



# Event Structures Drive Semantic Structural Priming, Not Thematic Roles: Evidence From Idioms and Light Verbs

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**Event structures drive semantic structural priming, not thematic roles:**

**Evidence from idioms and light verbs**

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## Abstract

What are the semantic representations that underlie language production? We use structural priming to distinguish between two competing theories. Thematic roles define semantic structure in terms of atomic units that specify event participants and are ordered with respect to each other through a hierarchy of roles. Event structures instead instantiate semantic structure as embedded sub-predicates that impose an order on verbal arguments based on their relative positioning in these embeddings. Across two experiments, we found that priming for datives depended on the degree of overlap in event structures. Specifically, while all dative structures showed priming, due to common syntax, there was a boost for compositional datives priming other compositional datives. Here the two syntactic forms have distinct event structures. In contrast, there was no boost in priming for dative light verbs, where the two forms map onto a single event representation. On the thematic roles hypothesis, we would have expected a similar degree of priming for the two cases. Thus, our results support event structural approaches to semantic representation and not thematic roles.

## 1. Introduction

Most events can be described in multiple ways. For instance, I can say “The man threw the dog the ball” or “The man threw the ball to the dog.” In both cases, I’m describing the same transfer event despite using different word orders. Theories of argument structure account for these different surface orderings by appealing to the structural representations that underlie them. In some theories, these differences are attributed to operations in the syntax itself (e.g., Beck & Johnson, 2004; Harley, 2003; Pesetsky, 1995). In others, it is assumed that they constitute a distinct level of semantic structure that maps to an independent syntactic representation (e.g., Baker, 1988, 1997; Fillmore, 1968; Goldberg, 1995; Gruber, 1965; Jackendoff, 1972, 1990, 2002; Pinker, 1989; Rappaport Hovav & Levin, 1998, 2011). In this paper, we will follow this latter tradition and describe syntax and semantics as different levels of representation that are linked via mapping. Here we are asking: What are the semantic representations that underlie language production? These representations have traditionally been described in one of two ways.

The first way in which semantic structure has typically been described is in terms of thematic roles (Baker, 1988, 1997; Fillmore, 1968; Gruber, 1965; Jackendoff, 1972). In these theories, verbs are associated with a small set of thematic roles which are usually described as atomic primitives (though cf., e.g., Dowty, 1991). These roles correspond to the different participants in an event (agent, patient, theme) and are ordered and linked to surface syntactic functions (subject, object). On this type of account, the different syntactic orderings of double-object (DO) datives (e.g., “The man threw the dog the ball”) vs. prepositional-object (PO) datives (e.g., “The man threw the ball to the dog”) reflect different mappings of thematic roles onto the different surface functions: recipient to direct object and theme to second object for DOs, and theme to direct object and recipient to oblique object for POs (e.g., Cai, Pickering, & Branigan, 2012; Salamoura & Williams, 2007; see also Hartsuiker & Kolk, 1998-b; Shin & Christianson, 2009). This we’ll call the *thematic roles hypothesis*.<sup>1</sup>

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<sup>1</sup> There are other possible thematic role hypotheses, including in terms of mappings between thematic roles and the (relative) linear positions of noun phrases (e.g., Cai et al., 2012; Köhne et al., 2014). We will return to these alternatives in the General Discussion.

Alternatively, another way of describing the semantic representations of language is as event structures (Goldberg, 1995; Jackendoff, 1990, 2002; Pinker, 1989; Rappaport Hovav & Levin, 1998, 2011; for review and discussion, see Levin & Rappaport Hovav, 2005). In these theories, verbs are decomposed into primitive predicates (ACT, BECOME, CAUSE, HAVE) that are embedded within each other, forming hierarchical relations among the arguments they take. For instance, DO datives consist of a HAVE predicate embedded within a CAUSE predicate (e.g., [X CAUSE [Z HAVE Y]]), while PO datives contain an embedded BE AT predicate (e.g., [X CAUSE [Y BE AT Z]]; structures from Levin & Rappaport Hovav, 2005, p. 207). Arguments in these event structures are then isomorphically mapped to surface syntax, such that the argument of the highest predicate becomes the subject and the lower ones get realized in post-verbal positions (at least for English). Accordingly, on this approach, the different syntactic orderings of DO and PO datives are a consequence of their different semantic event structures. We will refer to this as the *event structures hypothesis*.

In the present paper, we use structural priming to ask what the semantic representations are that underlie language production—thematic roles or event structures. To do so, we employ idioms (e.g., “Miss Piggy gives Kermit the cold shoulder”), light verbs (e.g., “Bert gives Ernie a hug”), and compositional datives (e.g., “Big Bird gives Julia a feather”), all of which occur in the same surface syntactic phrase structures but differ from each other in their semantics. In the remainder of this introduction, we first introduce structural priming and consider what the existing priming data have to say about the locus of semantic structural priming in particular. We then review the relevant semantic and syntactic representations for idioms, light verbs, and compositional datives, before turning to our predictions.

### *1.1. Structural priming and the priming of semantic structure*

Structural priming refers to the tendency for speakers to reuse previously encountered sentence structures (Bock, 1986; for a meta-analysis and reviews, see Branigan, 2007; Branigan & Pickering, 2017; Mahowald, James, Futrell, & Gibson, 2016; Pickering & Ferreira, 2008; Tooley & Traxler, 2010). For

instance, Bock (1986) found that speakers were more likely to describe an image using a DO dative (“The man is reading the boy a story”) following another DO dative (“A rock star sold an undercover agent some cocaine”) than they were following a PO dative (“A rock star sold some cocaine to an undercover agent”). Importantly, this basic finding cannot be due solely to the repetition of particular lexical items, verbal morphology, or metrical structure (Bock & Loebell, 1990; Pickering & Branigan, 1998). Instead, it results from a perseveration on the basic structure of the sentence itself. Accordingly, priming provides some of the strongest evidence for the existence of abstract structural representations in language, and can be used to diagnose similarities in structure across linguistic representations at all levels of analysis (Branigan & Pickering, 2017).

Although priming is often characterized as a largely syntactic phenomenon (e.g., Branigan, 2007; Branigan & Pickering, 2017; Branigan, Pickering, Liversedge, Stewart, & Urbach, 1995; Branigan, Pickering, McLean, & Stewart, 2006; Chang, Dell, & Bock, 2006), recent findings demonstrate that meaning also plays a role (e.g., Cai et al., 2012; Chang, Bock, & Goldberg, 2003; Cho-Reyes, Mack, & Thompson, 2016; Griffin & Weinstein-Tull, 2003; Hare & Goldberg, 1999; Köhne, Pickering, & Branigan, 2014; Pappert & Pechmann, 2014; Salamoura & Williams, 2007; Yi & Koenig, 2016; Ziegler & Snedeker, 2018). For instance, Chang et al. (2003; see also Yi & Koenig, 2016; Ziegler & Snedeker, 2018) found that location-theme locative sentences (“The maid rubbed the table with polish”) led to a higher proportion of location-theme responses (“The farmer heaped the wagon with straw”) as compared to theme-location locatives (“The maid rubbed polish onto the table”). This occurred despite the two locative types having the same syntactic structure (both NP-V-NP-PP). Thus, priming is sensitive to semantic structure in addition to the surface syntax.<sup>2</sup>

These data, however, are compatible with both theories about the nature of the semantic structures that underlie verb argument realization. On the *thematic roles hypothesis*, the location-to-direct-

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<sup>2</sup> The astute reader may remember that Bock and Loebell (1990) also addressed the question of whether thematic roles contribute to priming, seemingly finding evidence that they do not. We return to this issue in the General Discussion.

object and theme-to-oblique-object mappings of location-theme locatives would lead to more location-theme than theme-location responses, and vice versa for theme-location locatives. Conversely, on the *event structures hypothesis*, both forms have distinct event structures which could subserve priming. Specifically, the location-theme locatives correspond to [[X CAUSE [Z BE IN STATE]] WITH Y] structures, while the theme-location locatives correspond to [X CAUSE [Y BE AT Z]] structures (structures adapted from Rappaport & Levin, 1988, p. 26).

The other commonly used alternative for investigating semantic structural priming is the dative alternation (e.g., Cai et al., 2012; Cho-Reyes et al., 2016; Hare & Goldberg, 1999; Köhne et al., 2014; Pappert & Pechmann, 2014; Salamoura & Williams, 2007; Ziegler & Snedeker, 2018). Unfortunately, priming within datives is typically triply ambiguous. In addition to differing in their proposed event structures and thematic mappings (e.g., Beck & Johnson, 2004; Bruening, 2010; Goldberg, 1995; Harley, 2003; Pinker, 1989; Rappaport Hovav & Levin, 2008; for review and discussion, see Levin & Rappaport Hovav, 2005), DO and PO datives also differ with regard to their surface syntax: NP-V-NP-NP for DOs vs. NP-V-NP-PP for POs. Thus, dative-to-dative priming alone typically cannot isolate the effect of semantic structure from that of syntax, much less arbitrate on what the relevant semantic representations involved are. To get around these pitfalls, we employ constructions that use the same dative syntax but vary in terms of their event semantics and thematic mappings. We now turn to these cases.

### *1.2. The semantic and syntactic representations of idioms, light verbs, and compositional datives*

Idioms (e.g., “Miss Piggy gives Kermit the cold shoulder”), light verbs (e.g., “Bert gives Ernie a hug”), and compositional datives (e.g., “Big Bird gives Julia a feather”) are useful for addressing these issues for two reasons. First, they all occur in the same two dative syntactic phrase structures: NP-V-NP-NP for the double-object (DO) variant and NP-V-NP-PP for the prepositional-object (PO) variant (Fig. 1). This allows us to control for a variety of factors that are known to contribute to priming, including surface syntactic structure (e.g., Bock & Loebell, 1990; Messenger, Branigan, McLean, & Sorace, 2012; Ziegler & Snedeker, 2018), content- and function-word overlap (e.g., Ferreira, 2003; Pickering & Branigan, 1998;

Scheepers, Raffray, & Myachykov, 2017; Ziegler, Goldberg, & Snedeker, 2018), animacy (e.g., Bock, Loebell, & Morey, 1992; Gámez & Vasilyeva, 2015; Ziegler & Snedeker, 2018), morphosyntactic marking (e.g., Köhne et al., 2014; Pappert & Pechmann, 2014; Yamashita & Chang, 2006), and information structure (e.g., Bernolet, Hartsuiker, & Pickering, 2009; Vernice, Pickering, & Hartsuiker, 2012; see General Discussion). Thus, if priming is purely based on surface syntax (or any of these other factors), then idioms and light verbs should be just as good primes for compositional dative targets as are other compositional dative primes, and vice versa. These factors cannot, however, account for any differences we might observe among the three construction types.

