The building blocks of meaning: Psycholinguistic evidence on the nature of verb argument structure

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Abstract

This thesis is an experimental investigation of the semantic representations that underlie natural language syntax. Theories of semantic representation categorize the nouns in a sentence according to the roles they play in the event. For example, Sally is an agent in *Sally broke the cup*, while the cup is a patient, or undergoer of that action. We call these categories semantic (or thematic) roles. The earliest theories of semantic roles treat them as standalone units that have no internal structure. On these theories, the roles are in a ranked list (prominence hierarchy) that determines their syntactic expression. In *Sally broke the cup*, agents are assumed to be more prominent than patients, making the agent the subject and the patient the object. Contemporary approaches instead decompose verbs into smaller units (ACT, BECOME, CAUSE, HAVE, etc.) that are embedded within one another hierarchically, forming event structures. On these theories, semantic roles correspond to different positions within these structures, and are isomorphically mapped (based on the geometry of the semantic tree) to surface grammatical positions for syntactic expression. For example, *Sally broke the cup* has the structure: [Sally$_{agent}$ CAUSE [vase$_{patient}$ BECOME <*STATE*>$_{broken}$]], glossed as "Sally caused the cup to become broken." Building on earlier work, the experiments presented in this thesis (14 in total) demonstrate that event structures provide greater empirical coverage over atomic semantic roles. This work also begins to provide a clearer description of the inventory and scope of the primitive units that form these semantic event representations.

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Chapter 1

INTRODUCTION

Most events can be described in multiple ways. For instance, I can describe the same loading event by saying *The girl loaded the van with boxes* or *The girl loaded boxes in the van*. Theories of argument structure account for these different surface forms by positing distinct semantic event representations that underlie them. In some theories, these event representations are built into 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 thesis, I will follow this latter tradition and describe syntax and semantics as different levels of representation that are linked via mapping. A perennial challenge for linguistics and psycholinguistics has been characterizing these event meanings such that they capture the full range of available data. In this thesis, I present three novel experimental studies that address both the format and the content of the semantic building blocks of natural language, following earlier work (e.g., Gropen, Pinker, Hollander, & Goldberg, 1991; Gropen, Pinker, Hollander, Goldberg, & Wilson, 1989; Hartshorne et al., 2016; Kako, 2006; Wittenberg & Snedeker, 2014; Wittenberg, Khan, & Snedeker, 2017). Understanding these structures will inform our understanding of the conceptual representation of events more broadly, complementing recent insights from the domain of visual perception (e.g., Buchsbaum, Griffiths, Plunkett, Gopnik, & Baldwin, 2015; Radvansky & Zacks, 2014). It is also critical for theories of language acquisition and language emergence, a point I will return to in Chapter 5 (conclusion).

In the remainder of this chapter, I provide context for these studies by discussing relevant theoretical issues and reviewing prior research. First, I review existing accounts of semantic representation and the key evidence for or against them. Then, I highlight the questions that are addressed by the research presented in this thesis.

1.1. Theories of semantic representation

Theories of semantic representation categorize the nouns in sentences according to the roles they play in the event. For example, Sally is an agent in *Sally broke the cup*, while the cup is a patient, or undergoer of that action. We call these categories semantic (or thematic) roles. Different verbs are associated with different sets of semantic roles. Thus, verbs like *break* and *roll* have agents and patients, while verbs like *load* and *spray* have agents, themes, and destinations (for review, see, e.g., Levin & Rappaport Hovav, 2005).[1] That the role a participant plays in an event has direct grammatical relevance is one of the oldest and most profound observations about semantic event representation, dating back to the Sanskrit grammarian Pāṇini in the 6th to 4th century BCE (Misra, 1996). Some theories capture this relationship explicitly, while others do so only indirectly. Nevertheless, it has remained a powerful guiding principle behind modern theories of semantic representation.

1.1.1. Atomic semantic roles

The earliest modern theories of semantic roles (post-cognitive revolution) treat them as standalone units that have no internal structure (Fillmore, 1968; Gruber, 1965; see also Jackendoff, 1972), akin to Fodorian conceptual atoms (Fodor, 1998). On these theories, the roles are in a ranked list (prominence hierarchy) that determines their syntactic expression. For example, in a breaking

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[1] Destinations are also referred to as (spatial) goals or locations in the literature (see Levin & Rappaport Hovav, 2005).

event involving a cat and a vase, there is an agent (*a cat*) and a patient (*a vase*). Agents are assumed to be more prominent than patients, making the agent the subject and the patient the object (e.g., *The cat broke the vase*). On this type of account, the different syntactic orderings of *The girl loaded the van with boxes* and *The girl loaded boxes in the van* reflect different mappings from semantic roles to surface syntax: destination before theme for the former and theme before destination for the latter.

Note, however, that the mere existence of different surface orderings like these already poses a challenge to this general class of theories. As is, we need two separate mapping rules: one that ranks destinations above themes and another that ranks themes above destinations. Yet it's impossible to define a single prominence hierarchy that simultaneously accounts for both surface structures.[2] One solution is to stipulate a one-to-one correspondence between semantic roles and syntactic arguments, with different argument orderings resulting instead from syntactic transformation (Baker, 1988, 1997). Critically, this solution requires that the two locative structures derive from the same semantic event representation.

However, it's clear that these sentences do *not* mean the same thing: *The girl loaded the van with boxes* describes a change of state, while *The girl loaded boxes in the van* describes a change of location (see, e.g., Gropen et al., 1991; Pinker, 1989; Rappaport & Levin, 1988).[3] Thus, if someone loads a van with boxes, the van goes from being not full to completely full; accordingly, *The girl loaded the van with boxes, but the van wasn't full* is a contradiction, but *The girl loaded boxes in the van, but the van wasn't full* is not (Anderson, 1971; for review and discussion, see Levin &

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[2] Unless the different surface orderings aren't conditioned on semantic roles per se but rather on semantic properties of the NPs filling those roles, such as animacy and definiteness, among others (Bresnan, Cueni, Nikitina, & Baayen, 2007; Bresnan & Nikitina, 2009; Collins, 1995; Comrie, 1989; Evans, 1997; Gries, 2003; Haspelmath, 2004; Thompson, 1990).

[3] Two sentences can refer to the same event but have different meanings because they pick out different *construals*, or conceptualizations, of the event (e.g., Gleitman, 1990; Goldberg, 1995, 2006; Jackendoff, 1990; Levin & Rappaport Hovav, 2005; Pinker, 1989).

Rappaport Hovav, 2005). In contrast, loading boxes in a van doesn't trigger the same state-change entailment, instead conveying only a location change.

Critically, what changes in each perspective is the entity that is "affected" (the theme): the van in the former but the boxes in the latter (Dowty, 1991; Gropen et al., 1991; Pinker, 1989; Rappaport & Levin, 1988). This is consistent with the strong cross-linguistic tendency for direct objects to encode affected entities (for review and discussion, see Levin & Rappaport Hovav, 2005; Pinker, 1989). We could, in principle, capture this contrast with atomic roles by allowing them to vary across the two constructions, rather than the boxes being a theme in both cases and the van, a destination. Thus, the boxes could be a theme in *The girl loaded boxes in the van*, while the van is a theme in *The girl loaded the van with boxes* (for relevant discussion, see Dowty, 1991; Gropen et al., 1991). Accordingly, the van would be a destination in the former, while the boxes help define the resulting state in the latter (what the van becomes full of). If themes are ranked above both destinations and result states in the hierarchy, this would account for both surface structures.

However, this still misses a key generalization: As much as the composition of the event participants are integral to the interpretation of an event, so, too, are the dynamics of the event itself. Observations like this one (among others) have motivated a paradigm shift in semantic event representation within the past forty years. As we will shortly see, the new framework removes much of the arbitrariness of atomic role theories and makes new testable predictions.

1.1.2. Event structures

Most contemporary theories of lexical semantics no longer treat semantic roles as theoretical primitives but rather as pointers to positions in a more structured representation (e.g., Goldberg, 1995; Grimshaw, 1990; Jackendoff, 1990, 2002; Levin, 1985; Pinker, 1989; Rappaport Hovav & Levin, 1998, 2011; for review and discussion, see Levin & Rappaport Hovav, 2005), exemplifying the neo-classical view of concepts (see Laurence & Margolis, 1999). On these theories, verbs are

decomposed into primitive predicates (ACT, BECOME, CAUSE, HAVE) that specify the agentive, causal, and motional properties, among others, of the events they describe. These predicates are then embedded within each other, forming hierarchical relations among the arguments they take. For instance, a simple event like *The vase broke* (1) has only a single predicate (BECOME), which takes two arguments: an entity that is in a particular state (the vase) and the state that it is in (brokenness). A more complex structure can be built by embedding the structure of this simple event under the predicate CAUSE, which introduces a second argument (the causer of the event), yielding sentences like *The cat broke the vase* (2; Baker, 2003; Doron, 2003; Dowty, 1979; Embick, 2004; Grimshaw, 1982; Hale & Keyser, 2002; Härtl, 2003; Jackendoff, 1990; Kallulli, 2006; Lakoff, 1970; Pinker, 1989; Piñón, 2001; Reinhart, 2002; Reinhart & Siloni, 2005; though cf. Levin & Rappaport Hovav, 1995; Koontz-Garboden, 2009).

(1) a. The vase broke.

    b. [Y$_{patient}$ BECOME <*STATE*>$_{broken}$]

(2) a. The cat broke the vase.

    b. [X$_{agent}$ CAUSE [Y$_{patient}$ BECOME <*STATE*>$_{broken}$]]

On these theories, semantic roles correspond to different positions within these structures. These arguments are 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 the two locative constructions are a consequence of their different semantic event structures (3 and 4; structures adapted from Rappaport & Levin, 1988, p. 26).

(3) a. The girl loaded the van with boxes.

b. [[X$_{agent}$ CAUSE [Z$_{destination}$ BE IN *<STATE>*$_{loaded}$]] WITH Y$_{theme}$]

(4) a. The girl loaded boxes in the van.

b. [X$_{agent}$ CAUSE [Y$_{theme}$ BE AT Z$_{destination}$]]

Event structures provide several key advantages over atomic role theories (for review and discussion, see Gropen et al., 1991; Levin & Rappaport Hovav, 2005). First, they describe event dynamics in addition to event participants. Second, they allow us to do away with ad hoc prominence hierarchies in the mapping from semantics to syntax, instead requiring only that the geometry of the semantic tree be reflected in the syntax. This, in turn, simplifies the acquisition story, a point I will return to in Chapter 2. Third, event structures allow for greater precision with respect to the *content* of semantic representation. While semantic roles are notoriously hard to define (for discussion, see Dowty, 1991; Levin & Rappaport Hovav, 2005), event structures capture generalizations over arguments (and make distinctions thereof) on the basis of their well-defined positions within the structure: The arguments of a CAUSE predicate form a coherent class, which differ from the arguments of a HAVE predicate, and so on. Yet the overall structural geometry of the semantic tree also nicely accounts for the similar syntactic distributions of certain (distinct) arguments (e.g., the highest argument in the tree, usually CAUSE or ACT, is the subject, etc.). I will address these points in Chapters 2 and 3. In short, event structures provide both better empirical coverage and obvious descriptive advantages over atomic role theories. Chapters 2 and 4 will address some of the key predictions of this framework.

1.2. The studies presented in this thesis

1.2.1. Paper 1

In Paper 1, I use the relationship between psych verbs and an alternation known as the causative-inchoative alternation (see below) to provide evidence for the existence of a general

semantic event primitive of causation (CAUSE) that is shared between different classes of verbs. Like the locative alternation, psych verbs have long posed a challenge to theories of the mapping between syntax and semantics: While we sometimes express the experiencer of the emotion as the subject and the stimulus as the object (e.g., *Sally feared/hated/loved Max*), other times we express the stimulus as the subject and the experiencer as the object (e.g., *Max frightened/angered/delighted Sally*; Belletti & Rizzi, 1988; Croft, 1993, 2012; Dowty, 1991; Landau, 2010; Levin, 1993; Pesetsky, 1995). On atomic role theories, there is no absolute prominence ranking of stimuluses and experiencers that can account for the existence of both of these sentences.

Recent evidence from English, Mandarin, and Korean suggests, however, that language users perceive *frighten* verbs as more causal than *fear* verbs (Hartshorne et al., 2016). This is predicted by theories in which semantic structure encodes event dynamics in addition to event participants. In terms of event structure, *frighten* verbs would have a CAUSE predicate (5) and *fear* verbs would not (6). This distinction in mimicked in the causative-inchoative alternation: A causative sentence like *Sally broke the vase* has a CAUSE predicate (7), while its inchoative counterpart, *The vase broke*, does not (8).

(5) a. Max frightened Sally.

b. $[X_{stimulus}$ CAUSE $[Y_{experiencer}$ BE $[<EMOTIONAL\ STATE>_{fear}]]]$

(6) a. Sally feared Max.

b. $[Y_{experiencer}$ BE $[<EMOTIONAL\ STATE>_{fear}$ ABOUT $X_{stimulus}]]$

(7) a. Sally broke the vase.

b. $[X_{agent}$ CAUSE $[Y_{patient}$ BECOME $<STATE>_{broken}]]$

(8) a. The vase broke.

b. $[Y_{patient}$ BECOME $<STATE>_{broken}]$

In an implicit categorization task, our participants (N=64) grouped causal physical verbs (7) with causal emotion verbs (5) and non-causal physical verbs (8) with non-causal emotion verbs (6). These results are easily captured with event structures, but they are difficult to reconcile with traditional semantic role theories (though see, e.g., Levin & Rappaport Hovav, 2005, for relevant discussion). In addition, this work bears on both the content and the scope of the basic building blocks that compose event structures: Language relies on a representation of CAUSE that is broad and spans many domains, rather than narrower CAUSE predicates that are each specific to a particular domain (e.g., physical vs. psychological).

1.2.2. Paper 2

I continue to investigate the inventory of primitive predicates that make up event structures in Paper 2. Are there a small number of very broad predicates (like CAUSE)? Or do there also exist narrower predicates that capture more fine-grained distinctions, where appropriate? Consider, for example, the sentences in (9).

(9)   a. The boy loads the suitcase on the cart.

      b. The boy hands the suitcase to his mother.

On the surface, they both have the same syntactic phrase structure (NP-V-NP-PP). Correspondingly, many theorists also assume parallel semantic representations for the two cases (e.g., Anderson, 1971; Baker, 1996; Harley, 2003; Goldberg, 1995, 2002, 2006; Gruber, 1965; Lakoff & Johnson, 1980; Jackendoff, 1972, 1983; Pylkkänen, 2008). In the examples above, cart (9a) and mother (9b) would both be arguments of a BE AT predicate, as in (10).

