought/promised (the child) the sweets.

17e. The acquaintance bought.....

18a,b,c,d. The principal offered/awarded (the student) the scholarship.

18e. The commander offered.....

19a,b,c,d. The council granted/owed (the pensioner) the payment.

19e. The mother granted.....

20a,b,c,d. The boy wrote/brought (the bride) the card.

20e. The grandchild wrote.....

21a,b,c,d. The shopkeeper sold/posted (the client) the catalogue.

21e. The friend sold.....

22a,b,c,d. The proprietor allocated/lent (the visitor) the room.

22e. The boss allocated.....

23a,b,c,d. The registrar issued/sent (the student) the certificate.

23e. The executive issued.....

24a,b,c,d. The mafia allotted/forwarded (the assassin) the cash.

24e. The foreman allotted.....

25a,b,c,d. The schoolgirl threw/loaned (the boy) the Frisbee.

25e. The teammate threw.....

26a,b,c,d. The teacher promised/assigned (the children) the textbooks.

26e. The employer promised.....

27a,b,c,d. The merchant sold/sent (the customer) the goods.

27e. The classmate sold.....

28a,b,c,d. The colleague posted/bought (the lady) the book.

28e. The boyfriend posted.....

29a,b,c,d. The widow forwarded/wrote (the jeweller) the cheque.

29e. The collaborator forwarded.....

30a,b,c,d. The sailor promised/loaned (the tourist) the motorboat.

30e. The manager promised.....

31a,b,c,d. The superintendent offered/assigned (the newcomer) the contract.

31e. The king offered.....

32a,b,c,d. The man bought/lent (the student) the camera.

32e. The mistress bought.....