Second, idioms and light verbs differ from typical datives in that they are not fully compositional; that is, the meanings of their wholes are not transparently derivable from the meanings of their parts (e.g., Chomsky, 1957; Frege 1892).<sup>3</sup> Whereas “Big Bird gives Julia a feather” conveys the transfer of a physical feather from Big Bird to Julia, “Miss Piggy gives Kermit the cold shoulder” does not mean that Miss Piggy is transferring a physical cold shoulder from her possession to Kermit’s, as suggested by its compositional syntactic structure. Rather, it conveys a simple agent-patient interaction: Miss Piggy ignoring Kermit. Similarly, in the light verb sentence “Bert gives Ernie a hug,” one is not communicating an actual physical transfer event, but rather, as before, a transitive agent-patient hugging interaction (Wittenberg et al., 2014). However, in contrast to idioms, the event type of a light verb sentence is determined by the event nominal: “giving a hug” is “hugging”, but “giving the cold shoulder” is not “shouldering.” Light verb constructions have therefore been called “semi-transparent” (Family, 2008; Gyllstad & Wolter, 2016).

Crucially, because they are not fully compositional, idioms and light verbs do not have the same semantic representations that compositional dative structures do (Wittenberg & Snedeker, 2014; Wittenberg et al., 2014; Wittenberg, Khan, & Snedeker, 2017). Both variants of compositional datives,

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<sup>3</sup> Idioms and light verbs do, however, display some degree of compositionality, such that the noun phrase filling the patient role typically can vary (although there are some idioms for which even this limited type of compositionality is disallowed; for discussion, see Levin & Rappaport Hovav, 2005). Nevertheless, this is a separate issue from whether their fully-composed meanings are the direct sum of the meanings of their parts.



for instance, involve three event participants, differentiated from each other either by their event structures or thematic mappings (Fig. 1). Conversely, the idioms and light verbs discussed in this paper capture simple two-participant events, whether in the DO form or in the PO form. Accordingly, the two forms of, for example, a light verb have the same event structure (i.e., [X ACT Z]) but differ in their thematic mappings: patient to direct object for DOs vs. patient to oblique object for POs (Fig. 1; for discussion, see Levin & Rappaport Hovav, 2005; Wittenberg et al., 2014).

	DO	PO
Compositional datives	<div>NP-V-NP-NP</div> <div>           agent → subject            recipient → dirObj            theme → obj2         </div> <div>OR</div> <div>[X CAUSE [Z HAVE Y]]</div>	<div>NP-V-NP-PP</div> <div>           agent → subject            theme → dirObj            recipient → oblObj         </div> <div>OR</div> <div>[X CAUSE [Y BE AT Z]]</div>
Light verbs	<div>NP-V-NP-NP</div> <div>           agent → subject            patient → dirObj         </div> <div>OR</div> <div>[X ACT Y]</div>	<div>NP-V-NP-PP</div> <div>           agent → subject            patient → oblObj         </div> <div>OR</div> <div>[X ACT Y]</div>
	<div>□ Syntax □ Thematic mappings □ Event structure</div>	

**Figure 1.** Semantic and syntactic representations of compositional datives and light verbs (or idioms) in both double-object (DO) and prepositional-object (PO) structures. dirObj = direct object; obj2 = second object; oblObject = oblique object. (The structures for idioms are hypothesized to be the same as those depicted here for light verbs.)

### 1.3. Predictions

A growing body of evidence suggests that priming is cumulative, possibly even additive, such that the more features that align from prime to target, the greater the priming effect (e.g., Bernolet, Coleman, & Hartsuiker, 2014; Bernolet et al., 2009; Cai et al., 2012; Cleland & Pickering, 2003; Gámez & Vasilyeva, 2015; Griffin & Weinstein-Tull, 2003; Hartsuiker & Kolk, 1998-a; Pickering & Branigan, 1998; Potter & Lombardi, 1998; Scheepers et al., 2017; Vernice et al., 2012; Ziegler & Snedeker, 2018; for further discussion, see Ziegler & Snedeker, 2018). This claim does not apply to aspects of structure that do not participate in priming (e.g., verb morphology, metrical structure, overall or detailed syntactic structure; Bock & Loebell, 1990, Exp. 3; Branigan et al., 2006; Fox Tree & Meijer, 1999; Pickering & Branigan, 1998), but for those that do (e.g., local syntactic structure, semantic structure, lexical choice, animacy, information structure), we typically see a boost to priming whenever two or more align, relative to any one component individually.<sup>4</sup> This is key for the present study, since the idioms, light verbs, and compositional datives we are using all occur in the same two syntactic structures. Thus, on the basis of surface syntax alone, we expect priming between all three construction types: Across the board, DOs should prime DOs and POs should prime POs (Fig. 2).

On top of this baseline of syntactic priming, we can then look for semantic effects. If all that's shared between prime and target is syntax, then we should expect no additional priming on the basis of semantics. On the other hand, if both the syntactic and semantic structures are shared from prime to target, then we expect to see a boost to priming relative to the syntax-only case. This yields different predictions for our two hypotheses.

On the *thematic roles hypothesis*, priming should be boosted *within* constructions but not *across* them. Thus, for priming from compositional datives to other compositional datives, the mappings of recipient to direct object and theme to second object in DO primes should prime the same mappings in

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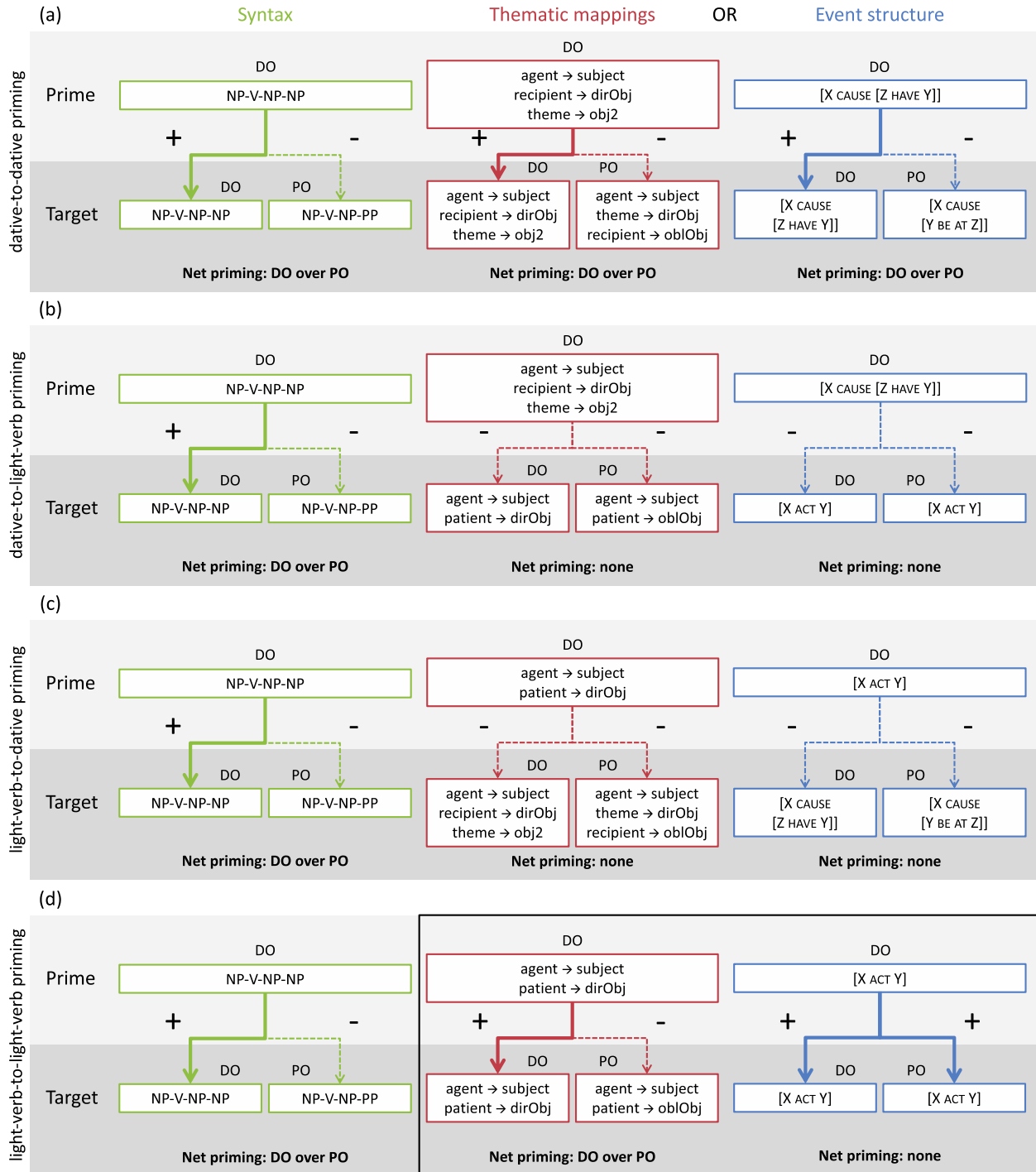
<sup>4</sup> We will return in the General Discussion to cases where semantic structure has been shown *not* to contribute additively to priming where it might otherwise have been expected (e.g., Bock & Loebell, 1990; Messenger et al., 2012; Ziegler et al., 2018).