(10)   [X CAUSE [Y BE AT Z]]

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Other theorists maintain distinct semantic representations for the two prepositional phrase arguments (e.g., Bresnan & Kanerva, 1989; Pinker, 1989; Rappaport Hovav & Levin, 2008; for discussion, see Levin & Rappaport Hovav, 2005). Thus, only cart (9a) stems from a BE AT predicate (11a), while mother (9b) might stem from, for example, a BE POSSESSED AT predicate (11b).

(11) a. [X CAUSE [Y BE AT Z]]

b. [X CAUSE [Y BE POSSESSED AT Z]]

I explore this question using structural priming, or the tendency for speakers to reuse previously encountered sentence structures across utterances (Bock, 1986; for discussion, meta-analysis, and reviews, see Branigan, 2007; Branigan & Pickering, 2017; Mahowald, James, Futrell, & Gibson, 2016; Pickering & Ferreira, 2008; Tooley & Traxler, 2010). For instance, speakers are more likely to describe a picture with a passive sentence after they've just heard a passive sentence than after they've just heard an active sentence (Bock, 1986). Psycholinguists use this priming to investigate the structural representations constructed during language production (Branigan & Pickering, 2017).

Across eleven structural priming experiments on Amazon Mechanical Turk (combined N=2,914), I look for priming between sentences like those in (9a) and (9b). The pattern of findings confirms that semantic event structure can be primed independent of syntactic structure, lexical content, and animacy. However, I find that this priming does not extend from BE AT predicates (11a)

to BE POSSESSED AT predicates (11b), or vice versa, providing evidence that these two sub-structures are distinct.[4]

1.2.3. Paper 3

Finally, Paper 3 addresses a mystery in the structural priming literature with respect to how and when semantic representations affect priming. Resolving this mystery forces us to distinguish between two kinds of alternations: those with distinct event structures and those that originate from structural (syntactic) operations on a single event structure.

One of the key takeaways from Paper 2 is that many distinct levels of representation can be primed, and when they are, the effects are cumulative: the more features that align from prime to target, the greater the priming effect (see also Bernolet, Colleman, & Hartsuiker, 2014; Bernolet, Hartsuiker, & Pickering, 2009; Cai, Pickering, & Branigan, 2012; Cleland & Pickering, 2003; Gámez & Vasilyeva, 2015; Griffin & Weinstein-Tull, 2003; Hartsuiker & Kolk, 1998; Pickering & Branigan, 1998; Potter & Lombardi, 1998; Scheepers, Raffray, & Myachykov, 2017; Vernice, Pickering, & Hartsuiker, 2012). Given this, we might always expect greater priming between constructions that share both their syntax *and* event structure (among other representations) than between constructions that only share one of these representations.

Yet, in a seminal study, Bock and Loebell (1990, Exp. 2) found no such boost in priming for passives: 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*). While passives and intransitive locatives share the same abstract syntax (i.e., NP-V-PP), their semantics is clearly distinct. In a passive

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[4] It's worth noting that a similar theory could have been true in the case of psych verbs (Paper 1): psychological causation as distinct from physical causation. This only further underlines the importance of testing our theoretical assumptions rather than taking them for granted.

sentence like *The construction worker was hit by the bulldozer*, the bulldozer is an agent the construction worker is a patient; in *The construction worker was digging by the bulldozer*, the construction worker is an agent but the bulldozer is a location. This led Bock and Loebell (1990) to conclude that structural priming only occurs at the level of an abstract phrase structure and is not sensitive to the semantic representation. However, this interpretation is at odds with a rich set of findings (including my own in Paper 2; see also 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) showing that semantic structure *can* contribute to priming.

In Paper 3, I do two things. First, in two replications of Bock and Loebell (1990, Exp. 2) with higher statistical power (combined N=500), I confirm that passives are primed equally by passives and intransitive locatives. Thus, semantic structure doesn't enhance priming in passive constructions. Second, I argue that these two sets of results can be reconciled if we treat the passive as a fundamentally different type of alternation than the locative or dative. The two syntactic realizations of locatives and datives are typically argued to differ from one another on the basis of their underlying event structures (e.g., Anderson, 1971; Beck & Johnson, 2004; Bruening, 2010; Goldberg, 1995; Harley, 2003; Levin & Rappaport Hovav, 2005; Pinker, 1989; Rappaport & Levin, 1988; Rappaport Hovav & Levin, 2008). In contrast, the active-passive alternation is typically considered to result from a *single* semantic representation rather than two (e.g., Baker, 1988; Bresnan, 1978, 1982; Chomsky, 1957, 1965; Katz & Postal, 1964; though cf. Pinker, 1989; for discussion, see Culicover & Jackendoff, 2005; Levin & Rappaport Hovav, 2005). Actives and passives are differentiated instead by their information structure: Passive sentences topicalize the

argument which would be the object in an active sentence, and "demote" or omit the argument which would normally be the subject argument (Fox & Hopper, 1994; Givón, 1994; Shibatani, 1985).[5]

Thus, when we choose one version of a locative or dative structure, we choose one of two competing event structures, opening up the possibility of priming future utterances at this level. For example, double-object datives have [X CAUSE [Z HAVE Y]] structures which prime other [X CAUSE [Z HAVE Y]] structures but do not prime the [X CAUSE [Y BE POSSESSED AT Z]] structures that underlie *to*-datives (Paper 2). Conversely, since both the active and passive version of a sentence have the same underlying event structure, we do not see semantic priming: Passive transitive [X ACT Z] structures equally prime both active transitive [X ACT Z] and passive transitive [X ACT Z] structures, resulting in no differential influence on one over the other. In other work (Ziegler, Snedeker, & Wittenberg, 2018), I have provided independent evidence supporting the prediction that event structure does not contribute to priming when it is the same in both forms of an alternation (using idioms and light verb constructions). Thus, treating the passive and locative/dative alternations as distinct from one another provides a straightforward explanation for when event structures should contribute to priming and when it should not.

1.3. Summary

In sum, the studies presented in this thesis comprise an examination of both the format and the content of the semantic representations that underlie natural language understanding and use, building on previous work in this domain. Together, they will not only show that event structures provide greater empirical coverage over atomic semantic roles (as other researchers also have), but

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[5] To see that event structure is not relevant to the function of passives in English, note that passivization is available as an option for either locative construction (e.g., *Paint was smeared on the wall* or *The wall was smeared with paint*) or either dative construction (e.g*., The dog was given a bone* or *A bone was given to the dog*).

they will also begin to provide a clearer description of the inventory and scope of the primitive

predicates (building blocks of meaning) that constitute these semantic event representations.

Chapter 2

[Paper 1]

WHY BAKING A CAKE IS LIKE SURPRISING A CHILD: EVIDENCE FOR SHARED CONCEPTUAL STRUCTURE

FOR PSYCHOLOGICAL AND PHYSICAL EVENTS

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Under review

Abstract

Natural languages are characterized by systematic correspondences between meaning and form. Thus, knowing how a verb is used tells you something about the type of event it labels, the participants involved, and their relationship to one another. For example, if someone tells you that a koala just rolted a panda, you have clear intuitions about who did what to whom, even though you've probably never heard the verb *rolt* before. Linguists capture these correspondences with structured event representations that mediate between non-linguistic cognition and syntax. On these theories, verb meanings consist of a verbal root and one or more primitive predicates (e.g., ACT, BECOME, CAUSE) which can be combined (by embedding one predicate within another) to form more complex semantic structures. These primitive predicates are reused across a wide range of events. Here, we provide evidence for a CAUSE predicate that is shared between verbs of physical and psychological events: In an implicit categorization task, participants grouped causal physical verbs (e.g., *Sally broke the vase*) with causal emotion verbs (e.g., *Max frightened Sally*) and non-causal physical verbs (e.g., *The vase broke*) with non-causal emotion verbs (e.g., *Sally feared Max*).

2.1. Introduction

Natural language is characterized by systematic correspondences between meaning and form. For example, in English and many other languages, an agent who causes another object to move or change its state gets expressed as the subject of an active sentence, rather than the object, regardless of the type of event (Baker, 1988; Croft, 2012; Dowty, 1991; Tenny, 1994; for review and discussion, see Levin & Rappaport Hovav, 2005). Thus, the *roller* is the subject of *roll* (e.g., *Sally rolled the ball*), the *baker* is the subject of *bake* (e.g., *Sally baked a cake*), and the *breaker* is the

subject of *break* (e.g., *Sally broke the vase*). This tight correspondence has led to the hypothesis that how we structure a sentence is *determined* by the meaning, or the conceptual content, that we wish to convey (e.g., Dowty, 1991; Fillmore, 1968; Hale & Keyser, 1987; Jackendoff, 1990; Levin, 1993; Pinker, 1989; for review and discussion, see Levin & Rappaport Hovav, 2005).

This hypothesis presents two challenges for cognitive science. First, to test this proposal, we must find a way to get independent evidence about the conceptual content of a sentence—i.e., evidence that does not depend on the syntactic structure itself. This is tricky because we do not have direct access to our internal representations of meaning. Most research in this area has relied on the judgments of theorists (e.g., Croft, 2012; Dowty, 1991; Goldberg, 1995, 2006; Jackendoff, 1990, 2002; Levin, 1993; Levin & Rappaport Hovav, 2005; Pinker, 1989). A smaller body of work has relied on the intuitions of everyday people (e.g., Paper 2; Gropen, Pinker, Hollander, & Goldberg, 1991; Gropen, Pinker, Hollander, Goldberg, & Wilson, 1989; Hartshorne et al., 2016; Kako, 2006; Wittenberg, Khan, & Snedeker, 2017).

Second, this hypothesis must provide an explanation for cases where the same meaning appears to be encoded in two different syntactic structures. Perhaps the most worrisome of these cases is the systematic variation in how we express emotions. In English, and in many other languages, we sometimes express the experiencer of the emotion as the subject and the stimulus as the object (e.g., *Sally feared/hated/loved Max*), while other times we express the stimulus as the subject and the experiencer as the object (e.g., *Max frightened/angered/delighted Sally*; Belletti & Rizzi, 1988; Croft, 1993, 2012; Dowty, 1991; Landau, 2010; Levin, 1993; Pesetsky, 1995). At first glance, widespread variation of this kind is incompatible with the claim that meaning determines form.

Such examples call into question the prevalence of broad, systematic mappings from semantics to syntax. However, in the same way that the words *car*, *automobile*, *Volkswagen Jetta*,

and *sedan* may all be used to refer to the same vehicle but nonetheless have distinct meanings, two sentences can refer to the same event but have different meanings because they pick out different *construals*, or conceptualizations, of the event (e.g., Gleitman, 1990; Goldberg, 1995, 2006; Jackendoff, 1990; Levin & Rappaport Hovav, 2005; Pinker, 1989). In this paper, we demonstrate that the two kinds of emotion verbs have different meanings that can account for their different syntactic realizations. This finding is critical for understanding the relation between semantic structure and linguistic form. Below, we address theories of semantic structure, the role of causation in our analysis of emotion verbs, and our predictions for the study that follows.

Theories of semantic representation categorize the nouns in sentences according to the roles they play in the event. For example, Sally is an agent in *Sally broke the vase*, while the vase is a patient, or undergoer of that action. We call these categories semantic roles. Different verbs are associated with different sets of semantic roles. Thus, verbs like *break* and *roll* have agents and patients, while verbs like *give* and *send* have agents, recipients, and themes. The earliest theories of semantic roles treated them as atomic units and posited that these roles varied in their prominence which determined their syntactic expression (Baker, 1988; Fillmore, 1968; Gruber, 1965; see also Jackendoff, 1972). Agents were assumed to be more prominent than patients, explaining why Sally is the subject and the vase is the object in the sentence above. This approach, however, ran into problems with sentences like *Sally feared Max* and *Max frightened Sally*, as there is no ranking of the roles stimulus and experiencer that can account for both.

Contemporary theories characterize verb meanings as structured representations that include both a verbal root and one or more primitive predicates (see, e.g., Jackendoff, 1990, 2002; Pinker, 1989; Rappaport Hovav & Levin, 1998, 2011; for review and discussion, see Levin & Rappaport Hovav, 2005). These primitive predicates encode aspects of meaning that are present in many different verbs, and can be used in combination (by embedding one predicate within another) to form more complex semantic structures. This is illustrated by the examples in Fig. 2.1a-b. A simple non-

causal event like *The vase broke* (Fig. 2.1a) has only a single predicate (BECOME), which takes two arguments: an entity that is in a particular state (the vase) and the state that it is in (brokenness). A more complex structure can be built by embedding the structure of this simple event under the predicate CAUSE, which introduces a second argument (the causer of the event), yielding sentences like *Sally broke the vase* (Fig. 2.1b; Baker, 2003; Doron, 2003; Dowty, 1979; Embick, 2004; Grimshaw, 1982; Hale & Keyser, 2002; Härtl, 2003; Jackendoff, 1990; Kallulli, 2006; Lakoff, 1970; Pinker, 1989; Piñón, 2001; Reinhart, 2002; Reinhart & Siloni, 2005; though cf. Levin & Rappaport Hovav, 1995; Koontz-Garboden, 2009).[6] Critically, for these types of structures, it is the argument that is highest in the semantic tree that becomes the subject of a sentence (which is the highest argument in the syntactic tree), while the argument that is lower in the semantic tree becomes the direct object. Thus, differences in structural prominence are preserved in the linking from semantics to syntax.