DO targets, and vice versa for PO structures, yielding a boost to priming above and beyond that of syntax alone (Fig. 2a). Priming should also be boosted for idiom primes on idiom targets or light verb primes on light verb targets, since the mapping of patient to direct or oblique object in the prime should suffice to boost priming for the same mapping in the target (Fig. 2c). We do not, however, expect the thematic mappings of idioms and light verbs to prime those of datives, or vice versa, since the set of roles (and their corresponding mappings) is distinct in each case: agents and patients in idioms and light verbs vs. agents, recipients, and themes in compositional datives (Fig. 2b).<sup>5</sup>

The *event structures hypothesis* similarly predicts no boost to priming *across* constructions. Thus, priming from idiom or light verb primes to compositional dative targets, and vice versa, should be driven purely by syntax alone, since the event structures are also not shared across them: [X ACT Z] for idioms and light verbs vs. [X CAUSE [Z HAVE Y]] and [X CAUSE [Y BE AT Z]] for compositional datives (Fig. 2b). Contrary to the *thematic roles hypothesis*, however, the *event structures hypothesis* makes divergent predictions for the profiles of priming *within* compositional datives vs. within idioms and light verbs. Indeed, we expect to see a boost to priming for compositional dative primes on compositional dative targets, since the two surface forms of compositional datives differ with respect to their underlying event structures: [X CAUSE [Z HAVE Y]] structures should prime other [X CAUSE [Z HAVE Y]] structures, while [X CAUSE [Y BE AT Z]] structures should prime other [X CAUSE [Y BE AT Z]] structures, but not the reverse (Fig. 2a). Priming within idioms or light verbs should not be boosted, however, since the event structures for both forms are the same and therefore cannot differentially contribute to either at the expense of the other (Fig. 2c).

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<sup>5</sup> Following common practice, we use “patient” for transitive meanings and “theme” for dative meanings, but we recognize that the definition of these roles has been problematic (for discussion, see Levin & Rappaport Hovav, 2005). We make no commitment to this division, nor do our predictions depend on it.



**Figure 2.** Hypothesized loci of semantic structural priming. (a) DO compositional datives share with other DO compositional datives their event structure and thematic mappings, but have a different event structure and thematic mappings from PO compositional datives. Thus, semantic structural priming (above and beyond surface syntax) could be due either to event structures or thematic mappings. (b-c) DO compositional datives have the same surface syntax as DO light verbs (or idioms) but not PO light verbs (or idioms), and do not share event structure or thematic mappings with either. Thus, priming can only be on the basis of syntax alone. (d) DO light verbs (or idioms) share with other DO light verbs (or idioms) their syntax, event structure, and thematic mappings, but have a different syntax and thematic mappings from PO light verbs (or idioms). If thematic mappings contribute to structural priming, priming should

thus be additive on the basis of both syntax and thematic mappings, above and beyond that between compositional datives and light verbs (or idioms). However, if event structure contributes to priming, priming should be on the basis of syntax alone. dirObj = direct object; obj2 = second object; oblObject = oblique object. (The structures for idioms are hypothesized to be the same as those depicted here for light verbs.)

#### *1.4. Current study*

In Experiment 1, we explore priming from idiom, light verb, and compositional dative primes on compositional dative targets. Snider and Arnon (2012) previously established priming from idiomatic dative primes on compositional dative targets. While they found no difference between idiom priming and priming within compositional datives, their primary goal was not to compare the magnitude of priming, but rather to determine whether idioms would prime compositional datives at all. Consequentially, their study was underpowered to detect differences between idioms and compositional datives (59% power with  $N=21$  in a within-subjects design at a medium effect size, Cohen's  $d=.5$ ; see also Mahowald et al., 2016). Experiment 1 builds off this finding with 192 participants (99.8% power, between-subjects). We confirm priming from idioms to compositional datives and demonstrate priming from light verbs to compositional datives. Importantly, we find that priming from compositional datives to other compositional datives is boosted relative to priming from either idioms or light verbs to compositional datives. As we note above, this difference is expected if semantic structure can be primed, but it does not, on its own, distinguish between the two hypotheses about the nature of semantic structure.

In Experiment 2, we fully cross compositional datives and light verbs as both primes and targets. If semantic structural priming relies on the mappings of thematic roles onto surface syntax, then light verb primes should provide a boost in priming on light verb targets relative to compositional dative primes. If, on the other hand, semantic structural priming is based on event structures rather than thematic mappings, we should expect no additional boost to priming on light verb targets for light verb over compositional dative primes. We again have high power to detect the critical interaction (97.6% for  $N=64$ , within-subjects). This experiment closely resembles a related study by Bernolet et al. (2014), which construes the difference as priming between polysemous verbs that share the same sense (either both concrete or both

abstract) vs. priming between polysemous verbs with different senses (one concrete and one abstract). We will return to this point in the General Discussion.

In both experiments, we restrict our materials to the dative verb *give*. Not only is *give* the only dative light verb (i.e., light verb with two consistently obligatory post-verbal arguments), but it is also by far the most common verb in dative idioms (e.g., Snider & Arnon, 2012). Thus, only by using *give* extensively could we look at priming between idioms, light verbs, and compositional datives. Critically, in both experiments, all three construction types are matched for surface syntax, overlap of content and function words (cf. Chang et al., 2003; Yi & Koenig, 2016), the ordering of animate and inanimate arguments (cf. Cai et al., 2012; Hare & Goldberg, 1999; Pappert & Pechmann, 2014; Salamoura & Williams, 2007), morphosyntactic marking (cf. Köhne et al., 2014; Pappert & Pechmann, 2014), and information structure (cf. Cai et al., 2012; Köhne et al., 2014; Pappert & Pechmann, 2014; Salamoura & Williams, 2007). Thus, any differences we see in priming cannot be attributed to these other factors.

## **2. Experiment 1**

### **2.1. Methods**

#### *2.1.1. Participants*

192 native English speakers recruited from Amazon Mechanical Turk participated in the experiment (108 female, 84 male; mean age=35[SD=10], range=18-67). All participants provided written consent prior to participating and received \$3.50 for their participation.

#### *2.1.2. Materials*

The study consisted of 14 critical trials interspersed with 70 filler trials, for a total of 84 trials. All trials included a sequence of one prime sentence, presented as text to be read out loud, followed by a target picture, to be described. For light verbs and compositional datives, we constructed 14 prime sentences each, all with *give* as their main verb, in both DO and PO variants. For idioms, since some don't alternate or sound equally natural in both dative structures, we constructed two different sets of prime materials: 14

in the DO form and an additional 14 in the PO form, all with *give* as their main verb. (For a full list of all prime sentences by experiment, see Appendix.) Prior to the experiment, prime sentences (including those for Exp. 2; see below) were normed for acceptability on Amazon Mechanical Turk (N=60), on a scale from 1 (very unnatural) to 4 (very natural). We then matched Compositional, Idiom, and Light sentences, such that each sentence had a rating of 2.6 or higher across DO and PO forms. On average, DO Compositional sentences had a rating of 3.48, while PO Compositional sentences had a rating of 3.44,  $F(1, 26)=.89, p=.35$ ; DO Light sentences had a rating of 3.41, while PO Light sentences had a rating of 3.21,  $F(1, 26)=3.10, p=.09$ ; and DO Idiom sentences had a rating of 3.42, while PO Idiom sentences had a rating of 3.44,  $F(1, 28)=.04, p=.85$ . There were no significant differences across Prime Construction,  $F(2, 78)=2.79, p=.07$ , or Prime Form,  $F(1, 78)=1.74, p=.19$ , and no significant interaction,  $F(2, 78)=1.38, p=.26$ .

To verify that the idiom and light verb sentences we constructed would be treated by participants as having two rather than three event participants, we took a random subset of our prime sentences (8 idioms, 8 light verbs, and 8 compositional datives, 4 in each variant, as well as 4 transitive sentences and 4 intransitive sentences from our filler materials; see below) and conducted a norming task on Amazon Mechanical Turk. In this task, participants (N=40) were asked to identify, for each of 14 different sentences, how many people or objects were performing the action or being acted upon in the event described. The participants reported that our idiom and light verb sentences had approximately the same number of event participants as our transitive sentences (2.13 vs. 2.14 vs. 2.00, respectively),  $F(2, 51)=2.30, p=.11$ , but attributed fewer roles to the intransitive sentences (1.18),  $F(2, 59)=71.19, p<.001$ , and more to the compositional dative sentences (2.40),  $F(2, 39)=4.20, p=.02$ .

We also collected imageability ratings on all our prime sentences (including those for Exp. 2; see below) to address the concern that our results might be driven by concreteness or imageability instead of the hypothesized differences in semantic representation. Specifically, compositional datives might be better primes overall by virtue of being more concrete and therefore more imageable (e.g., Bock & Warren, 1985). For this task, we asked 217 native English speakers on Amazon Mechanical Turk, for

each of 7 different sentences, first to think about the event that the sentence described and then to rate on a scale from 1 to 7 how easy it was to imagine that event happening (1=not easy at all – I couldn't conjure an image of it, 7=very easy – I could readily conjure an image of it). For the materials in Exp. 1, participants rated compositional datives as most imageable (5.81), light verbs as intermediately imageable (5.39), and idioms as the least imageable (4.44). Below, we correlate these ratings with the average magnitude of priming across participants for each prime item.

Across participants, prime sentences were randomly paired with 14 target pictures. For the targets, we commissioned 14 pictures that showed ditransitive scenes of transparent actions of giving and receiving (=3 event participants). All pictures were black-and-white drawings, similar to Bock and Loebell's (1990) target pictures, and uniformly formatted to 640 × 480 pixels. (For a full list of all target pictures by experiment, see Appendix.)

To ensure that the target pictures were interpreted in the way we anticipated, we subjected them (including those for Exp. 2; see below) to a naming task (presented without the verb) on Amazon Mechanical Turk (N=30) prior to the experiment. Naming scores were calculated based on the percentage of respondents who produced a sentence that described the picture exactly, using the correct action, and accurately naming the participants in the action. The descriptions were coded as exact matches regardless of the syntactic form used—e.g., “The boy is giving the girl a letter” and “The girl gets a letter from the boy” were both coded as exact matches. Overall scores were 86%. All pictures were displayed with the desired verb *give*, and participants were instructed to use exactly the verb provided. Thus, for all critical trials, both the prime sentence and the target picture used the same verb. For each Prime Condition, participants saw either only compositional datives (14 primes, 14 targets) or equal numbers of idioms or light verbs (14 primes) and compositional datives (14 targets).

We used 42 filler sentences and 42 filler pictures. We repeated 28 each of the sentences and pictures, yielding a total of 70 filler sentences and 70 filler pictures, all randomly paired across participants. The 42 unique filler pictures depicted a variety of scenes, containing both animate and inanimate objects, and events as well as states. Similarly, the 42 unique filler sentences varied in length,



subcategorization frame, animacy of the participants, and event and state type; crucially, none were Compositionals, Lights, or Idioms, and they never used *give*. In total, each participant saw 84 sentences (including the 14 primes) and 84 pictures (including the 14 targets). Filler trials were interspersed randomly between critical pairs, with the constraint that the first four trials be filler trials and at least three but no more than five filler trials intervene between subsequent target trials.

### 2.1.3. Procedure

Exp. 1 was administered online via Amazon Mechanical Turk using psiTurk (Gureckis et al., 2016). Participants were asked to read each sentence out loud, and to give an accurate description of each picture using the verb provided, all while recording themselves with their microphones (Fig. 3). Participants were told to not use pronouns, to mention every depicted character, and to be as precise as possible.

In addition, to mask the true purpose of the experiment, participants were asked to perform a distractor memory task and indicate whether they had seen each item (sentence or picture) before or not by pressing the appropriate key (left arrow for no, right arrow for yes) on their keyboards. Only filler items were repeated (see above). A post-test questionnaire confirmed that none of the participants doubted the cover story, realized the true purpose of the experiment, or noticed the repeated use of *give*. The whole experiment took roughly 30 minutes on average.



**Figure 3.** Procedure and example materials for Exp. 1.

#### 2.1.4. Design

We used a  $3 \times 2$  mixed design, with Prime Construction (Compositional, Light, Idiom) as a between-subjects factor and Prime Form (DO, PO) as a within-subjects factor. We manipulated Prime Construction between subjects to keep the frequency of occurrence of the competing structures constant within individuals (either half Light or Idiom and half Compositional, or all Compositional) so as to equate for surprisal, differences in which are known to correlate with priming (e.g., Jaeger & Snider, 2008, 2013). The dependent measure was the number of DO sentences produced by participants (coded as 1, with POs coded as 0) out of all dative responses (DO+PO). In presenting the production cell means (for

descriptive purposes), we have aggregated over both participants and items (DO/DO+PO). Participants were randomly assigned to one of eight counterbalanced lists within each Prime Construction.

### *2.1.5. Coding*

Participants' recorded responses were coded as DO, PO, or Other. DOs were responses in which participants' post-verbal productions reflected the RECIPIENT-THEME ordering of canonical DO dative sentences, with neither argument occurring in a prepositional phrase. POs were responses in which participants' post-verbal productions reflected the THEME-to-RECIPIENT ordering of canonical PO dative sentences. All other forms were discarded from the analysis. In total, 2,368 of the 2,591 produced target descriptions (91.4%) were dative structures and thus entered into the analysis. Over ten percent of the target responses were independently coded by a second coder, with an intercoder reliability of 98.8% (Cohen's  $\kappa=.98$ ).

### *2.1.6. Data analysis*

We analyzed the data for Exp. 1 with a logistic mixed-effects model (Baayen, Davidson, & Bates, 2008; Jaeger, 2008) in the lme4 package in R (Bates, 2010), with Prime Construction (Compositional, Light, Idiom), Prime Form (DO, PO), and their interaction as fixed effects. Maximal random effects structure (Barr, Levy, Scheepers, & Tily, 2013) did not significantly improve model fit,  $\chi^2(2)=3.31$ ,  $p=.19$ , so only random intercepts for participant and item (target picture) were included in the final model.<sup>6</sup> All fixed effects were effect coded (1, -1). We performed forward model comparisons using likelihood-ratio tests (anova function in R) to determine the significance of our fixed effects. Table 1 summarizes the results of these comparisons. Follow-up analyses were run on the full model minus the relevant level of Prime Construction.

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<sup>6</sup> The maximal model that converged included random intercepts for both participant and item and a random slope for Prime Form within participants.

<b>Table 1.</b> Stepwise forward model comparisons for fixed effects in Exp. 1.				
<b>Fixed effect term</b>	<b>AIC (<math>\Delta</math>AIC)</b>	<b>Df (<math>\Delta</math>Df)</b>	<b><math>\chi^2</math></b>	<b><math>p=</math></b>
Base model: Random intercepts for participant and item	2736.2 (---)	3 (---)	---	---
+ Prime Form (PF)	2646.8 (-89.4)	4 (1)	91.37	<.001*
+ Prime Construction (PC)	2649.0 (+2.2)	6 (2)	1.82	.40
+ PF*PC	2641.4 (-7.6)	8 (2)	11.59	.003*
* Significant at the $p < .05$ level.				

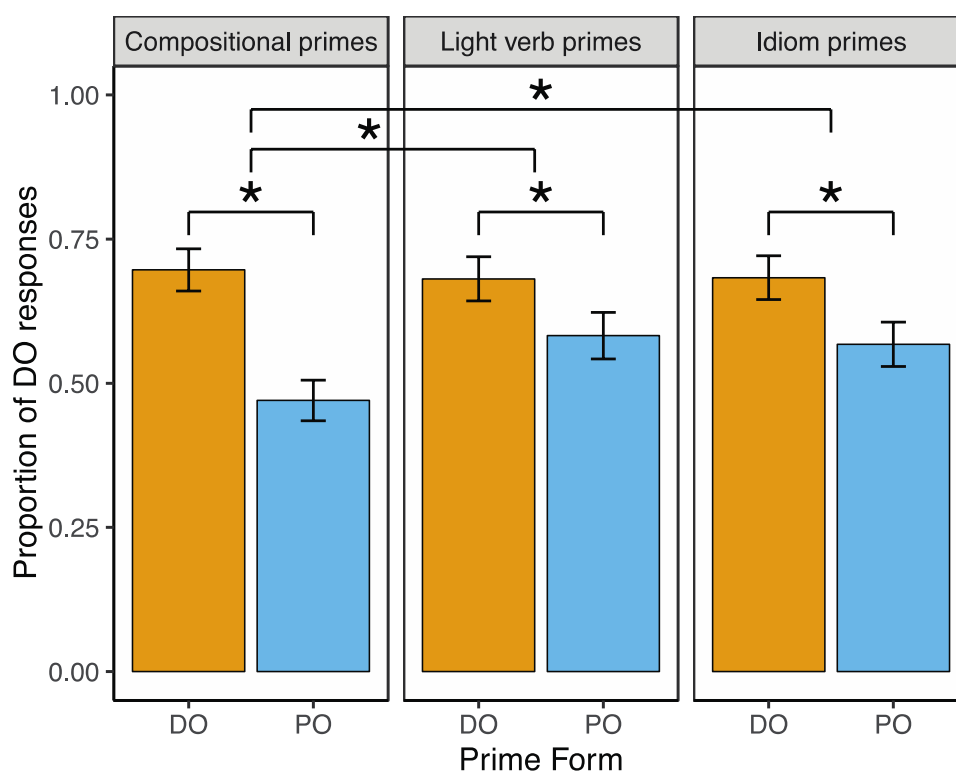
We calculated a Pearson's correlation between imageability and the magnitude of priming using `cor.test` in R.

## 2.2. Results

Accuracy on the distractor memory task was high (93.4%), with no differences by condition.

Fig. 4 shows the pattern of results for Exp. 1. The model comparisons revealed a significant main effect of Prime Form, such that DOs were produced significantly more often after DO primes than after PO primes (68-70% vs. 47-58%),  $\chi^2(1)=91.37$ ,  $p<.001$  (see Table 1). However, this was in the context of a significant Prime-Form-by-Prime-Construction interaction,  $\chi^2(2)=11.59$ ,  $p=.003$  (see Table 1). Follow-up pairwise models revealed that priming for Compositionals was significantly greater than that for both Lights (23% vs. 10%),  $\beta=.20$ (SE=.06),  $z=3.20$ ,  $p=.001$ , and Idioms (23% vs. 12%),  $\beta=.16$ (SE=.06),  $z=2.55$ ,  $p=.01$ , while there was no difference in priming between Lights and Idioms (10% vs. 12%),  $\beta=-.05$ (SE=.06),  $z=-.73$ ,  $p=.46$ . Each follow-up model also confirmed the main effect of Prime Form ( $ps<.001$ ). None of the models (full or otherwise) yielded a main effect of Prime Construction ( $ps\geq.22$ ).

We found no evidence for a correlation between imageability and the magnitude of priming,  $r=-.06$ ,  $t(82)=-.53$ ,  $p=.60$ , 95% CI [-.27, .16].



**Figure 4.** Overall proportion of double-object (DO) productions in Exp. 1 by Prime Form in the three Prime Constructions. Error bars reflect by-subject standard errors.

### 2.3. Discussion

The results of Exp. 1 confirm the existence of priming from idioms to compositional datives (Snider & Arnon, 2012) and establish priming from light verbs to compositional datives. More importantly, however, priming was significantly larger for compositional dative targets following compositional dative primes, relative to idiom and light verb primes. As discussed above, this boost has at least two possible explanations. It could, for instance, be due to the shared event structures among compositional datives, such that [X CAUSE [Z HAVE Y]] structures prime other [X CAUSE [Z HAVE Y]] structures and [X CAUSE [Y BE AT Z]] structures prime other [X CAUSE [Y BE AT Z]] structures, in line with the *event structures hypothesis*. Alternatively, the thematic mappings are also consistent across compositional dative primes and targets, such that recipient-to-direct-object and theme-to-second-object mappings in DO structures prime other such DO mappings, and vice versa for PO structures, consistent with the *thematic roles*

*hypothesis*. Idioms and light verbs, however, have neither the same event structures as compositional datives nor the same thematic mappings. Thus, on either hypothesis, we expect no increase to priming (above and beyond syntax alone) for idiom and light verb primes on compositional dative targets.