This approach provides a straightforward solution to the linking problem posed by sentences with *frighten* and *fear* verbs. Fig. 2.1c-d provides proposed representations for *frighten* and *fear* sentences (from Hartshorne et al., 2016; see also Pesetsky, 1995). For the *fear* sentences (Fig. 2.1c), the highest predicate is BE, which takes two arguments: an entity that is in a particular state (the experiencer) and the state that s/he is in (in this case an emotional state). The emotional state is itself a complex object consisting of a modifier (the verbal root which specifies the kind of emotion) and the entity that this emotion is directed towards (the target). If prominence relations are preserved during linking, then the experiencer will become the subject of the sentence because it is higher in

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[6] As many researchers have argued that the causative structure derives from the non-causative structure (e.g., Baker, 2003; Dowty, 1979; Embick, 2004; Hale & Keyser, 2002; Jackendoff, 1990; Lakoff, 1970; Pinker, 1989) as have argued that the non-causative structure derives from the causative structure (e.g., Grimshaw, 1982; Härtl, 2003; Kallulli, 2006; Reinhart, 2002; Reinhart & Siloni, 2005). Still others derive both structures from a more abstract root (e.g., Doron, 2003; Piñón, 2001). We make no derivational commitments here. Important for present purposes is that the two structures differ specifically in the presence of CAUSE (though cf. Levin & Rappaport Hovav, 1995; Koontz-Garboden, 2009).

the tree (less embedded) than the target. For the *frighten* sentences (Fig. 2.1d), the highest predicate

is CAUSE, which takes two arguments: the entity that is causing the event and the predicate BE which

describes the state that is being caused. As before, BE takes two arguments: the entity experiencing

the emotion and the emotional state itself.[7] Consequently, the causer is higher in the tree than the

experiencer and should appear as the subject of the sentence. Thus, we maintain a tight systematic

correspondence between meaning and form.

a BECOME

y   STATE

The vase broke

b CAUSE

x   BECOME

y   STATE

Sally broke the vase

c BE

y   EMOTIONAL
STATE
|
ABOUT
|
x

Sally feared Max

d CAUSE

x   BE

y   EMOTIONAL
STATE

Max frightened Sally

---
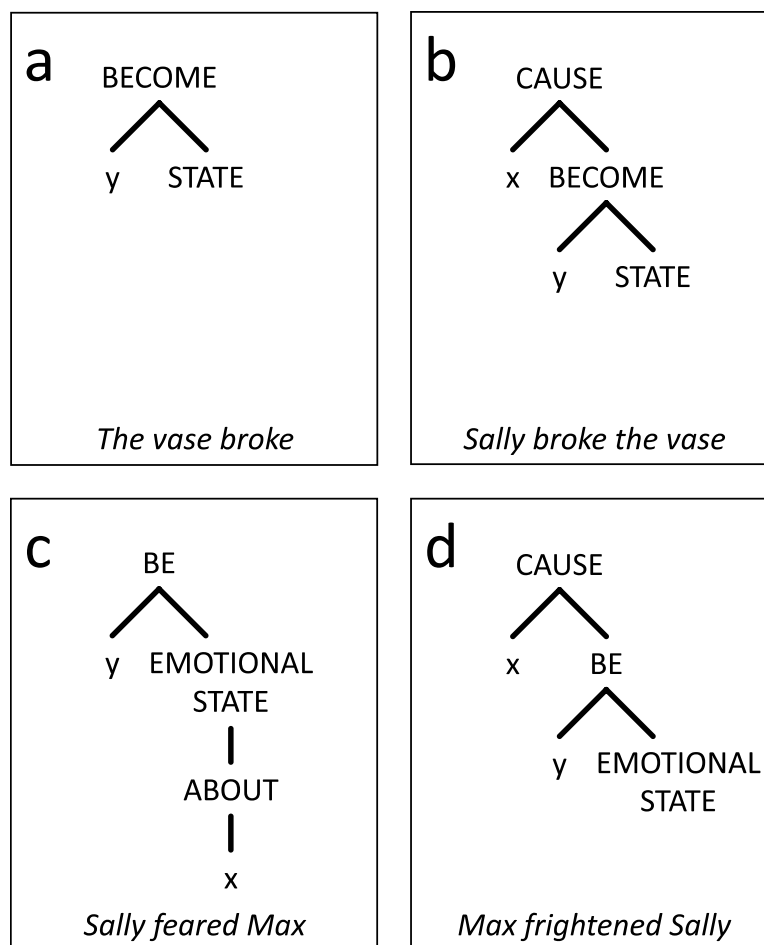
[7] Note that under this theory emotional state gets represented differently in the two cases, presumably because the stimulus of a *fear* verb must also be the target of the emotion (e.g., if Sally hates the newspaper article, her rage is directed at the article itself), whereas the stimulus of a *frighten* verb need not be the emotional target (e.g., the newspaper article can anger Sally even if she is not angry at the article itself; see Pesetsky, 1995).

Figure 2.1. Example semantic structures for *break-* (a-b) and *fear-* and *frighten*-type (c-d) verbs (from Hartshorne et al., 2016). Argument positions are marked by the variables *x* and *y*.

This theory of verb meaning makes several predictions. The first and weakest prediction is that language users should perceive *frighten* verbs as more causal than *fear* verbs. Recent work confirms this for English, Mandarin, and Korean speakers (Hartshorne et al., 2016). Second, if these two kinds of verbs are categorially different, participants should readily learn a rule that differentiates the *frighten* and *fear* verbs. Third, on this hypothesis, the distinction between emotion verbs (*Max frightened Sally* vs. *Sally feared Max*) is parallel to the distinction between causal and non-causal physical events (*Sally broke the vase* vs. *The vase broke*). Thus, if participants learn a rule that applies to *frighten* verbs (but not *fear* verbs), we should expect them to extend it to the causal physical events (but not non-causal ones). The present study tests these two strong predictions. Generalization of this kind would provide evidence that language relies on a representation of CAUSE that is broad enough to encompass both physical and psychological causation.

In this study, we use an implicit measure of categorization (predictive eye gaze). We chose an implicit task to avoid tapping participants' explicit theories about language. Our task is based on Wittenberg and colleagues' implicit categorization procedure (Wittenberg et al., 2017). Specifically, on each trial, a Y-shaped tube appeared on the screen. A pink ball entered the tube at its base as a prerecorded sentence played over speakers. On training trials, after the sentence ended, the ball came out the top left side or top right side of the tube (Fig. 2.2a). Participants were instructed to listen to the sentences, and to click on the ball as soon as it emerged. On training trials, *frighten* verbs always came out one side, and *fear* verbs always came out the other side (counterbalanced across participants). Importantly, we never told participants the pattern that determined which side the ball would come out, nor did we give any feedback on how to categorize the test trials.

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On test trials, the ball "got stuck," and two gray circles appeared on either side of the tube indicating the two possible landing sites (Fig. 2.2b). Participants had to guess which side the ball would have come out of by clicking on the corresponding circle. We recorded participants' anticipatory eye gazes (and mouse clicks) as they performed the task.
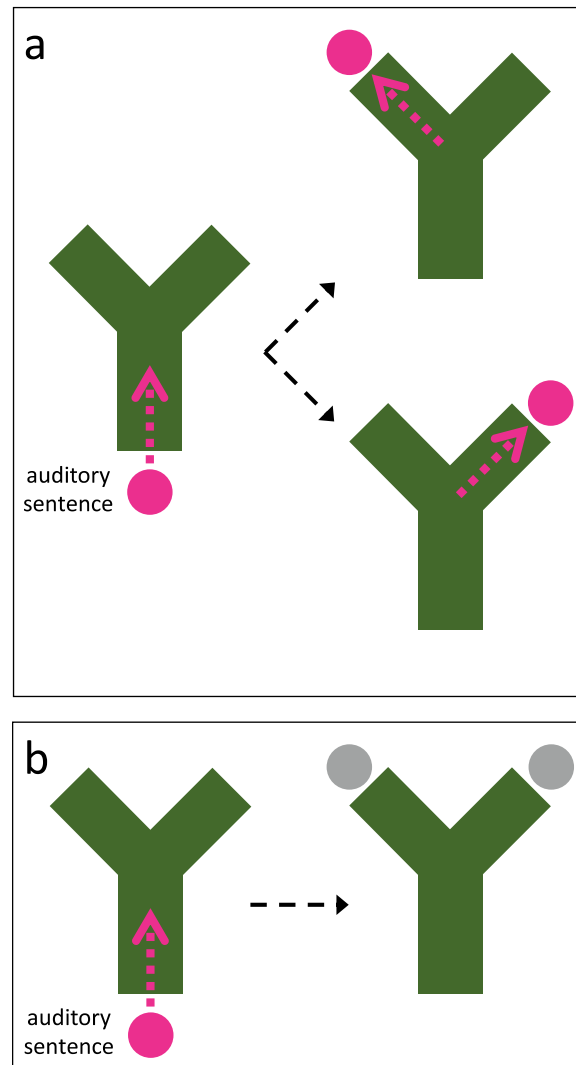
Figure 2.2. Schematic of paradigm. On training trails (a), the ball entered the green tube and came out the top left side or top right side (paths indicated by dashed pink arrows). There was a consistent match between side and verb type (*frighten-* or *fear*-type, counterbalanced across participants). On

test trials (b), the ball did not emerge from the tube, and participants had to guess which side the ball would have come out of by clicking on the corresponding gray circle.

We had two predictions. First, if *frighten* and *fear* sentences do in fact have different semantic structures *and* these structures are readily accessible for generalization, then participants should correctly categorize new sentences using the emotion verbs that they were trained on and generalize this behavior to new sentences with emotion verbs that they were not trained on. Specifically, they should look to, and click on, the side of the screen where verbs of that type had appeared before. Second, if the CAUSE predicate is shared between *frighten* events and causal physical events (but not between *fear* events and non-causal physical events), then participants should also extend this learning to the physical event trials.

2.2. Results

Fig. 2.3 shows the pattern of looks to the *frighten*-verb side over time for all sentence types. Because we had no a priori hypotheses about when the looking patterns would diverge, we used non-parametric cluster-based permutation tests (Maris & Oostenveld, 2007). This analysis allowed us to detect all contiguous clusters that met a statistical threshold, and to test whether these clusters would be likely to occur by chance, correcting for multiple comparisons. We analyzed each set of test trials separately.

The permutation tests identified a long time window, from 300 to 3,000 ms after verb offset, over which the trained *frighten* and *fear* verbs diverged (summed *t* statistic for cluster=107.09, *p*<.001), indicating that participants learned to associate each side of the screen with the correct landing site for the ball for *known* emotion verbs. Importantly, participants generalized this rule to *new* emotion verbs of each kind: There was a significant difference between the untrained *frighten* and *fear* verbs in the time window between 100 and 3,000 ms after verb offset (summed *t* statistic for

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cluster=175.48, *p*<.001). These results demonstrate that these two kinds of verbs are categorially distinct.

Critically, we also found a significant cluster of differences between causal and non-causal physical events from 900 to 3,000 ms (summed *t* statistic for cluster=66.64, *p*<.001). Thus, participants extended the generalization *across* domains, from the emotion trials to the physical event trials. When they heard a causal physical event sentence, they were more apt to look to the side of the screen associated with *frighten* verbs, demonstrating a commonality between physical and psychological causation. This effect emerged somewhat later than the effects reported above, suggesting that extending the rule from emotion verbs to physical events may have required additional effort. Analysis of the mouse click data revealed similar findings (see Appendix A).
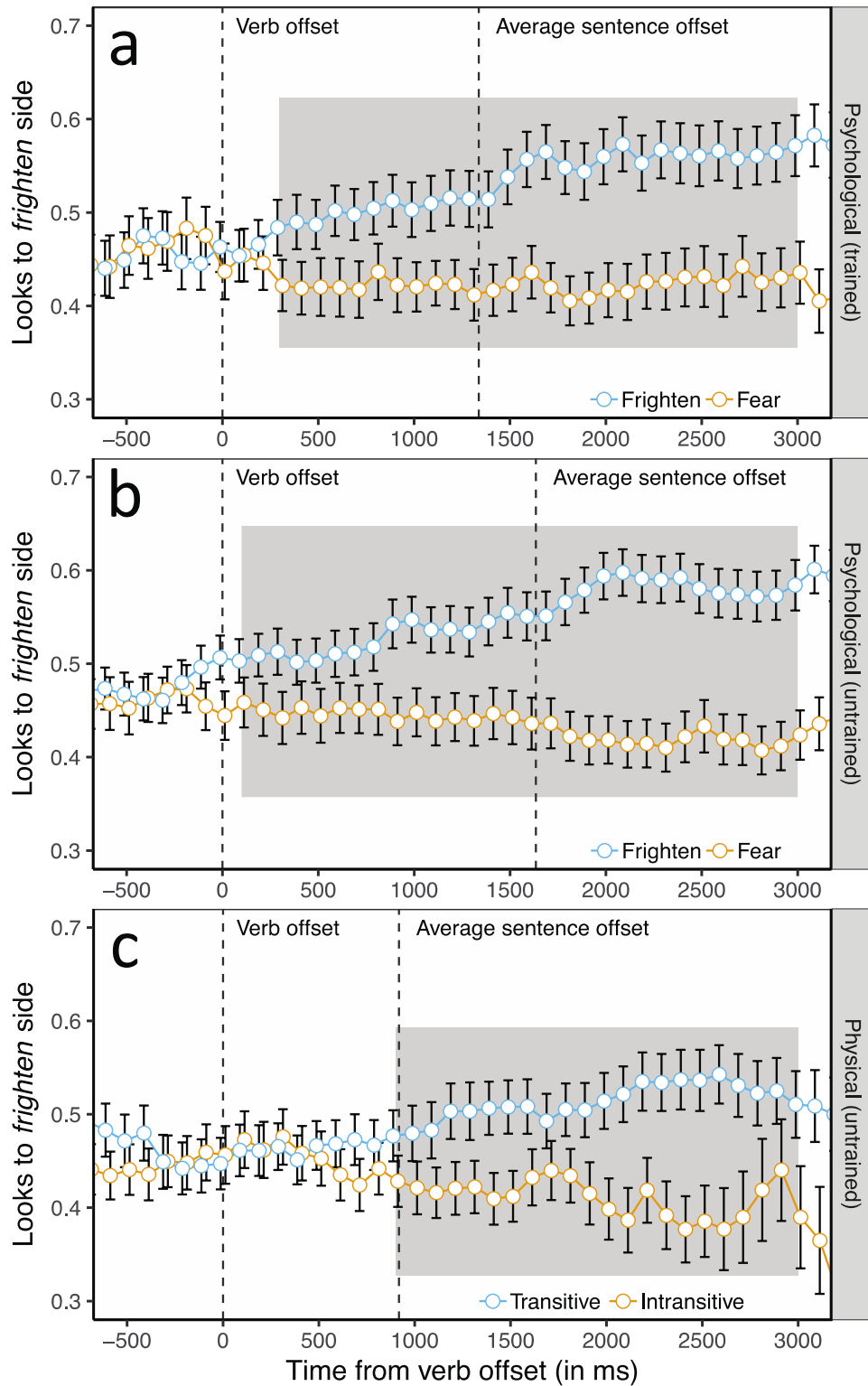
Figure 2.3. Proportion of looks to *frighten* side for trained *frighten* and *fear* verbs (a), untrained *frighten* and *fear* verbs (b), and causal (transitive) and non-causal (intransitive) physical events. Gray

boxes indicate significant clusters of differences (per the permutation tests). Dotted lines represent

verb offset and average sentence offset (by test trial type), respectively (corrected for saccade

planning). Error bars reflect by-subject standard errors.