Importantly, the noted differences among priming conditions cannot be due to differences in surface syntactic structure, content- and function-word overlap, animacy, morphosyntactic marking, or information structure, as all three prime types were matched on these features.

Experiment 2 now asks what the basis for this semantic boost is. Here we fully cross light verbs and compositional datives ( $2 \times 2$ ): light verbs and compositional datives as primes for compositional dative targets, and light verbs and compositional datives as primes for light verb targets. We focus on light verbs because idioms are difficult to elicit via picture description. However, because light verbs and idioms had the same pattern of results in Exp. 1, we expect the results for light verbs in Exp. 2 to generalize to idioms as well. Using a fully-crossed design also equates the frequency of occurrence of the competing structures (and thereby surprisal; e.g., Jaeger & Snider, 2008, 2013), allowing us to shift to a within-subjects design for better comparison with past work. Finally, we collect data in the lab for Exp. 2 to confirm our findings from Exp. 1 and further validate online marketplaces as a reliable source of production priming data (see also Ziegler & Snedeker, 2018).

For compositional dative targets, we expect to replicate the pattern of results in Exp. 1: more priming from compositional dative primes than from light verb primes. For light verb targets, we expect to find measurable priming from both construction types, on the basis of syntax alone. Our critical question is whether the magnitude of priming will differ depending on whether the prime is a light verb or compositional dative. On the *thematic roles hypothesis*, we expect light verbs to be more effective in priming light verb targets than compositional dative primes, because the mapping of thematic roles onto surface syntax will be shared between prime and target. We expect no boost to priming for light verb primes on the light verb targets under the *event structures hypothesis*, however, because both syntactic realizations have the same event structure, making the DO and PO primes (and targets) equivalent in this respect (Fig. 2).

### 3. Experiment 2

#### 3.1. Methods

##### 3.1.1. Participants

64 native English speakers recruited from Harvard University participated in the experiment (42 female, 22 male; mean age=21[SD=6], range=18-49). All participants provided written consent prior to participating and received course credit for their participation.

##### 3.1.2. Materials

The study consisted of 40 critical trials interspersed with 100 filler sentence trials and 75 filler picture trials, for a total of 215 trials. As in Exp. 1, all critical trials included a sequence of one prime sentence, presented as text to be read out loud, followed by a target picture, to be described; filler trials consisted of either a sentence or a picture. For each Prime Construction, we constructed 20 prime sentences (including 9 Compositional primes and 8 Light primes from Exp. 1), all with *give* as their main verb, in both DO and PO variants. (For a full list of all prime sentences by experiment, see Appendix.) As before, prime sentences were normed for acceptability on Amazon Mechanical Turk (see Exp. 1 for details). We then matched Compositional and Light sentences, such that each sentence had a rating of 2.6 or higher in across DO and PO forms. On average, DO Compositional sentences had a rating of 3.56, while PO Compositional sentences had a rating of 3.57,  $F(1, 38)=.06$ ,  $p=.81$ ; and DO Light sentences had a rating of 3.35, while PO Light sentences had a rating of 3.38,  $F(1, 38)=.10$ ,  $p=.75$ . There was a significant but small difference by Prime Construction (0.20),  $F(1, 76)=21.08$ ,  $p<.001$ , but not by Prime Form,  $F(1, 76)=.16$ ,  $p=.69$ , and no significant interaction,  $F(1, 76)=.03$ ,  $p=.87$ . In terms of imageability (see Exp. 1 for details), compositional datives were rated as more imageable (6.14) and light verbs as less imageable (5.22).

Target pictures depicted 20 ditransitive scenes (including the 14 from Exp. 1) and 20 transitive (agent-patient) scenes that could be described with a light verb. (For a full list of all target pictures by

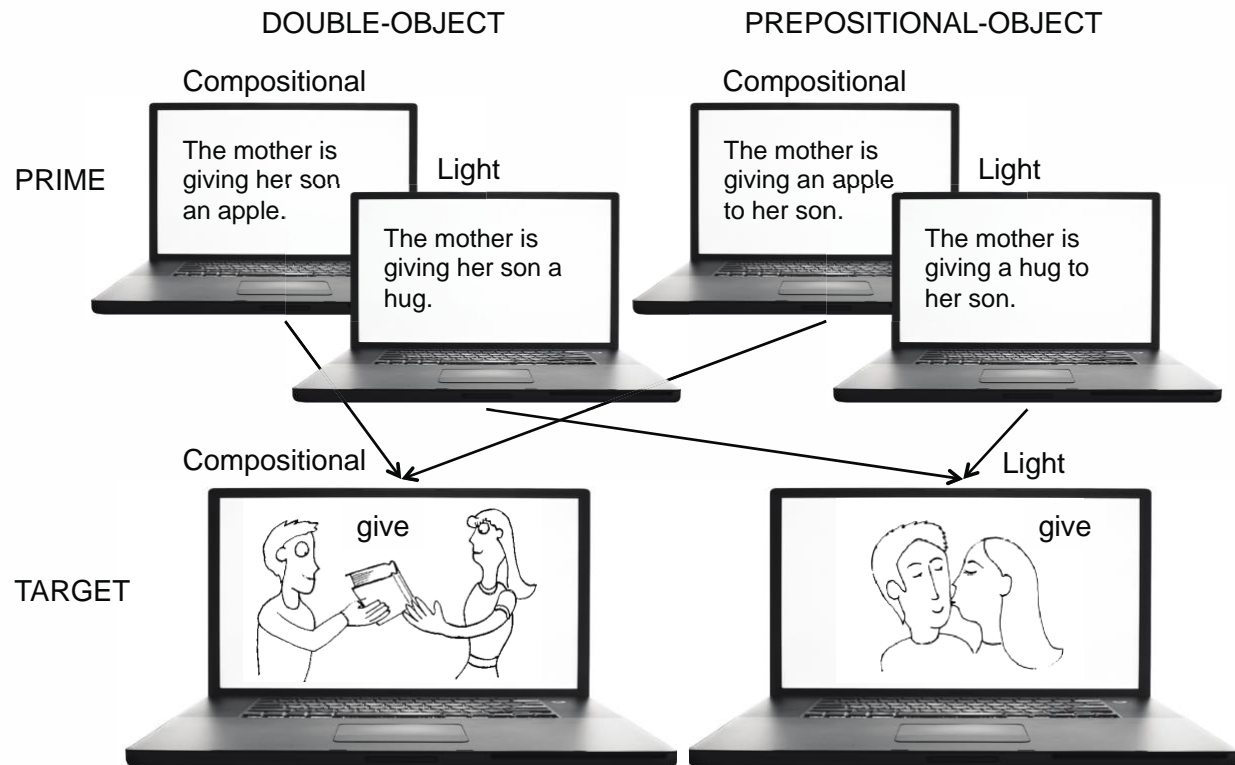
experiment, see Appendix.) Picture norming results (see Exp. 1 for details) did not differ significantly between the two picture types (83% for Compositional vs. 90% for Light),  $F(1, 38)=2.55, p=.12$ . Each prime sentence was matched up with two pictures, one ditransitive transfer scene and one agent-patient scene. As before, all pictures were displayed with the desired verb *give*, and participants were instructed to use exactly the verb provided. Participants saw equal numbers of light verbs (20 primes, 20 targets) and compositional datives (20 primes, 20 targets).

We used the same filler materials from Exp. 1, with an additional 30 sentences and 5 pictures, constructed under the same constraints. As before, 35 of the 65 filler sentences and 22 of the 53 filler pictures in Exp. 2 were repeated over the course of the experiment. Thus, each participant saw a total of 140 sentences (including the 40 primes) and 115 pictures (including the 40 targets). Filler trials were interspersed randomly between critical pairs.

### 3.1.3. Procedure

Exp. 2 was administered in the lab using E-Prime (Psychology Software Tools, Pittsburgh, PA). Participants were asked to read each sentence out loud, and to give an accurate description of each picture using the verb provided, all while being recorded with a digital microphone (Fig. 5). Participants were told to not use pronouns, to mention every depicted character, and to be as precise as possible. As before, participants performed a distractor memory task for the purpose of masking the true intentions of the experiment. Only filler items were repeated (see above). Responses to critical trials were live-coded by the experimenter, who sat in a chair behind the participant; responses to the distractor memory task were recorded by E-Prime. A post-test questionnaire confirmed that none of the participants doubted the cover story, realized the true purpose of the experiment, or noticed the repeated use of *give*. The whole experiment lasted approximately one hour.





**Figure 5.** Procedure and example materials for Exp. 2.

### 3.1.4. Design

We used a  $2 \times 2 \times 2$  design, with Prime Construction (Compositional, Light), Target Construction (Compositional, Light), and Prime Form (DO, PO) all as within-subjects factors. We were able to manipulate all factors within subjects due to our materials being fully balanced between conditions. The dependent measure was the number of DO sentences produced by participants (coded as 1, with POs coded as 0) out of all dative responses (DO+PO). In presenting the production cell means (for descriptive purposes), we have aggregated over both participants and items (DO/DO+PO). Participants were randomly assigned to one of eight counterbalanced lists.

### 3.1.5. Coding

Participants' recorded responses were coded as in Exp. 1. In total, 2,346 of the 2,560 produced target descriptions (91.6%) were dative structures and thus entered into the analysis. Ten percent of the target

responses were independently coded by a second coder, with an intercoder reliability of 96.4% (Cohen's  $\kappa=.91$ ).