2.3. Discussion

The present experiment tested for shared semantic structure between events of physical and

psychological causation. We found that when participants were trained on the distinction between

frighten and *fear* verbs, which differ from each other in causal structure but were matched on many

other dimensions, they generalized this training to causal and non-causal *physical* events. This

suggests a common representation of causation underlying *frighten* verbs and causal physical events,

and supports the analysis that *frighten* and *fear* verbs have different meanings that account for their

different syntactic realizations. Below, we discuss: (1) alternative explanations for these effects, (2)

implications for the existence of systematic syntax-semantics mappings, (3) implications for theories

of linguistic representation and language acquisition, and (4) some questions raised by these results.

Any time we categorize two types of sentences into two classes, there will be multiple

possible characterizations of the distinction we draw. Our design allowed us to rule out a number of

critical alternative explanations. First, our *frighten-* and *fear*-verb sentences all had the same surface

syntactic phrase structure (NP-V-NP) and number of event participants (two). Thus, the

generalization to causal and non-causal physical verbs cannot be explained on the basis of

transitivity. They also had the same patterns of animacy (both subjects and objects were animate; see

Appendix A). In addition, we controlled the valency of the events (how positive or negative the event

being described was; see Appendix A). Moreover, while *frighten* and *fear* verbs typically differ from

each other in both stativity and duration (*fear* verbs describe *states* that typically last a while, while

frighten verbs describe relatively shorter-lived *events*; Dowty, 1991; Tenny, 1994), causal and non-

causal physical sentences do not vary along these dimensions (both are events of similar duration).

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Thus, these differences also cannot explain participants' generalization from the psychological events to the physical events. There was one potential confound in our stimuli: The actions in our causal physical events were judged, on average, to be more intentional, or more deliberate, than those in our non-causal physical events (see Appendix A). But this difference between the classes was probabilistic rather than categorical, and when we controlled for intentionality we still found a reliable difference between causal and non-causal verbs (see Appendix A).

More broadly, these results provide strong support for the existence of systematic mappings from semantics to syntax. While there are other classes of verbs that have similar meanings but appear in different syntactic constructions (see, e.g., Levin, 1993), emotion verbs have long been considered one of the most intractable counterexamples to systematic syntax-semantics mappings (e.g., Culicover & Jackendoff, 2005; Pinker, 1984). Several theorists have suggested that the two classes of verbs differ in their meanings, but they have disagreed about what the relevant semantic distinction is (Croft, 2012; Dowty, 1991; Grimshaw, 1990; Jackendoff, 1990; Landau, 2010; Pesetsky, 1995; Talmy, 1985; Tenny, 1994). Our results provide compelling evidence not only that a semantic distinction does exist (see also Hartshorne et al., 2016)—rescuing systematic mappings—but also that this distinction is specifically one of causation.

These findings also have broad implications for theories of linguistic representation and language acquisition. In particular, they support an architecture of semantic representation, discussed in the Introduction, that encodes verb meanings via embedded sub-predicate structures which reflect the hierarchical relations between arguments encoded in the syntax. As we have shown here, the same CAUSE predicate appears in the semantic representation of verbs spanning two different domains (psychological and physical). While this finding is promising, it is a single example. Theories of event structure provide a host of other primitive predicates that could be studied in the same way (for review, see Levin & Rappaport Hovav, 2005).

Representational theories of this kind have clear implications for theories of language acquisition. By representing meaning as a series of hierarchically embedded predicates, these theories reduce the problem of mapping meaning to form: Instead of requiring dozens of rules that link particular roles to particular syntactic positions, learners can acquire a simpler principle: Map arguments high in the predicate structure to phrases high in the syntactic tree (i.e., preserve prominence; Bouchard, 1995; Grimshaw, 1990; Hartshorne et al., 2016; Jackendoff, 1990; Wechsler, 1995; for review and discussion, see Levin & Rappaport Hovav, 2005). While prominence preservation cannot account for the syntactic realization of all arguments, it does capture many of the most robust cross-linguistic patterns and correctly accounts for the syntactic expression of the four event types discussed here.

These representational theories thus substantially reduce the distance between the viable nativist and empiricist theories of language acquisition. Rather than dozens of innate linking rules, the nativist infant need only expect prominence to be preserved. Accordingly, when the construal of an event is unambiguous (e.g., caused motion), she can use her expectations about prominence and mapping to figure out the syntax (the causer is subject). When the construal of the event is unclear, then knowledge of syntactic structure and expectations about prominence can help clarify the meaning that should be attributed to the verb (e.g., if the experiencer is lower than the stimulus, then the event is being construed as a caused emotional episode). Similarly, rather than figure out the linking rules verb-by-verb, the empiricist infant need only be alert to broad generalizations about how meaning maps to form. She can discover prominence preservation in the process of learning her first transitive verbs, and then immediately apply it to verbs for psychological states.

Finally, this work raises several important questions about the origins of these sub-predicates. Many of the primitives invoked in theories of semantic event representation appear in theories of infants' prelinguistic conceptualization of events (causation, agents vs. objects, goal-directedness; e.g., Spelke & Kinzler, 2007). This suggests a natural hypothesis about the developmental origins of

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language—specifically, that the primitive units of event representation derive directly from these prelinguistic conceptual categories (e.g., Brown, 1973; Pinker, 1984, 1989, 2007; Strickland, 2016; for discussion, see Hartshorne et al., 2016; Kline et al., 2017). Recent work on children's acquisition of emotion verbs suggests that these representations are in place by 4-5 years of age (Hartshorne et al., 2016). But it is still unclear whether they are an input to language learning or a result of it. Moreover, there is ample evidence that very young infants are capable of distinguishing caused motion events from non-causal events (Kotovsky & Baillargeon, 2000; Leslie, 1982; Leslie & Keeble, 1987). But do infants have an abstract concept of CAUSE that applies equally to psychological and physical events? Or are their representations of CAUSE more fragmented (Muentener & Carey, 2010)?

2.4. Methods

This study was preregistered on the Open Science Framework (OSF) prior to data collection: https://www.doi.org/10.17605/OSF.IO/BFRXZ.

2.4.1. Participants. Sixty-four native English speakers from Harvard University participated in the experiment in exchange for $10 or course credit (37 female, 27 male; mean age=21, SD=4, range=17-34). All participants gave informed consent in accordance with the guidelines of the Committee on the Use of Human Subjects at Harvard University.

2.4.2. Materials and Procedure. The training trials consisted of 180 sentences using *frighten* and *fear* verbs. To generate these sentences, we selected 10 *frighten* verbs (*amaze*, *bother*, *charm*, *delight*, *distract*, *frighten*, *impress*, *inspire*, *threaten*, *upset*) and 10 *fear* verbs (*admire*, *adore*, *dread*, *enjoy*, *envy*, *fear*, *miss*, *regret*, *treasure*, *trust*). We created nine sentences per verb, which varied

along several dimensions in order to encourage broad generalization (see Appendix A). Examples are provided in (1-4).

(1) These protestors impressed last year's mayor.

(2) Is the archer distracting the naive cyclops?

(3) The president regretted his Supreme Court nominee.

(4) Roland from HR trusts the security personnel.

The first set of test trials consisted of 20 sentences using the same *frighten* and *fear* verbs that were used in the training trials (one sentence per verb). These trials allowed us to test the sensitivity of the paradigm: If participants were learning about the specific verbs they were exposed to (or making broader generalizations), then they should be able to predict the location of the ball.

The second set of test trials consisted of 40 sentences using 4 new *frighten* verbs (*fascinate*, *irritate*, *please*, *scare*) and 4 new *fear* verbs (*dislike*, *hate*, *love*, *respect*), at 5 sentences per verb. These sentences served to test within-class generalization.

The third set of test trials used 20 physical event verbs that can be both transitive (causal) and intransitive (non-causal). These included 16 change-of-state verbs (*accelerate*, *boil*, *break*, *burst*, *crash*, *crumble*, *deflate*, *melt*, *open*, *pop*, *rip*, *shatter*, *sink*, *snap*, *split*, *thaw*) and 4 manner-of-motion verbs (*bounce*, *move*, *roll*, *spin*). Examples are provided in (5-6). Participants only saw a single sentence per verb, 10 transitive and 10 intransitive (see Appendix A). These sentences served to test across-class generalization.

(5) The summer heat is thawing the ice palace.

(6) Are the spaghetti noodles boiling?

Stimuli were presented using E-Prime (Psychology Software Tools, Pittsburgh, PA), and eye movements were recorded on a Tobii eye tracker (Tobii Group, Sweden) that sampled at 60 Hz (i.e., recording participants' gazes every 16.6 ms). All sentences were prerecorded by an adult female native English speaker (second author). Further methodological details are provided in Appendix A.

2.4.3. Analysis. We divided the screen into two halves and coded looks to the *frighten*-verb (causal) side as 1, looks to the *fear*-verb (non-causal) side as 0, and missing data as NA. We then time-locked the eye-tracking data to verb offset, and averaged these values into 100 ms time bins. We calculated the mean proportion of looks to the *frighten*-verb side in each time bin and performed a log-odds transformation on these proportions. Only eye movements for target sentences were included.

Analysis was carried out on the 0-3,000 ms region post-verb offset (following Wittenberg et al., 2017). Three hundred thirty-nine trials (7%) were excluded due to excessive track loss (>50% missing data in this critical region). The permutation test procedure for a given contrast was as follows: For each 100 ms time bin in this region, we ran a logistic mixed-effects model (Baayen, Davidson, & Bates, 2008; Jaeger, 2008) on the log-odds of looking to the *frighten*-verb side using the lme4 package in R (Bates, 2010), with Condition as an effect-coded fixed effect (1, -1) and random intercepts for participant and item (target sentence). We then found clusters of temporally adjacent 100 ms bins that each had t-values larger than 1.6 (for discussion, see Hahn, Snedeker, & Rabagliati, 2015; Maris & Oostenveld, 2007), and summed these values across the time bins in each cluster. After this, we permuted the data: (1) Trial labels for Condition were randomly shuffled within participants. (2) We repeated the cluster-finding and summation procedure on the permuted data. (3) We extracted the largest cluster among the clusters that were identified. This permutation procedure was repeated 1,000 times in order to create the empirical null distribution. Finally, we compared the clusters from the original data to this distribution. The p-value for each cluster was calculated as the proportion of permuted clusters with equal or larger cluster-level t-values than the observed cluster.

Chapter 3

[Paper 2]

HOW BROAD ARE THEMATIC ROLES? EVIDENCE FROM STRUCTURE PRIMING

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Abstract

Verbs that are similar in meaning tend to occur in the same syntactic structures. For example, *give* and *hand*, which denote transfer of possession, both appear in the prepositional-object construction: "The child gave / handed the ball to the dog." We can call the child a "giver" in one case and a "hander" in the other, or we can refer to her more generally as the agent, or doer of the action. Similarly, the dog can be called the recipient, and the ball, the theme. These generalized notions of agent, recipient, and theme are known as thematic roles. An important theoretical question for linguists and psycholinguists is what the set of thematic roles is. Are there a small number of very broad roles, perhaps with each one mapping onto a single canonical syntactic position? Or are there many distinct roles, several mapping to the same syntactic position but conveying subtly different meanings? We investigate this question across eleven structural priming experiments on Amazon Mechanical Turk (total N=2,914), asking whether speakers treat the thematic roles recipient and destination (i.e., location or spatial goal) as interchangeable, suggesting the broad role of goal, or distinct, suggesting two separate roles. To do so, we look for priming between dative sentences (e.g., "The man gave the ball to the dog"), which have a recipient role (dog), and locative sentences (e.g., "The man loaded hay onto the wagon"), which instead have a destination role (wagon). Our pattern of findings confirms that thematic role mappings can be primed independent of syntactic structure, lexical content, and animacy. However, we find that this priming does not extend from destinations to recipients (or vice versa), providing evidence that these two roles are distinct.

3.1. Introduction

Linguistic theories posit systematic mappings between meaning (semantics) and form (syntax). One such critical pattern of regularity is how participants in an event get mapped to syntactic positions, allowing us to reconstruct who did what in a sentence despite variations in

surface word order. For example, if I tell you that "Beatrice glorped an orange to Dante," you know instantly that I'm describing an event in which an orange was transferred from Beatrice to Dante, even if you're fuzzy on exactly how this transfer was accomplished. This is because for a prepositional-object dative sentence like this one, the subject tells you who the agent, or doer, of the action is (Beatrice); the first object identifies the theme, or thing acted upon (orange); and the final, oblique argument indicates the recipient (Dante). These constructs (agent, theme, recipient, etc.) are known as *thematic roles* (Fillmore, 1968; Gruber, 1965; Jackendoff, 1972; for review and discussion, see Levin & Rappaport Hovav, 2005). Had I instead said "Beatrice glorped Dante an orange," you would have arrived at the same interpretation, despite the different configuration of nouns, because different sentence types (constructions) have their own systematic mappings between thematic roles and syntactic positions (e.g., subject, object, etc.).[8]

A central and unresolved question in linguistics and psycholinguistics is what the set of thematic roles is. Are there a small number of very broad roles, perhaps with each one mapping onto a single canonical syntactic position? Or are there many distinct roles, several mapping to the same syntactic position but conveying subtly different meanings? The present paper explores the breadth of these thematic categories by looking closely at one example: the goal-like roles in events of transfer of possession and caused motion. Consider, for instance, the prepositional-object dative and theme-first locative sentences in (1).

(1)   a.   The boy <u>hands</u> the suitcase to his mother.   (=prepositional-object dative)

       b.   The boy <u>loads</u> the suitcase on the cart. (=theme-first locative)

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[8] These regularities can be formulated in many ways (e.g., Baker, 1988; Dowty, 1991; Fillmore, 1968; Fisher, Gleitman & Gleitman, 1991; Gruber, 1965; Jackendoff, 1972, 1983, 1990; Levin, 1993; for review, see Levin & Rappaport Hovav, 2005). In the present paper, we follow the convention in psycholinguistics and conceptualize them as mappings between thematic roles and syntactic positions.

Both constructions have the same surface phrase structure (i.e., NP-V-NP-PP). Correspondingly, many theorists also assume parallel semantic representations across the two cases (e.g., Anderson, 1971; Baker, 1996; Harley, 2003; Goldberg, 1995, 2002, 2006; Gruber, 1965; Lakoff & Johnson, 1980; Jackendoff, 1972, 1983; Pylkkänen, 2008). For instance, Jackendoff's (1983) Localist Hypothesis subsumes both of the prepositional arguments in (1), mother in (1a) and cart in (1b), under the same umbrella role of goal. We will refer to this possibility as the *broad roles hypothesis*. Other theorists maintain distinct semantic representations for the two prepositional phrase arguments, typically a recipient for prepositional-object datives and a destination for theme-first locatives (e.g., Bresnan & Kanerva, 1989; Pinker, 1989; Rappaport Hovav & Levin, 2008; for discussion, see Levin & Rappaport Hovav, 2005).[9] This we will call the *narrow roles hypothesis*. To address the viability of these two hypotheses, we turn to structural priming.