### 3.1.6. Data analysis

We analyzed the data for Exp. 2 with a logistic mixed-effects model in the lme4 package in R, with Prime Construction (Compositional, Light), Target Construction (Compositional, Light), Prime Form (DO, PO), and their interactions as fixed effects. As in Exp. 1, maximal random effects structure did not significantly improve model fit,  $\chi^2(18)=18.77$ ,  $p=.41$ , so only random intercepts for participant and item (target picture) were included in the final model.<sup>7</sup> All fixed effects were effect coded (1, -1). We performed forward model comparisons using likelihood-ratio tests (anova function in R) to determine the significance of our fixed effects. Table 2 summarizes the results of these comparisons. Follow-up analyses were run on the full model within each level of Target Construction.

As in Exp. 1, we calculated a Pearson's correlation between imageability and the magnitude of priming using cor.test in R.

<b>Table 2.</b> Stepwise forward model comparisons for fixed effects in Exp. 2.				
<b>Fixed effect term</b>	<b>AIC (<math>\Delta</math>AIC)</b>	<b>Df (<math>\Delta</math>Df)</b>	<b><math>\chi^2</math></b>	<b><math>p=</math></b>
Base model: Random intercepts for participant and item	2525.0 (---)	3 (---)	---	---
+ Target Construction (TC)	2516.4 (-8.6)	4 (1)	10.63	.001*
+ Prime Form (PF)	2312.1 (-204.3)	5 (1)	206.33	<.001*
+ Prime Construction (PC)	2313.9 (+1.8)	6 (1)	.16	.69
+ TC*PF	2315.5 (+1.5)	7 (1)	.46	.50

<sup>7</sup> The maximal model that converged included random intercepts for both participant and item, random slopes for Prime Construction, Target Construction, and Prime Form within participants, and random slopes for Prime Construction, Prime Form, and their interaction within items.

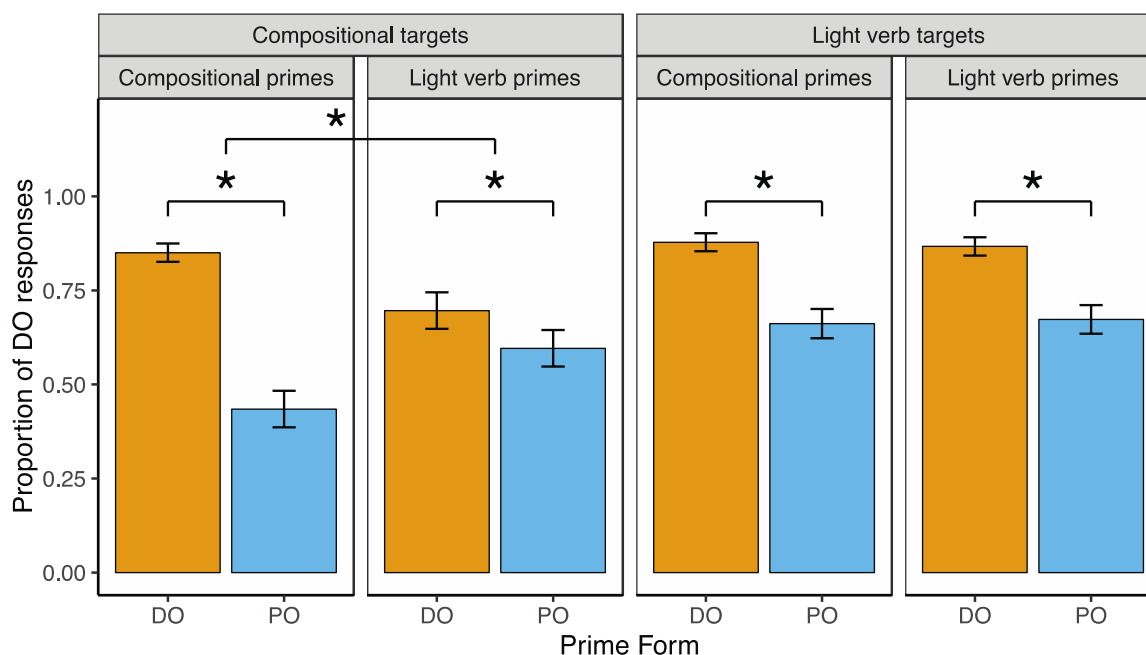
+ TC*PC	2317.5 (+2.0)	8 (1)	.0004	.98
+ PF*PC	2309.3 (-8.2)	9 (1)	10.19	.001*
+ TC*PF*PC	2304.9 (-4.3)	10 (1)	6.32	.01*
* Significant at the $p < .05$ level.				

### 3.2. Results

Accuracy on the distractor memory task was very high (99.8%), with no differences by condition.

Fig. 6 shows the pattern of results for Exp. 2. The model comparisons revealed a significant main effect of Prime Form, such that DOs were produced significantly more often after DO primes than after PO primes (70-88% vs. 43-67%),  $\chi^2(1)=206.33$ ,  $p<.001$  (see Table 2). However, this was in the context of a significant Prime-Form-by-Prime-Construction interaction,  $\chi^2(1)=10.19$ ,  $p=.001$  (see Table 2). Follow-up models revealed that Compositional primes led to significantly greater priming than Light primes for Compositional targets (42% vs. 10%),  $\beta=.50$ (SE=.17),  $z=3.02$ ,  $p=.003$ , but not for Light targets (22% vs. 19%),  $\beta=.08$ (SE=.09),  $z=.96$ ,  $p=.34$ . We also found a main effect of Target Construction, such that participants produced fewer overall DOs for Compositional targets than for Light targets (64% vs. 77%),  $\chi^2(1)=10.63$ ,  $p=.001$  (see Table 2). Finally, there was a significant three-way interaction,  $\chi^2(1)=6.32$ ,  $p=.01$  (see Table 2). Each follow-up model also confirmed the main effect of Prime Form ( $ps<.001$ ), but not the main effect of Target Construction ( $ps>.53$ ).

There was no evidence for a correlation between imageability and the magnitude of priming,  $r=.06$ ,  $t(78)=.55$ ,  $p=.58$ , 95% CI [-.16, .28].



**Figure 6.** Overall proportion of double-object (DO) productions in Exp. 2 by Prime Form as a function of Prime Construction and Target Construction. Error bars reflect by-subject standard errors.

### 3.3. Discussion

These results verify and extend our findings in Exp. 1. Specifically, we again see that compositional datives are better primes for other compositional datives than are light verb primes, consistent with either the *thematic roles hypothesis* or *event structures hypothesis*. Importantly, however, light verb primes are no better at priming light verb targets than are compositional dative primes, which was predicted by the *event structures hypothesis* only. Thus, these data suggest that semantic structural priming is subserved not by mappings of thematic roles onto surface syntax, but instead by event structures, which are different for the two variants of the dative alternation (and thus contribute to priming) but not for the two syntactic realizations of light verbs.

## 4. General Discussion

The present study investigates the locus of semantic structural priming to shed light on the nature of the semantic representations that underlie argument realization during language production. We entertained two hypotheses. On to the *thematic roles hypothesis*, semantic structural priming results from the priming

of the mappings of thematic roles onto surface syntactic functions. On the *event structures hypothesis*, semantic structural priming results from the priming of distinct configurations of embedded verbal sub-predicates. Across two experiments, we found priming from idioms, light verbs, and compositional datives to other compositional datives and from light verbs and compositional datives to other light verbs. Importantly, though, only when the event structures across prime and target were consistent *and* different for the two possible syntactic realizations (compositional-dative-to-compositional-dative priming) did we find a boost to priming (Exps. 1 and 2). We found no additional boost to priming in the comparable light-verb-to-light-verb case (Exp. 2). Critically, the DO and PO forms of light verbs arise from a single event structure, even though they have different thematic role mappings. Thus, the absence of a priming boost in this condition (and the presence of the boost for compositional datives) strongly supports the *event structures hypothesis*. Our results cannot be accounted for by traditional atomic thematic role list approaches to argument realization (e.g., Baker, 1988, 1997; Fillmore, 1968; Gruber, 1965; Jackendoff, 1972) but instead support event structures (e.g., Goldberg, 1995; Jackendoff, 1990, 2002; Pinker, 1989; Rappaport Hovav & Levin, 1998, 2011; Rappaport & Levin, 1988; for review, see Levin & Rappaport Hovav, 2005).

One important feature of the present study is the degree of control our design afforded us in ruling out other possible contributors to the priming differences we saw. Specifically, because the idioms, light verbs, and compositional datives we used all have the same surface syntax, content- and function-word overlap, animacy features, morphosyntactic marking, and information structure, these factors cannot explain our results. Nor can our results be due to differences in the imageability of our prime stimuli (e.g., Bock & Warren, 1985), since we found no evidence for a correlation between the imageability ratings that we collected on our prime sentence materials and the magnitude of priming in either experiment.

A final key feature of the present study is the relatively large sample size of each of our experiments, and particularly our Exp. 1. Most priming studies to date have been underpowered (Mahowald et al., 2016). We have shown that the basic production priming effects can be reliably and

robustly elicited online (see also Ziegler & Snedeker, 2018), thereby allowing us to recruit hundreds rather than tens of subjects, increasing the power we have to detect differences in priming considerably.

In the remainder of this discussion, we consider how our results bear on the existing priming data, shedding new light on an old but puzzling result in the priming literature (i.e., Bock & Loebell, 1990). We then turn to discussion of event structures as a viable theory of semantic representation, before closing with a brief note on the implications of our results for the semantic representation of light verbs in particular.

#### *4.1. Relation to verb sense priming*

Our design was very similar to that used in Bernolet et al. (2014), which investigated the representation of polysemous verbs. In their first experiment, Bernolet et al. (2014) found that concrete transfer-of-possession datives (our compositional datives) primed other concrete datives better than did datives with more abstract senses (parallel to our idioms and light verbs). Our hypothesis fully explains this finding. However, our hypothesis does not explain the marginal interaction they observed in their third experiment ( $p=.054$ ), which would suggest that abstract datives prime other abstract datives better than concrete datives do. In our own Exp. 2, we found no evidence for more priming within light verbs than from light verbs to compositional datives. Critically, however, our light verb materials were more varied in their verb senses (e.g., “give a kiss” is a contact event, while “give a compliment” is an utterance event) than our compositional datives, which all instantiated the concrete transfer-of-possession sense. Thus, it is possible that our primes and targets within the light verb conditions were not actually matched on verb sense, and this could be why we observed less priming overall.

To address this hypothesis, we did the following. First, we classified our light verb primes and targets in Exp. 2 using the verb sense classification scheme in Bernolet et al. (2014). Then, we determined which of these pairings shared a consistent verb sense between prime and target (e.g., both the “direct at” sense, such as “give an answer” and “give an order”) and which did not (e.g., one the “direct at” sense and the other the “cause an effect” sense, such as “give a bribe” and “give a haircut,” respectively). If we were

unable to make this determination on the basis of the senses provided, we erred on the side of conservatism and treated such pairings as non-matching. This yielded an even division in terms of numbers of pairings that matched vs. those that mismatched (50-50 split). Finally, we ran a post hoc model on light verb primes and targets only, with Prime Form (DO, PO), this new Sense Overlap factor (Yes, No), and their interaction as fixed effects, and the same random effects structure as before. Importantly, we found no evidence for greater priming among light verbs with shared senses (17% priming) than among those with different senses (23% priming), interaction  $p=.59$ .<sup>8</sup> Thus, our results cannot be explained by the hypothesis that priming is greater within verb senses (shared lemma representations) and weaker across verb senses (separate lemma representations). Instead, they support our original interpretation given above: Priming is greater from compositional dative primes to compositional dative targets but not from light verb primes to light verb targets. This is consistent with the *event structures hypothesis*. Future work should manipulate verb sense similarity within light verbs to more directly address this concern.

We must now ask how we can reconcile our findings with Bernolet et al. (2014). First, we note that the boost to priming they found within their abstract datives was only marginal ( $p=.054$ ). Thus, it remains to be seen whether this effect is robust and replicable. Second, the author's *verb sense hypothesis* fails to explain a salient feature of their own data: namely, that the boost within concrete datives was greater than that within abstract datives (13.5% vs. 7%). We do not know whether this interaction is reliable, but it looks as large as the interaction they observed within their abstract datives (i.e., 7% boost). At face value, this is the exact pattern of results we would have expected on the *event structures hypothesis*, and one that the *verb sense hypothesis* cannot explain. In sum, the full range of data presented here and in Bernolet et al. (2014) can be explained either by the *event structures hypothesis* alone or by a

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<sup>8</sup>  $\beta=-.07$ (SE=.13),  $z=-.54$ ,  $p=.59$ . We get the same results if we instead classify our light verbs according to the categories of event nominals they combine with (e.g., Wittenberg et al., 2014): 21% priming across shared categories vs. 19% priming across different categories,  $\beta=-.04$ (SE=.13),  $z=-.34$ ,  $p=.74$ .

combination of the *event structures hypothesis* and the *verb sense hypothesis*, but it cannot be accounted for by the *verb sense hypothesis* alone.

#### *4.2. Mechanisms of priming and the lexical boost*

To achieve the level of experimental control we did, we had to repeat the verb from prime to target. Many researchers have noted that priming is typically greater when the verb is held constant (i.e., “lexical boost”; Pickering & Branigan, 1998), though the mechanisms by which they explain this vary (e.g., Chang et al., 2006; Jaeger & Snider, 2013; Pickering & Branigan, 1998). Our findings do not speak to this debate and they cannot be explained away by the mechanisms that have been argued to account for the lexical boost. In all conditions, the prime and the target used the same verb (*give*). Thus, any contribution this made to priming was shared between the compositional datives, the light verbs, and the idioms. Our critical finding is that priming varies across these construction types: It is greater when the prime and target are both compositional, consistent with the *event structures hypothesis*. In other words, we may have inflated the syntactic component of priming with verb overlap, but we could not have created the event structure priming in this way. Nevertheless, we recognize that using a single verb does, to some extent, limit the generality of our claims. Although we expect the same pattern of results to hold if we were to use a variety of light verbs to explore between-verb priming, it is in fact an empirical question. But this would require that we abandon the dative alternation for an alternation that permits a wider range of verbs (e.g., active-passive). We leave this to future research.

#### *4.3. Alternative thematic role hypotheses*

In the present work, we tackled a thematic role hypothesis in which the locus of priming was the mappings of thematic roles onto surface syntactic functions (e.g., Cai et al., 2012; Salamoura & Williams, 2007; see also Hartsuiker & Kolk, 1998-b; Shin & Christianson, 2009). On this hypothesis, for example, DO light verbs prime other DO light verbs on the basis of a shared mapping of patient to direct object. This hypothesis predicts that light verbs should be primed more by other light verbs than by



compositional datives (where it is a recipient that appears as the direct object of the DO form). Thus, our data are inconsistent with this hypothesis. Importantly, our data also rule out a related account in which thematic roles map onto phrasal constituents (e.g., patient to NP vs. PP) rather than syntactic functions (for discussion, see Köhne et al., 2014).

However, there are other ways of operationalizing the mapping of thematic roles onto surface syntax. Table 3 summarizes four possibilities, two of which were mentioned above. The third possibility is that there's priming of the mappings between thematic roles and the linear positions of noun phrases (e.g., *Bert<sub>1</sub> gives Ernie<sub>2</sub> a hug<sub>3</sub>* vs. *Bert<sub>1</sub> gives a hug<sub>2</sub> to Ernie<sub>3</sub>*; Köhne et al., 2014; see also Pappert & Pechmann, 2014). So long as the event nominal of a light verb sentence (i.e., *hug*) counts as a noun phrase (for discussion, see Wittenberg et al., 2014), this hypothesis makes the same predictions as the one we initially considered: In a DO light verb, the patient role is mapped to the second noun phrase, while in a PO light verb, it is mapped to the third noun phrase.

<b>Table 3.</b> Alternative thematic role hypotheses.					
<b>DO light verb</b>	<b>Bert (Agent)</b>	<b>gives</b>	<b>Ernie (Patient)</b>	<b>a hug (Co-event)</b>	<b>Primes DO?</b>
Thematic roles to syntactic functions	Subject		Direct object	Second object	Yes
Thematic roles to syntactic constituents	NP		NP	NP	Yes
Thematic roles to absolute linear order of NPs	NP <sub>1</sub>		NP <sub>2</sub>	NP <sub>3</sub>	Yes
Thematic roles to relative linear order of NPs	NP <sub>1</sub>		NP <sub>2</sub>	--	Yes
<b>PO light verb</b>	<b>Bert (Agent)</b>	<b>gives</b>	<b>a hug (Co-event)</b>	<b>to Ernie (Patient)</b>	<b>Primes DO?</b>
Thematic roles to syntactic functions	Subject		Direct object	Oblique object	No
Thematic roles to syntactic constituents	NP		NP	PP	No
Thematic roles to absolute linear order of NPs	NP <sub>1</sub>		NP <sub>2</sub>	NP <sub>3</sub>	No
Thematic roles to relative linear order of NPs	NP <sub>1</sub>		--	NP <sub>2</sub>	Yes

There is, however, one thematic mapping hypothesis which makes a different prediction (row 4 of Table 3). Suppose that priming is based on the mapping of thematic roles onto *relative* linear order (e.g., Cai et al., 2012), such that the event nominal in a light verb sentence plays no role in the representation of these mappings. If this were the case, then DO and PO light verbs would have the same mappings (e.g., *Bert<sub>1</sub> gives Ernie<sub>2</sub> a hug* vs. *Bert<sub>1</sub> gives a hug to Ernie<sub>2</sub>*). Consequently, thematic role mappings wouldn't differentially contribute to priming of the DO vs. PO form for light verbs, and we would expect no boost for light-verb-to-light-verb priming. This makes the same predictions as our *event structures hypothesis*.

However, this version of the thematic roles hypothesis is inconsistent with other data in the literature (e.g., Bock & Loebell, 1990; Messenger et al., 2012; Shin & Christianson, 2009; Ziegler et al., 2018). For example, in Korean, PO datives canonically order their recipients before their themes (e.g., *Mary-NOM John-to book-ACC gave* "Mary gave a book to John"). This ordering parallels the absolute thematic role ordering of DO datives in both languages. If speakers are guided by the order of thematic roles, Korean-English bilinguals should be equally likely to produce English DO datives following Korean PO datives as following Korean DO datives. However, Shin and Christianson (2009) instead observed more English PO datives following Korean PO datives than following Korean DO datives. This finding is thus at odds with both linear order hypotheses (rows 3 and 4 of Table 3), but it *is* consistent with priming of the shared event structures between PO datives across the two languages.<sup>9</sup> Note also that neither linear order hypothesis can account for the priming pattern of passives, which we discuss below.

A final hypothesis one might have considered is one in which priming acts on the assignment of focus to particular thematic roles (Bernolet et al., 2009; Fleischer, Pickering, & McLean, 2012; Heydel & Murray, 2000; Vernice et al., 2012).<sup>10</sup> Vernice et al. (2012) found that Dutch participants were more

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<sup>9</sup> Shin and Christianson (2009) interpret these findings as evidence that syntactic structure can prime across languages independent of argument ordering: Korean POs prime English POs because they both have one NP and one PP (post-verbally), while Korean DOs prime English DOs because they both have two NPs. However, this interpretation is inconsistent with the German results of Pappert and Pechmann (2014, especially Exp. 3), in which they found no increased priming for NP-NP primes on NP-NP targets relative to NP-PP primes (independent of ordering). Instead, these data are more compatible with priming at the level of event structure.