Structural priming is the tendency for speakers to reuse previously encountered sentence structures across utterances (Bock, 1986; for discussion, 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) showed that speakers were more likely to describe a picture with a prepositional-object dative ("The man is reading a story to the boy") following another prepositional-object dative ("A rock star sold some cocaine to an undercover agent") than following a double-object dative ("A rock star sold an undercover agent some cocaine"). Importantly, priming withstands variation in lexical items from prime to target and even variation in tense, aspect, and number (Bock, 1986; Pickering & Branigan, 1998). Structural priming also does not result solely from parallels in metrical structure (Bock & Loebell, 1990). For these reasons,

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[9] Destinations are variously referred to as (spatial) goals or locations in the literature (for review, see Levin & Rappaport Hovav, 2005). To avoid confusion, either with the umbrella role goal or locations that are not specifically spatial goals, we use the term destination throughout this paper.

psycholinguists use this priming to investigate the structural representations constructed during language production (Branigan & Pickering, 2017).

3.1.1. Structural priming as a window onto thematic structure

For those familiar with this literature, it may seem counterintuitive to use structural priming to investigate thematic roles, since structural priming is often regarded as a largely syntactic phenomenon (e.g., Branigan, 2007; Branigan & Pickering, 2017; Branigan, Pickering, Liversedge, Stewart, & Urbach, 1995; Chang, Dell, & Bock, 2006). However, a growing body of literature demonstrates that structural priming can occur on purely a thematic basis (e.g., Cai, Pickering, & Branigan, 2012; Chang, Bock, & Goldberg, 2003; Cho-Reyes, Mack, & Thompson, 2016; Hare & Goldberg, 1999; Köhne, Pickering, & Branigan, 2014; Pappert & Pechmann, 2014; Salamoura & Williams, 2007; Yi & Koenig, 2016; Ziegler, Snedeker, & Wittenberg, 2017a). For example, Chang et al. (2003) found that speakers were more likely to produce theme-first locative sentences ("The farmer heaped straw onto the wagon") following other theme-first locatives ("The maid rubbed polish onto the table") relative to theme-second locative primes ("The maid rubbed the table with polish"), despite the two having the same surface syntax (both NP-V-NP-PP). Crucially, thematic structural priming persists even after factoring out several well-known confounds, including prepositional overlap, animacy cues, and morphosyntactic marking (Ziegler et al., 2017a). Thus, this priming can only be explained as priming based on the ordering of the thematic roles. By isolating this thematic component of priming from the influence of syntax, we will be able to address our central question.

But hasn't the specific question of whether recipients and destinations prime each other already been addressed? Indeed, Bock and Loebell (1990, Exp. 1) found that participants produced as many prepositional-object dative descriptions after motion verb sentences with locative prepositional phrases ("The wealthy widow drove an old Mercedes to the church") as after other prepositional-

object dative primes ("The wealthy widow gave an old Mercedes to the church"), relative to a double-object dative baseline ("The wealthy widow gave the church an old Mercedes").[10] On the *narrow roles hypothesis*, church in the prepositional-object sentence is a recipient but a destination in the motion verb sentence. Yet the two led to equivalent priming, in accordance with the *broad roles hypothesis*. Importantly, however, both constructions also have the same surface syntax (both NP-V-NP-PP), while the double-object dative baseline Bock and Loebell (1990) used is different in both thematic *and* surface structure. Thus, this finding cannot distinguish between priming on the basis of thematic roles and priming based on syntax, or simultaneous priming of both structures. Moreover, some of the motion verbs Bock and Loebell (1990) used were actually non-alternating datives (e.g., *return*; see Levin, 1993), further muddying the intended distinction.

In a replication of this work, Potter and Lombardi (1998) did find, however, that prepositional-object dative primes led to a greater proportion of prepositional-object dative responses relative to motion verb primes. This is consistent with participants having treated the thematic structures of the two sentences differently, despite their shared surface syntax. Nevertheless, Potter and Lombardi's (1998) motion verb sentences had *inanimate* location arguments (e.g., "Lenore drove her new convertible to the beach early this afternoon"), while their dative primes and targets had *animate* recipients (e.g., "The prompt secretary wrote a message to her boss every week"). We know that animacy can influence priming (see section 3.1.2 below). Thus, this finding is equally ambiguous. We return to these issues in Exp. 11.[11]

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[10] Bock and Loebell (1990) refer to these motion verb sentences as "(prepositional) locatives." However, we reserve the term locative for those change-of-location verbs, introduced in our discussion of Chang et al. (2003), that alternate between two sentence configurations (following, e.g., Levin, 1993; Pinker, 1989).

[11] Salamoura and Williams (2007, Exp. 3) also investigated the priming of datives by transitive sentences with locative prepositional phrases. However, since their study investigated priming from one language to another, rather than within the same language, it is not clear how to interpret these results in the context of the current discussion. Nevertheless, although not significant across all comparisons, the authors observed the same general pattern of results as Potter and Lombardi (1998).

There are two other phenomena that involve priming across constructions (cross-structural priming) which potentially address our question about the scope of thematic roles. The first is the much-replicated observation that benefactive constructions ("John baked a cake for Susan") prime dative constructions ("John gave a cake to Susan") (Bock, 1989; Chang et al., 2003; Pappert & Pechmann, 2013). This observation *could* suggest that beneficiaries and recipients take the same thematic role, in support of the *broad roles hypothesis*. But these findings, like those in Bock and Loebell (1990) above, are also compatible with a purely syntactic explanation: prepositional-object structures prime other prepositional-object structures (e.g., "A cheerleader saved a seat for her friend" → "The girl is handing the paintbrush to the man on the ladder"), and double-object structures prime other double-object structures (e.g., "A cheerleader saved her friend a seat" → "The girl is handing the man on the ladder the paintbrush") (Bock, 1989).

The final phenomenon, and the more informative one, is the priming of datives by fulfilling verbs, which either place the theme first (e.g., "John provided funds to the school") or second (e.g., "John provided the school with funds"). Hare and Goldberg (1999; also Cho-Reyes, Mack, & Thompson, 2016; Salamoura & Williams, 2007) found that, like double-object datives, theme-second fulfilling verbs (e.g., "His editor credited Bob with the hot story") resulted in more double-object dative responses to targets (e.g., "A man hands a woman a box of candy"), relative to a prepositional-object dative baseline (e.g., "His editor promised the hot story to Bob"). This cannot be due to priming of the surface syntax: theme-second fulfilling constructions have the same syntax as prepositional-object datives (i.e., NP-V-NP-PP) and a different surface structure from double-object datives. Thus, on the basis of syntax alone, theme-second fulfilling verbs should have led to an increase in prepositional-object dative responses, and a corresponding *decrease* in double-object dative responses. The results appear instead to reflect the ordering of thematic roles. As before, this suggests that the roles involved in these two constructions are similar enough to support priming, consistent with the *broad roles hypothesis*. However, these data do not provide substantial constraints

on our theory of thematic roles. On the face of it, both verb classes appear to have post-verbal themes (entities transferred or possessed) and recipients (prototypically animate possessors; see, e.g., McIntyre, 2006; Rappaport Hovav & Levin, 2008). Thus, even on a narrow construal of thematic roles, fulfilling verbs and datives have parallel roles and mappings. Consequently, the question of whether recipients and destinations belong to a single broader class remains open.

3.1.2. Structural priming and animacy

A related question concerns what the role of animacy is in these previous findings. Two things are clear. First, thematic role priming cannot be reduced to animacy. For example, in Chang et al. (2003), both post-verbal arguments were inanimate, and thus animacy was equated across the two constructions (see also Bernolet, Hartsuiker, & Pickering, 2009; Carminati, van Gompel, Scheepers, & Arai, 2008; Cho-Reyes et al., 2016; Huang, Pickering, Yang, Wang, & Branigan, 2016; Köhne, Pickering, & Branigan, 2014; Ziegler et al., 2017a). Second, it is also clear that animacy *can* influence priming (Bock, Loebell, & Morey, 1992; Gámez & Vasilyeva, 2015; for review and discussion, see Branigan, Pickering, & Tanaka, 2008). For example, Bock et al. (1992) found that participants were more likely to use animates as subjects in their target descriptions, for both active and passive sentences, if the prime sentence also had an animate subject. Moreover, Gámez and Vasilyeva (2015) found that these influences interacted in children, such that passive priming was even greater when primes and targets matched in animacy features (e.g., both with animate patients) than when they mismatched (e.g., animate patient in one vs. inanimate patient in the other). Because datives, benefactives, and fulfilling verbs all have one animate post-verbal argument and one inanimate post-verbal argument, this leaves open the possibility that the cross-structural priming effects reviewed above (benefactive-to-dative, fulfilling-verb-to-dative) may well have been carried, in part or entirely, by these differential animacy cues rather than the thematic (or syntactic) structures alone. Cho-Reyes et al. (2016) controlled for the influence of animacy on fulfilling-verb-to-dative-

priming by using fulfilling verb primes that had inanimate recipients (e.g., "The critic is crediting the restaurant with the dessert"). This created a mismatch in the animacy features of the recipient roles for the fulfilling verb primes and the dative targets. Crucially, priming persisted despite this mismatch, suggesting that it was the roles themselves that were primed and not the animacy features per se. However, the magnitude of priming appeared to be smaller with this mismatch (29% vs. 22%).[12]

One straightforward interpretation of these findings is that animacy is an independent contributor to priming, such that priming is boosted if both thematic structure and animacy move in the same direction, but either component alone can create priming. This would be consistent with the findings for passives (e.g., Bock et al., 1992; Gámez & Vasilyeva, 2015). Alternatively, it is also possible that animacy is a defining property of recipients (e.g., Goldberg, 1995), such that changing the animacy of the role filler completely changes the nature of the role itself. Under this type of account, Cho-Reyes et al.'s (2016) priming from fulfilling verbs to datives in the face of mismatching animacy features could have been due to participants interpreting the putatively inanimate recipient in the fulfilling verb sentences (e.g., restaurant) as referring to an animate entity (e.g., chef, restaurant staff, etc.), thereby equating the thematic roles across the two constructions (for related discussion pertaining to datives, see Harley, 2003). It therefore remains to be seen exactly whether and how changes in animacy of the recipient argument alter dative priming in particular. In the experiments that follow, we will explore the role of animacy in conjunction with and independent of thematic roles.

3.1.3. Current study

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[12] This magnitude difference was not significant, but with only 13 participants in total, their study was likely underpowered to detect the interaction (see, e.g., Mahowald et al., 2016).

To more directly address how broad thematic roles are, we asked whether locative constructions would prime dative constructions (and vice versa). We chose these two verb classes because of the proposed distinction in their respective thematic roles on a narrow role construal: Locatives have a destination role and datives have a recipient role (Levin & Rappaport Hovav, 2005). Importantly, destinations differ from recipients in several respects. Recipients are typically animate, and they must possess the theme, as in (2a); destinations (2b) do not need to meet either criterion (McIntyre, 2006; Rappaport Hovav & Levin, 2008). In contrast, a destination is necessarily the physical locus of the theme at the end of the event (2b), while a recipient is not (2a) (Rappaport Hovav & Levin, 2008).

(2)   a.   John bequeathed the castle to Alice.

       b.   John piled the books on the table.

If destinations and recipients are both instances of the broader role goal, in line with the *broad roles hypothesis*, then we should expect to see differences in priming between the two locative types on participants' dative productions and between the two dative types on participants' locative productions. Specifically, theme-first locatives should lead to a greater proportion of prepositional-object dative responses (and vice versa), since they both order their themes before their non-themes; and double-object datives should lead to a greater proportion of theme-second locative responses (and vice versa), since they both order their non-themes before their themes. If, however, destinations and recipients constitute distinct thematic roles, according to the *narrow roles hypothesis*, then we should observe no priming between locatives and datives. Importantly, in neither direction can syntax play a role. Both locative types have the same surface phrase structure as prepositional-object datives (NP-V-NP-PP), such that any differences we see in the priming of prepositional-object datives by locatives cannot be due to syntax. Conversely, both locative sentence types have a different phrase

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structure from double-object datives (NP-V-NP-PP vs. NP-V-NP-NP), so we also shouldn't see any differences in double-object dative productions on the basis of phrase structure either. Rather, only if thematic roles are broadly shared across locatives and datives do we expect any priming between the two classes.

But to ask this question, we must also consider the ways in which animacy interacts with thematic roles. Recall that our key contrast (locatives vs. datives) differs not only with respect to the putative thematic roles involved, but also with regard to the typical animacy features of the fillers of those roles. This raises the possibility that our results might reflect differences in animacy across our materials rather than properties of the thematic roles themselves. To address this concern, we also conduct two extensions of our locative-to-dative priming in particular. Specifically, we constructed locative prime sentences that have either animate destinations (e.g., "The boy sprayed the man with the cologne / the cologne on the man") or animate themes (e.g., "The girl loaded the trailer with the horses / the horses onto the trailer"), thus now matching the animacy features of the dative targets themselves (one animate argument, one inanimate argument), but in opposite directions.

In pursuing these critical cases, we also replicate five key findings in the literature on which they are built: (1) dative-to-dative priming (e.g., Bock, 1986), (2) locative-to-locative priming (e.g., Chang et al., 2003), (3) benefactive-to-dative priming (e.g., Bock, 1989), (4) fulfilling-verb-to-dative priming (e.g., Hare & Goldberg, 1999), and (5) motion-verb-to-dative priming (Bock & Loebell, 1990). Our motivations for replication are threefold. First, some of these findings have only been replicated a couple times (e.g., Bock & Loebell, 1990; Chang et al., 2003; Hare & Goldberg, 1999), sometimes with conflicting results (e.g., Potter & Lombardi, 1998). Our critical experiments can only be interpreted if we are confident in the stability of these basic effects. Second, in the current studies, we switch from a lab-based production paradigm to an online paradigm using Amazon Mechanical Turk. These replications ensure that the known effects are present and robust in an online population.

Finally, we need to be sure that the materials we have constructed reliably elicit the intended priming effects, thereby making any potential priming failures more interpretable.

A final critical feature of the present study is the large sample size and emphasis on self-replication, both of which we hope will contribute to the stability of the literature on structural priming. Except for direct replications, we use a standard sample size of 172 participants per experiment (but 174 for Exp. 11), which is 2 to 6 times larger than most existing structural priming work. We also self-replicate all but 2 of our critical experiments (see below), with an even larger sample size of 300 in each case.

3.2. Methods Overview

All eleven experiments reported here were administered online via Amazon Mechanical Turk using psiTurk (Gureckis et al., 2016), both to increase sample size and to target a more representative cross-sectional population of English-speakers (as opposed to typical college convenience samples). Several of these replicate findings in the literature. Experiments 1 and 2 replicate priming within the two sets of constructions that are the focus of this paper (datives and locatives, respectively), validating our method and providing a baseline for the studies that follow. Experiment 3 explores priming within locatives in the face of conflicting animacy features from prime to target. Experiments 4 and 5 include the critical cross-structural cases of locative-to-dative priming and dative-to-locative priming, respectively. Experiments 6 and 7 verify that this kind of priming is independently motivated by replicating two key cross-structural priming effects within the literature. Experiments 8 and 9 reexamine locative-to-dative priming with matched animacy features from prime to target. Experiment 10 tests for cross-structural priming between fulfilling verbs and locatives. Finally, Exp. 11 revisits the priming of datives by motion verbs (i.e., Bock & Loebell, 1990). To ensure the stability of our findings, we replicated all studies that were not direct replications (with the exception of Exps. 10 and 11, which produced clear and predicted effects).

Each of these replications included an even larger sample size (N=300). (For a summary of all eleven experiments, see Table 3.1.)

Exp.	Prime Type	Target Type	Motivation	Priming	Contributor(s) to Priming
			Table 3.1. Summary of experiments.		
1	Dative	Dative	Replicate Bock (1986)	31%, $p<.001$*	Syntax, narrow thematic roles, and animacy
2	Locative	Locative	Replicate and extend Chang, Bock, & Goldberg (2003)	21%, $p=.004$*	Narrow thematic roles
3	Locative (with **animate destinations**)	Locative	Replicate and extend Chang, Bock, & Goldberg (2003); test for role of animacy	8%, $p=.004$* (6%, $p=.03$*)[†]	Narrow thematic roles
4	Locative	Dative	Test for priming of broad roles	3%, $p=.35$ (0%, $p=.96$)[†]	None
5	Dative	Locative	Test for priming of broad roles	1%, $p=.54$ (5%, $p=.19$)[†]	None
6	Benefactive	Dative	Replicate Bock (1989)	21%, $p<.001$*	Syntax, narrow thematic roles, and animacy
7	Fulfilling verb	Dative	Replicate and extend Hare & Goldberg (1999)	13%, $p=.02$*	Narrow thematic roles and animacy
8	Locative (with **animate destinations**)	Dative	Test for role of animacy	7%, $p=.03$* (5%, $p=.02$*)[†]	Animacy
9	Locative (with **animate themes**)	Dative	Test for role of animacy	-6%, $p=.01$* (-4%, $p=.003$*)[†]	Animacy
10	Fulfilling verb	Locative	Test for priming of broad roles	0%, $p=0.75$	None

11	Dative	Dative	Revisit Bock & Loebell (1990)	23%, *p*<.001*	Syntax, narrow thematic roles, and animacy
	Motion verb			12%, *p*<.001*	Syntax and animacy
* Significant at the *p*<.05 level.					
† Self-replication results in parentheses.					

3.2.1. Participants

2,914 native English speakers recruited from Amazon Mechanical Turk participated in these experiments (1,827 female, 1,039 male, 15 trans, 17 unreported; mean age=34[SD=11], range=18-77, 61 unreported). All participants provided written consent prior to participating and received $1.00 for their participation.

3.2.2. Materials

3.2.2.1. Experiments 1-10

Each study consisted of 8 critical trials interspersed with 8 filler trials, for a total of 16 trials. All trials included a sequence of two prime sentences, presented verbally as audio clips, followed by a target animation, to be described by participants. Each prime sentence was paired with two cartoon still images. The images depicted two separate events, one consistent with the prime sentence and one distractor (a different event with the same agent). For within-structure priming (Exps. 1-3), primes and targets contained one of eight alternating verbs in one of two constructions, each appearing once as a target and twice as primes (in different pairings). For cross-structural priming (Exps. 4-10), primes and targets contained one of sixteen alternating verbs from two distinct classes (eight from one class for primes, each appearing twice, and eight from another for targets, each appearing once). In no case did verbs repeat within a trial. (For a summary of all constructions used, see Table 3.2.) Recipients (datives) were always animate. Destinations (locatives) were always

inanimate for target animations, but varied in animacy by experiment for primes (see individual experiments for details). Themes (for both datives and locatives) were always inanimate for target animations, but also varied in animacy by experiment for primes (see individual experiments for details). All prime sentences were normed on Amazon Mechanical Turk for naturalness. Filler trials were the same across all experiments and contained direct objects with either one or two noun phrases (e.g., one: "The man bit the donut"; two: "The woman broke the plate and the jar"). All materials had one of four agents (boy, girl, man, woman), in equal proportions across items.[13] Sentences were prerecorded by an adult male native English speaker (first author). (For a full list of all prime sentences and target animations by experiment, see Appendix B.)

We created four counterbalanced lists within each experiment. Within each list, half of the primes appeared in one form of the alternation, and the other half appeared in the other form. All lists began with a filler trial before the first critical trial, and alternated between filler and critical trials thereafter. There were never more than two critical trials of the same type back-to-back (e.g., prepositional-object trial, filler trial, prepositional-object trial, etc.), and this occurred at equal frequency for one form of the alternation as for the other. Across lists, each target animation occurred an equal number of times with primes of one form as with primes of the other form, and an equal number of times in the first half of the experiment as in the second half of the experiment. All experiments followed this same list setup.

3.2.2.2. Experiment 11

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[13] There were a few trials in which the agent in the second prime sentence was the same as that in the target animation (≤25% per experiment). However, it was never the case that any of the other content items (nouns or verbs) were repeated within a trial. Recent evidence (Scheepers, Raffray, & Myachykov, 2017) suggests that repetition of even the agent argument alone can increase priming. To determine what effect this might have had, we reran each of our models coding for this factor. However, doing so did not alter the observed pattern of results. We therefore report only results of the models as described below.

The materials for Exp. 11 had the same basic structure as those for Exps. 1-10, except for the following changes. Rather than two prime sentence types, Exp. 11 had three: prepositional-object datives, double-object datives, and motion verb sentences with locative prepositional phrases. To keep the number of trials per condition consistent with the previous experiments, we added 4 additional critical trials and 4 additional filler trials, for a total of 12 critical trials, 12 filler trials, and 24 overall trials. Items were counterbalanced across six rather than four lists, subject to the same constraints. The four additional filler trials had the same structure as before.

Table 3.2. Summary of constructions.			
Exp.	**Verb**	**Construction**	**Example**
Primes: 1, 5, 11 Targets: 1, 4, 6-9, 11	Dative	Prepositional-object / double-object	The woman fed the strawberry to the goose / the goose the strawberry.
Primes: 2, 4 Targets: 2, 3, 5, 10	Locative	Theme-first / theme-second	The boy sprayed the water on the plant / the plant with the water.
Primes: 3, 8	Locative (with **animate destinations**)	Theme-first / theme-second	The boy sprayed the cologne on the **man** / the **man** with the cologne.
Primes: 9	Locative (with **animate themes**)	Theme-first / theme-second	The girl loaded the **horses** onto the trailer / the trailer with the **horses**.
Primes: 6	Benefactive	Prepositional-object / double-object	The man ordered the pizza for the lady / the lady the pizza.
Primes: 7, 10	Fulfilling verb	Theme-first / theme-second	The girl supplied the materials to the contractor / the contractor with the materials.
Primes: 11	Motion verb	Motion verb with locative prepositional phrase	The woman raised the ball above the bird.

3.2.3. Procedure

For prime trials, participants listened to the prerecorded sentences while viewing the cartoon images on a screen (Fig. 3.1). Participants were instructed to select which of the two images matched the sentence being played. Across all eleven experiments and five self-replications, participants were highly accurate (all>97.9%, overall=99.1%) on this task.

On target trials, participants were shown a three-second cartoon animation of an event, along with a word to be used to describe that event. This word was our target verb (dative or locative), and was presented to increase the likelihood that participants would use the intended constructions and decrease the likelihood of verb overlap between primes and targets. The target verb was displayed in capital letters above the animation (see Fig. 3.1). Participants' responses were recorded for later coding.
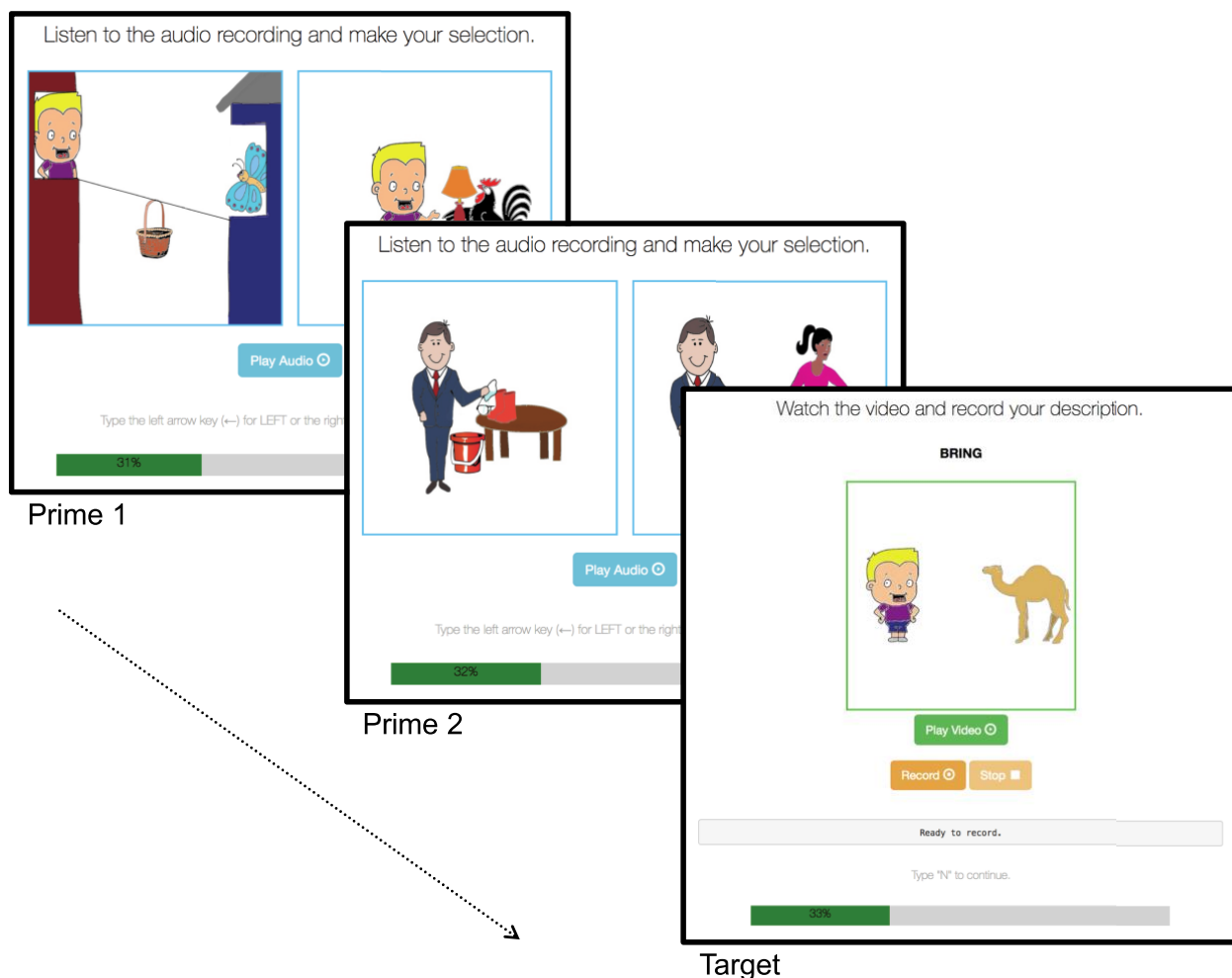
Figure 3.1. Procedure and example materials.

3.2.4. Design

For all experiments, the independent variable was Prime Type (Prepositional-object vs.

Double-object for Exps. 1, 5, and 6; Theme-first vs. Theme-second for Exps. 2-4 and 7-10;

Prepositional-object vs. Double-object vs. Motion verb for Exp. 11), and the dependent measure was

the number of prepositional-object datives (Exps. 1, 4, 6-9, 11) or theme-first locatives (Exps. 2, 3, 5,

10) produced by participants (coded as 1, with double-object datives/theme-second locatives coded

as 0) out of all dative (prepositional-object+double-object) or locative (theme-first+theme-second)

responses, respectively. In presenting the production cell means (for descriptive purposes), we have

aggregated over both participants and items (prepositional-object/prepositional-object+double-object, theme-first/theme-first+theme-second).

3.2.5. Coding

Participants' recorded responses were coded as "prepositional-object," "double-object," or "other" for dative targets, and as "theme-first," "theme-second," or "other" for locative targets. Prepositional-objects were sentences with a post-verbal THEME followed by the preposition *to* and a RECIPIENT. Any responses with this ordering that omitted the preposition *to* or used a different preposition altogether (e.g., *at*) were counted as other. Double-objects were sentences with a post-verbal RECIPIENT followed by a THEME, without any intervening prepositions. Theme-firsts were sentences with a post-verbal THEME followed by a locational preposition and a DESTINATION. Here we accepted the prepositions *on(to)*, *in(to)*, *around* (e.g., "The woman wrapped a bandage around the boy's arm"), and *all over* (e.g., "The boy smeared mud all over the house"). Finally, theme-seconds were sentences with a post-verbal DESTINATION followed by the preposition *with* and a THEME. Here the preposition was usually *with*, although we also counted *in* for the verb *wrap* (e.g., "The woman wrapped the boy's arm in a bandage"). All other forms were counted as other, including any responses that omitted an argument altogether or that included prepositions that were ambiguous or inconsistent with the expected thematic role (e.g., *inside* or *behind*). Responses in which participants used a different verb than we expected were included in the analysis so long as the verb produced was also an alternating dative or locative verb and was different from the verbs used in the primes (for Exps. 1-3). In total, 20,773 of the 23,665 target descriptions produced were dative (94.9%) or locative (76.6%) constructions and thus entered into the analysis, with no differences in the number of excluded trials by Prime Type within each experiment (Exp. 1: 2.5% prepositional-object loss, 4.9% double-object loss; Exp. 2: 17.9% theme-first loss, 20.9% theme-second loss; Exp. 3+replication: 22.2% theme-first loss, 20.5% theme-second loss; Exp. 4+replication: 5.7% theme-

first loss, 5.1% theme-second loss; Exp. 5+replication: 25.3% prepositional-object loss, 25.0% double-object loss; Exp. 6: 5.4% prepositional-object loss, 3.9% double-object loss; Exp. 7: 6.4% theme-first loss, 3.4% theme-second loss; Exp. 8+replication: 6.6% theme-first loss, 4.3% theme-second loss; Exp. 9+replication: 4.2% theme-first loss, 4.8% theme-second loss; Exp. 10: 24.8% theme-first loss, 25.7% theme-second loss; Exp. 11: 4.8% prepositional-object loss, 6.3% double-object loss, 5.5% motion verb loss). Twelve percent of the target responses for Exps. 1, 2, 6, and 7, and ten percent of the target responses for Exps. 3-5 and 8-11 were independently coded by a second coder. Intercoder reliability ratings were overall very high (all>93.8%, all Cohen's κs>.89).