<sup>10</sup> Called "thematic emphasis" in the structural priming literature (for discussion, see Bernolet et al., 2009; Vernice et al., 2012).

likely to produce a passive sentence (e.g., *De jongen wordt geraakt door de bal* “The boy is hit by the ball”), which puts focus on the patient subject, after a cleft sentence that emphasized the patient (e.g., *Degene die hij slaat is de cowboy* “The one who he is hitting is the cowboy”) than after a cleft sentence that instead emphasized the agent (e.g., *Degene die hem slaat is de cowboy* “The one who is hitting him is the cowboy”), despite differences in surface word order and thematic mappings. Importantly, however, our stimuli were all matched for information status across conditions. Following standard information structure assignment, sentences are typically ordered with presupposed, or given, information first and focused, or new, information last (e.g., Chomsky, 1970; Gundel, 1988). This puts (relative) focus on the theme argument in a DO sentence and on the recipient argument in a PO sentence. Evidence comes from the observation that DO datives in particular do not allow pronouns, which necessary encode given information, as themes (e.g., \**“The customer handed the cashier it”*) but do allow them as recipients (e.g., *“The customer handed her the money”*; Collins, 1995; see also Arnold, Wasow, Losongco, & Ginstrom, 2000; Bresnan, Cueni, Nikitini, & Baayen, 2007). Crucially, this was true for our compositional datives as well as our idioms and light verbs, so that participants should have been no more likely to persevere on this mapping within compositional datives as within light verbs (or between compositional datives and light verbs). Thus, the differences we see in priming across conditions cannot be attributed to the priming of information structure.

#### *4.4. Reconciling the present findings with the priming behavior of passives*

In a seminal study, Bock and Loebell (1990, Exp. 2) found that priming for passives was just as great after intransitive sentences with locative prepositional phrases (“The construction worker was digging by the bulldozer”) as it was after true passives (“The construction worker was hit by the bulldozer”). The oblique object (i.e., *bulldozer*) in the intransitive sentence is a location, but it is an agent in the passive sentence. The thematic structure of these two constructions didn’t contribute to priming, either by enhancing or diminishing it. This led Bock and Loebell (1990) to conclude that priming is situated at the level of abstract phrase structure independent of differences in thematic roles.

This finding is at odds with a rich set of data showing that semantic structure *can* contribute to priming (e.g., Cai et al., 2012; Chang et al., 2003; Cho-Reyes et al., 2016; Griffin & Weinstein-Tull, 2003; Hare & Goldberg, 1999; Köhne et al., 2014; Pappert & Pechmann, 2014; Salamoura & Williams, 2007; Yi & Koenig, 2016; Ziegler & Snedeker, 2018). However, the two sets of results are easily reconcilable if we distinguish between thematic roles and event structures. The active-passive alternation is typically considered to result from a single semantic representation rather than two (Baker, 1988; Bresnan, 1978, 1982; Chomsky, 1957, 1965; Katz & Postal, 1964; for discussion, see Culicover & Jackendoff, 2005; Levin & Rappaport Hovav, 2005; though cf. Pinker, 1989). Accordingly, since the same event structure underlies both syntactic realizations, the event structure of the prime cannot bias the listener to produce either the active or the passive structure. Thus, the *event structures hypothesis* predicts no boost to priming in Bock and Loebell (1990; see also Messenger et al., 2012; Ziegler et al., 2018), as observed.<sup>11</sup> If semantic structural priming were instead the result of the mappings of thematic roles onto surface syntactic functions (or to absolute or relative linear noun phrase order), then priming from passives to other passives should have yielded greater priming on the basis of both shared phrase structure *and* thematic structure, whereas priming from intransitives to passives should have been carried only by the shared phrase structure alone. Bock and Loebell's (1990) results are thus consistent with our finding of priming on the basis of event structures but not thematic roles. In the alternations where semantic structural priming is observed, such as the locatives and datives, the two forms are typically interpreted as arising from different event structures.

#### 4.5. Event structure as a theory of semantic representation

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<sup>11</sup> Weber and Indefrey (2009) observed cross-linguistic passive priming from German to English, despite differences in surface phrase structure between the two languages (cf. Loebell & Bock, 2003). However, this particular finding is ambiguous: Priming in this case *could* be due to thematic roles, but it could also be due to perseveration in the mappings of animacy onto syntactic positions (e.g., Bock et al., 1992; Gámez & Vasilyeva, 2015; Ziegler & Snedeker, 2018).

Event structural approaches to semantic representation have been around in modern theorizing nearly as long as thematic role theories themselves (e.g., Jackendoff, 1976; for review, see Levin & Rappaport Hovav, 2005). In most cases, the two types of theories are isomorphic in their predictions; that is, event structures were designed to capture the same patterns of data as thematic roles, and in the vast majority of cases the two approaches lead to the same results. This has two main consequences. First, researchers familiar with thematic role terminology can easily adopt event structures without sacrificing their intuitions about the kinds of phenomena thematic roles are meant to explain. Second, this makes deciding between the two theories relatively more challenging. Indeed, as we saw, compositional dative priming is captured equally well by both theories.

Yet, there are also clear cases where the predictions pull apart, as in our light verbs (and idioms). Our data clearly favor event structures for capturing the full range of semantic structural effects in priming. However, there are deeper theoretical reasons for preferring event structures as well. For instance, thematic roles are notoriously hard to define; it's often not clear what constitutes a theme or patient, for instance, or how the two roles should be distinguished (for discussion, see Dowty, 1991; Levin & Rappaport Hovav, 2005). Event structural approaches instead capture generalizations over arguments (and make distinctions thereof) on the basis of their well-defined positions within the structure: arguments of a CAUSE predicate vs. arguments of an ACT predicate, etc. Even worse, thematic role approaches are incapable of capturing the differences in meaning associated with alternations that in principle have the same event participants, such as those that form the basis of this paper (datives). To illustrate, consider again the locative sentences from Chang et al. (2003) in (1).

- (1) a. The maid rubbed the table with polish.
- b. The maid rubbed polish onto the table.

Despite having the same thematic roles (agents, themes, locations), these two sentences in fact express slightly different meanings: If someone rubs the table with polish, the entire table is understood as being covered in polish, whereas rubbing polish on the table doesn't trigger the same entailment (Anderson,

1971; Levin & Rappaport Hovav, 2005; Pinker, 1989; Rappaport & Levin, 1988). Accordingly, as Anderson (1971, adapted from p. 389) points out, (2a) is a contradiction, but (2b) is not.

- (2) a. The maid rubbed the table with polish, but most of the table didn't get any polish on it.
- b. The maid rubbed polish onto the table, but most of the table didn't get any polish on it.

Event structures capture these differences in meaning quite naturally via the sub-predicate structures that comprise them (e.g., [[X CAUSE [Z BE IN STATE]] WITH Y] vs. [X CAUSE [Y BE AT Z]]; for additional arguments in favor of event structures and against thematic roles, see Gropen, Pinker, Hollander, & Goldberg, 1991; Levin & Rappaport Hovav, 2005).

#### *4.6. Consequences for the semantic representation of light verbs*

Lastly, our results also have implications for the semantic representation of light verbs. Like idioms, light verbs are characterized by non-canonical mappings between syntax and semantics: In the cases discussed here, three syntactic arguments map to two semantic arguments (Wittenberg & Snedeker, 2014; Wittenberg et al., 2014, 2017). However, unlike idioms, light verbs have also been proposed to participate in argument sharing: In addition to being associated with the two event participants of typical agent-patient verbs, light verbs may also inherit the dative event structure from the main verb itself (e.g., Jackendoff, 1974; Wittenberg et al., 2014). This type of account accords well with existing data showing that participants treat light verbs differently from compositional datives (Wittenberg et al., 2014), and typically as intermediate between compositional datives and canonical agent-patient verbs (Wittenberg & Snedeker, 2014; Wittenberg et al., 2017). For example, Wittenberg and Snedeker (2014; see also Wittenberg et al., 2017) found that participants treated light verbs as having three rather than two event participants at least some of the time (23%), although the overwhelming majority of cases were treated as two-participant events (75%).<sup>12</sup> However, in our Exp. 1, we found no difference between idioms and light

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<sup>12</sup> If participants sometimes construe light verb sentences as describing transfer events, then this should result in some degree of semantic structural priming from light verbs to compositional datives. Such an effect would have only increased priming from light verbs to compositional datives in the current study rather than diminishing it. This would have *decreased* the likelihood that we would find a difference between these conditions. The fact that we did

verbs in their effectiveness as primes for compositional dative targets; if anything, idioms were slightly better primes than light verbs. This suggests that the primary (perhaps only) event structure that structural priming is drawing on for light verbs is, like for idioms, the agent-patient one.

## 5. Conclusion

Priming is clearly a powerful means for studying linguistic representation (e.g., Branigan & Pickering, 2017). As the field has grown, evidence has mounted that priming can occur at multiple levels (syntactic, semantic, lexical, conceptual, information structural; e.g., Bock & Loebell, 1990; Bock et al., 1992; Chang et al., 2003; Pickering & Branigan, 1998; Vernice et al., 2012; Ziegler & Snedeker, 2018; for reviews, see Branigan & Pickering, 2017; Pickering & Ferreira, 2008). Here we have used structural priming to ask about the semantic representations involved in language production, favoring event structures to thematic roles. These results contribute to a growing body of research revealing the influence of abstract event components on language (e.g., Bunger, Papafragou, & Trueswell, 2013; Goldwater, Tomlinson, Echols, & Love, 2011; Raffray, Pickering, Cai, & Branigan, 2014; Zhao & Hu, 2018). Crucially, our findings cannot be due to surface phrase structure, content- or function-word overlap, animacy cues, morphosyntactic marking, or information structure, which were all equated in the current study. Nor are they reducible to differences in imageability. Since many levels can be primed at once, we as researchers need to take great care in constructing our contrasts if we wish to isolate a single level of linguistic representation (see Ziegler et al., 2017). The present study is one small but important step in that direction.

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find a difference supports the *event structures hypothesis*, though we cannot definitively rule out the possibility that this difference is only driven by a subset of the trials (the 75% from Wittenberg & Snedeker, 2014).

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Appendix. Supplementary material.

The materials, data, and analysis scripts associated with this article can be found at

<https://doi.org/10.17605/OSF.IO/ZX6WV>.