3.2.6. Data analysis

For each experiment, participants' productions were analyzed using a logistic mixed-effects model (Baayen, Davidson, & Bates, 2008; Jaeger, 2008) in the lme4 package in R (Bates, 2010), with Prime Type as a fixed effect. We used the maximal random effects structure appropriate for this experimental design (Barr, Levy, Scheepers, & Tily, 2013), including random intercepts for participant and item (target verb) and random slopes for Prime Type within both participants and items. Follow-up analyses for Exp. 11 were run on the same model, minus the relevant level of Prime Type. All fixed effects were effect coded (1, -1). Confidence intervals were computed by running the `confint` function on the glmer model in the R stats package.[14] Model goodness-of-fit (R^2) was calculated on the correlation between fitted and observed values.[15]

Where appropriate, we also looked for pairwise interactions of Prime Type by Experiment, when target trials were the same. For these analyses, our models included Prime Type, Experiment,

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[14] https://www.rdocumentation.org/packages/stats
[15] r2.corr.mer<-function(m){
       lmfit<-lm(model.response(model.frame(m))~fitted(m))
       summary(lmfit)$r.squared}

and their interaction as fixed effects, with the same random effects structure as before. Both fixed effects were effect coded (1, -1).

3.3. Experiment 1: Replicating Bock (1986)

Experiment 1 replicates Bock's (1986) finding of dative-to-dative priming. This finding has been frequently replicated (see Mahowald et al., 2016). Our goals in doing this are to validate our experimental paradigm and dative stimuli, and to provide a baseline for the priming effects in the subsequent experiments.

3.3.1. Materials

Prime and target stimuli for Exp. 1 used the following eight alternating dative verbs: *bring*, *feed*, *give*, *hand*, *pass*, *send*, *show*, and *throw*.

3.3.2. Results

As expected, Exp. 1 (N=52) yielded a significantly increased proportion of prepositional-object dative productions following prepositional-object dative primes relative to double-object dative primes (75% vs. 43%), β=.95(SE=.16), z=5.94, p<.001, 95% CI [.65, 1.32], R^2=.48 (Fig. 3.2).

3.3.3. Discussion

These results validate our dative materials and confirm that conducting structural priming studies online is a viable alternative to lab-based testing.

3.4. Experiments 2 and 3: Replicating and Extending Chang et al. (2003)

Experiments 2 and 3 replicate and extend Chang et al.'s (2003) locative findings and validate our locative stimuli. These studies make three contributions to the literature. First, locative priming

has been studied far less than dative priming. To the best of our knowledge, the only published conceptual replication of Chang et al. (2003) is Yi and Koenig (2016). Critically, both Chang et al. (2003) and Yi and Koenig (2016) used a different paradigm than the Bock studies and our own experiments. In these studies, participants saw sentences presented rapidly and repeated them back (following Potter & Lombardi, 1998). Thus, it is critical that we replicate locative priming in an event description task to establish the presence and magnitude of this effect.

Second, one limitation of Chang et al.'s (2003) stimuli is that most of the destinations they used were singular count nouns (e.g., table), while most of the themes they used were mass or plural nouns (e.g., polish, pins). We know that mass and plural nouns are similar to each other and distinct from count nouns (e.g., Chierchia, 1998), leaving open the possibility that priming in the original Chang et al. (2003) involved a mapping between these conceptual features of noun phrases and syntactic functions (for further discussion, see Chang et al., 2003). We addressed this possibility in Exp. 2 by varying our themes across the primes and targets, such that when the primes had mass themes the targets had discrete, non-plural themes, and vice versa (e.g., prime themes: water, lemonade; target theme: suitcase).

Third and finally, one key feature of locatives, in contrast to datives, is that both of their post-verbal arguments can be, and typically are, inanimate. Thus, locative priming cannot be explained as a mapping between animacy and word order. However, in our later experiments, we will be looking for priming between locatives and datives, which would require that priming persist despite animacy differences in the arguments. In Exp. 3, to ensure that this can occur when the construction and narrow thematic roles are held constant, we constructed locative primes with animate destinations and used targets with destinations that were inanimate (see below). Prior work on the role of animacy in priming has found that priming persists despite animacy mismatches from prime to target (Bock et al., 1992; Gámez & Vasilyeva, 2015). Priming also clearly occurs even when animacy cannot be used as a reliable cue to argument order, as is true for the locatives (see also Bernolet et al., 2009;

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Carminati et al., 2008; Cho-Reyes et al., 2016; Huang et al., 2016; Köhne et al., 2014; Ziegler et al., 2017a). Thus, we expect to find priming in Exp. 3, in line with this past work. However, as reviewed above, animacy can also play a pivotal role in priming (Bock et al., 1992; Gámez & Vasilyeva, 2015). Thus, introducing conflicting animacy features might well reduce the size of the priming effect. We will investigate this possibility by comparing the effects we find in Exp. 3 with those in Exp. 2.

3.4.1. Materials

Prime and target stimuli for Exp. 2 used the following eight alternating locative verbs: *load*, *pack*, *rub*, *smear*, *splash*, *spray*, *stuff*, and *wrap*. Prime stimuli for Exp. 3 used the following eight alternating locative verbs: *inject*, *load*, *pump*, *rub*, *splash*, *splatter*, *spray*, and *wrap*. Target stimuli for Exp. 3 were the same as in Exp. 2. Prime sentences for Exp. 3 had animate destination and inanimate theme arguments (e.g., "The boy sprayed the man with the cologne / the cologne on the man"), while the target animations, as in Exp. 2, had inanimate destinations and inanimate themes (e.g., "Boy loading the cart with the suitcase / the suitcase on the cart").

3.4.2. Results

We found a significant increase in the proportion of theme-first locative productions following other theme-first locative primes, both for Exp. 2 (N=52) (83% theme-first vs. 63% theme-second), β=1.05(SE=.37), z=2.85, p=.004, 95% CI [.51, 2.24], R^2=.44, and for Exp. 3 (N=172) (80% theme-first vs. 72% theme-second), β=.43(SE=.15), z=2.90, p=.004, 95% CI [.14, .83], R^2=.35. A self-replication (N=300) of Exp. 3 yielded similar results (80% theme-first vs. 73% theme-second), β=.22(SE=.10), z=2.17, p=.03, 95% CI [-.03, .43], R^2=.32 (Fig. 3.2).

A comparison of the effects in Exp. 3+replication to those in Exp. 2 (total N=524) yielded a significant Prime Type by Experiment interaction, β=.23(SE=.08), z=2.79, p=.005, 95% CI [.07, .41], R^2=.34, with priming in Exp. 2 greater than that in Exp. 3+replication (21% vs. 7%).

3.4.3. Discussion

These results provide a conceptual replication of Chang et al. (2003) within a new paradigm and validate the sensitivity of our method and our locative materials. Moreover, we have demonstrated that locative priming occurs despite mismatches in animacy across primes and targets (Exp. 3 and its replication). Critically, we also found that priming is significantly reduced by these animacy mismatches. This accords with past work that has also found persistent, albeit reduced, priming in the face of conflicting animacy features (e.g., Gámez & Vasilyeva, 2015).

3.5. Experiments 4 and 5: Assessing the Priming of Broad Roles

The central question of this paper is what the scope of thematic roles is. Are there a few very broad roles that each map to a single canonical syntactic position? Or are there many distinct roles, some of which map to the same syntactic structural position but convey different meanings? Having established the sensitivity of our paradigm and replicated the critical prior findings, we now address this question by looking at priming between locatives and datives. The *broad roles hypothesis* treats the thematic structures underlying both locatives and datives as the same (themes and goals), such that we should expect priming between the two classes. The *narrow roles hypothesis*, on the other hand, treats their thematic structures as distinct (themes and destinations for locatives vs. themes and recipients for datives), which, accordingly, should not yield priming between them. Exp. 4 assesses priming from locatives to datives, and Exp. 5 assesses priming from datives to locatives.

3.5.1. Materials

Prime stimuli for Exp. 4 were the same as in Exp. 2. Target stimuli for Exp. 4 were the same as in Exp. 1. Prime stimuli for Exp. 5 were the same as in Exp. 1. Target stimuli for Exp. 5 were the same as in Exps. 2 and 3.

3.5.2. Results

Participants in Exp. 4 (N=172) produced equivalent proportions of prepositional-object datives following theme-first locative primes as following theme-second locative primes (69% vs. 66%), β=.09(SE=.10), z=.94, p=.35, 95% CI [-.15, .32], R^2=.55, and participants in Exp. 5 (N=172) produced equivalent proportions of theme-first locatives following prepositional-object dative primes as following double-object dative primes (79% vs. 78%), β=-.09(SE=.15), z=-.61, p=.54, 95% CI [-.55, .20], R^2=.47. Self-replications (each N=300) of both experiments yielded similar results: Exp. 4 (64% theme-first vs. 64% theme-second), β=.01(SE=.11), z=.05, p=.96, 95% CI [-.25, .28], R^2=.49; Exp. 5 (81% prepositional-object vs. 76% double-object), β=.14(SE=.10), z=1.30, p=.19, 95% CI [-.12, .41], R^2=.37 (Fig. 3.2).

Priming in Exp. 5+replication was significantly less than priming in Exp. 3+replication (4% vs. 7%), (total N=944) β=.08(SE=.04), z=2.23, p=.03, 95% CI [.01, .16], R^2=.36.[16]

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[16] We did not compare Exps. 1 and 4 because the prime sentences in each differ on more than just their thematic role configurations (e.g., syntax, animacy).
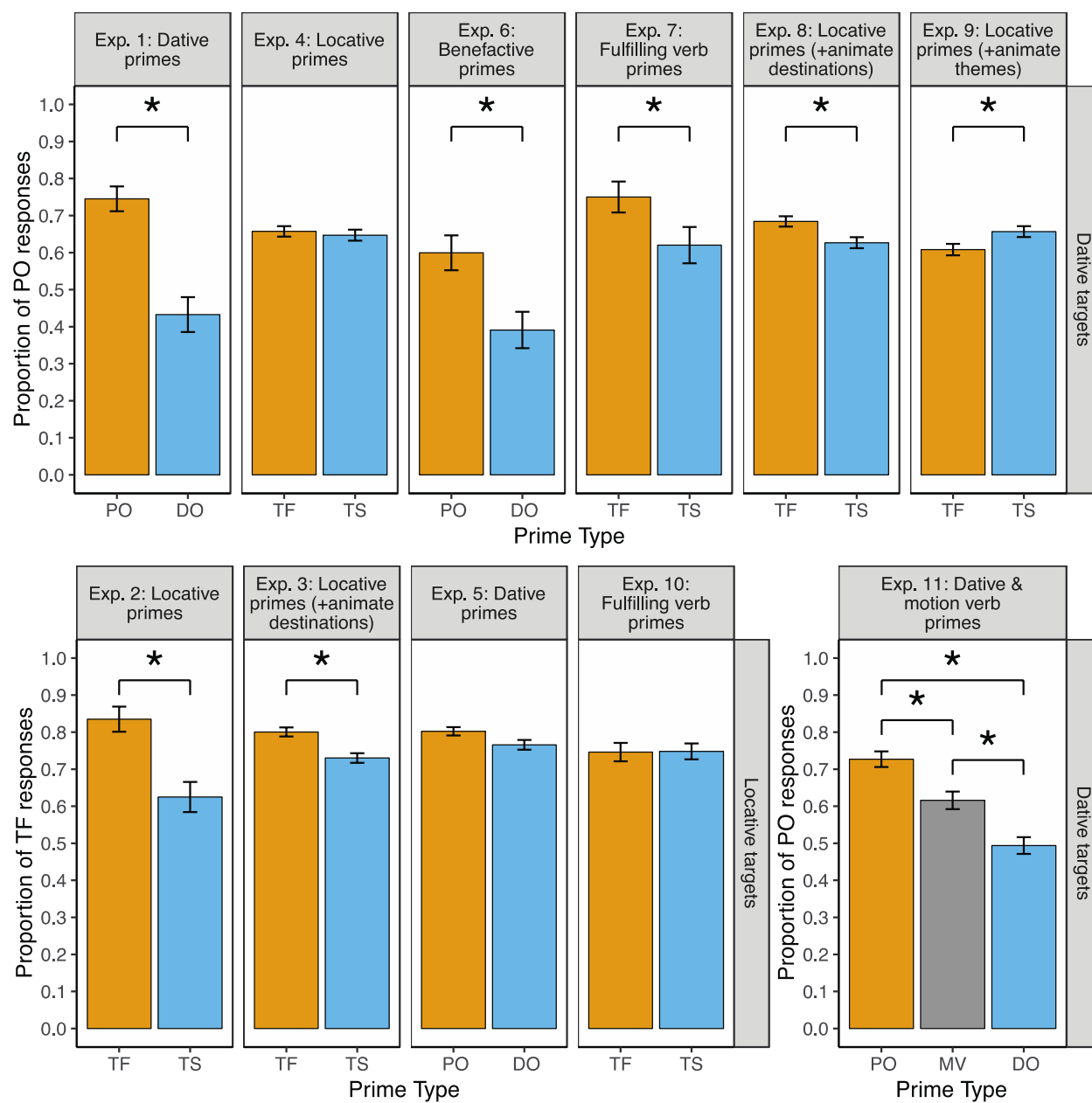
Figure 3.2. Overall proportions of prepositional-object datives and theme-first locatives by Prime Type by experiment (including self-replication data). Error bars reflect by-subject standard errors. PO=propositional-object; DO=double-object; TF=theme-first; TS=theme-second; MV=motion verb.

3.5.3. Discussion

We found no evidence that locatives prime datives (Exp. 4) or that datives prime locatives (Exp. 5). Critically, the comparison between Exp. 5 and its closest control, Exp. 3, resulted in a reliable interaction: Locative primes with animacy mismatches (Exp. 3) have a reliably greater effect on other locatives than datives do (Exp. 5). Since the two forms of the locative share a syntactic structure, and since the animacy mismatches between prime and target are the same for these two studies, the critical difference between Exps. 3 and 5 is in the nature of their thematic roles (the question at the heart of this paper). When the narrow thematic roles match (e.g., locative-to-locative), we get priming; when they do not match (e.g., dative-to-locative), we get no priming. This suggests that the recipient role for datives and the destination role for locatives are distinct, in line with the *narrow roles hypothesis*.

However, there is a second difference between these two experiments that we must address. In Exp. 3, we are priming within the same construction (locatives), while in Exp. 5 (and Exp. 4), we are priming between two different constructions (datives and locatives). This raises the possibility that thematic priming occurs solely within specific constructions (specified for both their syntactic and thematic features) but not across constructions (cross-structurally). Exps. 6 and 7 begin to address this concern.

3.6. Experiments 6 and 7: Replicating Bock (1989) and Hare & Goldberg (1999)

Experiment 6 replicates Bock's (1989) benefactive-to-dative findings, while Experiment 7 replicates and extends Hare and Goldberg's (1999) fulfilling-verb-to-dative findings. As mentioned in the Introduction, the interpretation of our critical experiments requires that priming across constructions (cross-structural priming) be robust and sensitive to thematic role mappings. These replications serve to verify both the robustness of cross-structural priming in the current paradigm (Exps. 6 and 7) and its sensitivity to thematic role ordering in particular (Exp. 7). We extend Hare and Goldberg (1999) in the following way. Their original study and the two subsequent replications

(Salamoura & Williams, 2007; Cho-Reyes et al., 2016) have used only the theme-second variant of fulfilling verbs (e.g., "His editor credited Bob with the hot story"), relative to a prepositional-object dative baseline (e.g., "His editor promised the hot story to Bob"). Here we directly contrast the theme-second variant of fulfilling verbs with its theme-first counterpart (e.g., "His editor credited the hot story to Bob"). This is critical to ensure that it is the thematic ordering that accounts for the cross-structural priming in this case.

3.6.1. Materials

Prime stimuli for Exp. 6 used the following eight alternating benefactive verbs: *bake*, *buy*, *fetch*, *find*, *get*, *make*, *order*, and *save*. Prime stimuli for Exp. 7 used the following eight alternating fulfilling verbs: *credit*, *entrust*, *issue*, *leave*, *present*, *provide*, *serve*, and *supply*. Target stimuli for Exps. 6 and 7 were the same as in Exps. 1 and 4.

3.6.2. Results

As expected, participants in Exp. 6 (N=52) produced significantly more prepositional-object datives following prepositional-object benefactive primes relative to double-object benefactive primes (60% vs. 39%), β=.77(SE=.16), z=4.79, p<.001, 95% CI [.44, 1.16], R^2=.57, and participants in Exp. 7 (N=52) produced significantly more prepositional-object datives following theme-first fulfilling verb primes over theme-second fulfilling verb primes (75% vs. 62%), β=.64(SE=.28), z=2.26, p=.02, 95% CI [.09, 1.36], R^2=.65 (Fig. 3.2).

Priming in Exp. 6 was not significantly different from priming in Exp. 1 (21% vs. 31%), (total N=104) β=.15(SE=.10), z=1.48, p=.14, 95% CI [-.05, .35], R^2=.51. Priming in Exp. 7 was, however, significantly less than priming in Exp. 1 (13% vs. 31%), (total N=104) β=.28(SE=.11), z=2.67, p=.008, 95% CI [.08, .50], R^2=.50, and significantly greater than priming in Exp.

4+replication (13% vs. 1%), (total N=524) β=-.25(SE=.07), z=-3.36, p<.001, 95% CI [-.41, -.10], R^2=.52.

3.6.3. Discussion

These results confirm that the present paradigm is sensitive to priming across constructions (cross-structural priming), using two different contrasts. First, we have replicated Bock (1989; also Chang et al., 2003; Pappert & Pechmann, 2013), showing priming from benefactives to datives (Exp. 6). Second, we have replicated and extended Hare and Goldberg (1999; also Salamoura & Williams, 2007; Cho-Reyes et al., 2016), showing priming from fulfilling verbs to datives (Exp. 7). As noted in the Introduction, however, benefactive-to-dative priming could well be due to surface syntax alone, since prepositional-object benefactives and prepositional-object datives share one constituent structure (i.e., NP-V-NP-PP), while double-object benefactives and double-object datives share another (i.e., NP-V-NP-NP). Critically, priming from fulfilling verbs to datives cannot be explained in this way: Both variants of fulfilling verbs share the same surface syntax. But they have different thematic mappings: theme-first fulfilling verbs have the same thematic ordering as prepositional-object datives, while theme-second fulfilling verbs have the same thematic ordering as double-object datives. Thus, Exp. 7 provides strong evidence for the influence of thematic roles on cross-structural priming, thereby strengthening our results in Exps. 4 and 5.

We also observed a difference in the magnitude of priming in these two experiments. Benefactives (Exp. 6) primed datives as strongly as other datives did (Exp. 1). In contrast, fulfilling verbs primed datives to a lesser degree (Exp. 7). We suspect that this reflects differences in the degree to which the prime and target structures share surface syntax. Past work investigating the relative contributions of the different structural representations to priming (e.g., thematic roles, surface syntax, animacy, information structure, etc.) suggests that priming is cumulative, possibly even additive (e.g., Bernolet, Colleman, & Hartsuiker, 2014; Bernolet et al., 2009; Gámez &

Vasilyeva, 2015; Griffin & Weinstein-Tull, 2003; Vernice, Pickering, & Hartsuiker, 2012; Ziegler et al., 2017a). For example, in our prior work, we found increased priming in dative constructions with strong thematic overlap above and beyond the influences of surface syntax, prepositional overlap, morphosyntax, and animacy (Ziegler et al., 2017a). In short, the more features that align from prime to target, the greater the priming effect. Benefactives are parallel to datives in surface structure, animacy, and likely thematic structure; thus, we expect similar levels of priming. In contrast, while fulfilling verbs and datives have the same mappings of both animacy features and thematic roles to surface positions, they do not share a syntactic structure, yielding less priming. Our finding of enhanced priming in locatives when animacy features matched (Exps. 2 and 3) is also perfectly in line with this notion.

Critically, cross-structural priming between fulfilling verbs and datives (Exp. 7) was also substantially greater than that between locatives and datives (Exp. 4). However, these two experiments are not a minimal pair: In addition to the putative thematic structural differences between the two cases (recipients for both fulfilling verbs and datives but destinations for locatives), Exp. 7 also has parallel animacy-to-linear-order mappings among primes and targets (animate entity to first object vs. second), while Exp. 4 does not. Accordingly, animacy (either alone or in combination with thematic structure) may play a crucial role in dative priming. We explore this possibility in Exps. 8 and 9.

3.7. Experiments 8 and 9: Reassessing Locative-to-Dative Priming with Parallel Animacy Features

To investigate the role that animacy features play in priming involving dative constructions, Exp. 8 asks whether there is locative-to-dative priming when the destinations in locatives share the same animacy features as the recipients in datives. To do this, we used the locative primes with animate destinations from Exp. 3.

Successful priming in this case would, of course, be consistent with at least two possible interpretations. On the one hand, animacy could be an entirely independent contributor to dative priming, in line with the passive results (e.g., Bock et al., 1992; Gámez & Vasilyeva, 2015). Accordingly, matching animacy features from prime to target may well be sufficient to carry priming from locatives to datives, even if the thematic structures are different. If this were so, and assuming additivity of the priming effects, we might expect priming in Exp. 8 to be significantly less than that in Exp. 7, because the priming in Exp. 7 would be based both on shared thematic structure *and* shared animacy mappings while that in Exp. 8 would be based on shared animacy mappings alone. The alternative is that locatives and datives do in fact share a broad goal role, but that the nature of this role is very sensitive to the animacy features of the nouns filling it. If this were so, we might expect that by changing the animacy of the destinations in the locatives we've now created parallel thematic structures across the two constructions (both with animate goals), thereby yielding equivalent levels of priming to Exp. 7. Note that our finding of enhanced priming in locatives when animacy features matched (Exps. 2 vs. 3) is broadly consistent with either interpretation. On the one hand, priming may have been enhanced for Exp. 2 because of the shared combination of thematic structure and animacy mappings compared to just the shared thematic structure in Exp. 3. On the other hand, changing the animacy of the destination role (Exp. 3) may have fundamentally changed the nature of the role itself (though, curiously, not so much so as to wipe out the priming entirely).

To further address this question, we also constructed locative primes with animate themes instead of destinations (Exp. 9), thus equating the animacy features between the datives and the locatives (one animate argument, one inanimate argument) but only when the thematic roles are misaligned (locative themes with dative recipients, locative destinations with dative themes). Specifically, theme-first locatives with animate themes (e.g., "The girl loaded the horses onto the trailer") are now parallel in animacy-to-linear-order mappings (animate before inanimate) to double-object datives rather than prepositional-object datives, while theme-second locatives with animate

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themes (e.g., "The girl loaded the trailer with the horses") now have parallel animacy mappings with prepositional-object datives instead of double-object datives. If animacy is a fully independent source of priming, then we should expect to see, somewhat counterintuitively, a *decrease* in prepositional-object dative productions following theme-first locatives with animate themes, and a corresponding *increase* in double-object dative productions following theme-second locatives with animate themes. This pattern would be in direct opposition to the predictions of the *broad roles hypothesis*. If, on the other hand, animacy is a key factor defining broad thematic roles, but does not exert its own independent influence, then we should expect to see successful priming in Exp. 8, as hypothesized above, but not in Exp. 9.

3.7.1. Materials

Prime stimuli for Exp. 8 were the same as in Exp. 3. Prime stimuli for Exp. 9 used the following eight alternating locative verbs: *cram*, *drape*, *load*, *pack*, *pile*, *stock*, *stuff*, and *wrap*. Target stimuli for Exps. 8 and 9 were the same as in Exps. 1, 4, 6, and 7. As in Exp. 3, prime sentences for Exp. 8 had animate destination and inanimate theme arguments (e.g., "The boy sprayed the man with the cologne / the cologne on the man"), parallel to the target dative animations' animate recipients and inanimate themes (e.g., "Boy bringing the camel the keys / the keys to the camel"). Prime sentences for Exp. 9 had animate theme and inanimate destination arguments (e.g., "The girl loaded the trailer with the horses / the horses onto the trailer"), oppositely parallel to the target dative animations' animate recipients and inanimate themes.

3.7.2. Results

Participants in Exp. 8 (N=172) produced significantly more prepositional-object datives following theme-first locative primes with animate destination roles over theme-second locative primes (68% vs. 61%), β=.22(SE=.10), z=2.22, p=.03, 95% CI [-.01, .45], R^2=.50. Participants in

Exp. 9 (N=172), conversely, produced significantly *fewer* prepositional-object datives following theme-first locative primes with animate theme roles over theme-second locative primes (58% vs. 64%), β=-.22(SE=.09), z=-2.50, p=.01, 95% CI [-.41, -.04], R^2=.55. Self-replications (each N=300) of both experiments yielded similar results: Exp. 8 (69% theme-first vs. 64% theme-second), β=.16(SE=.07), z=2.37, p=.02, 95% CI [-.001, .30], R^2=.51; Exp. 9 (62% theme-first vs. 66% theme-second), β=-.20(SE=.07), z=-2.93, p=.003, 95% CI [-.28, -.04], R^2=.53 (Fig. 3.2).[17]

Priming in Exp. 8+replication was significantly greater than priming in Exp. 4+replication (6% vs. 1%), (total N=944) β=-.08(SE=.03), z=-2.48, p=.01, 95% CI [-.15, -.02], R^2=.51, and significantly less than priming in Exp. 7 (6% vs. 13%), (total N=524) β=.17(SE=.07), z=2.28, p=.02, 95% CI [.02, .33], R^2=.51.

3.7.3. Discussion

In Exps. 8 and 9, we found priming from locatives to datives when the animacy mappings were shared from prime to target. This occurred both when the broad thematic roles were aligned (Exp. 8: animate locative destinations with animate dative recipients, inanimate locative themes with inanimate dative themes) and when they were misaligned (Exp. 9: animate locative themes with animate dative recipients, inanimate locative destinations with inanimate dative themes). Moreover, the effect in Exp. 8 was significantly greater than its closest control (Exp. 4) without the shared animacy mappings. Together, these findings further implicate animacy as an independent contributor to priming from the thematic roles themselves (see also Bock et al., 1992; Gámez & Vasilyeva, 2015), and additionally suggest that the failure to prime between locatives and datives in Exps. 4 and 5 is due to their thematic differences and not merely the differences in their animacy mappings.

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[17] We were unable to compute the profile likelihood confidence intervals on the maximal model for our replication of Exp. 9, so we calculated them instead on a simpler model without the random slopes.

Critically, priming in Exp. 8 was also significantly less than that in Exp. 7. Exps. 7 and 8 are a minimal pair in that they both contain matching animacy features from primes to targets and both cannot be explained by surface syntax. Thus, the most straightforward explanation of these magnitude differences is that thematic structure is additively contributing in Exp. 7 but not in Exp. 8, similar to our Exps. 3 vs. 2 (animacy additively over the thematic roles).

3.8. Experiment 10: Reassessing the Priming of Broad Roles

Our results thus far paint a clear picture of how semantic factors affect priming. Priming occurs both in the face of animacy mismatches from prime to target (Exp. 3) and cross-structurally (Exps. 6 and 7). Yet, priming does not occur between locatives and datives in either direction (Exps. 4 and 5), except for when the priming is plausibly carried by a match in animacy mappings from prime to target rather than by the thematic structures themselves (Exps. 8 and 9). Importantly, we see this lack of priming specifically when the thematic roles from prime to target are seemingly distinct (destinations vs. recipients), in line with the *narrow roles hypothesis*.

As a further test of this claim, we reasoned as follows: Fulfilling verbs prime datives, despite different syntaxes, and both plausibly involve a recipient thematic role, as argued in the Introduction. Indeed, like datives, the non-theme argument in fulfilling verbs is typically an animate entity capable of possession. Locatives and datives do not prime each other, however, which likely reflects a thematic mismatch between the two, in accordance with the *narrow roles hypothesis*: Locatives have a destination role and datives have a recipient role. Correspondingly, by transitivity, if we use fulfilling verbs to prime locatives, we should expect a similar failure, because the two have distinct thematic structures (and distinct animacy mappings).

3.8.1. Materials

Prime stimuli for Exp. 10 were the same as in Exp. 7. Target stimuli for Exp. 10 were the same as in Exps. 2, 3, and 5.

3.8.2. Results

As predicted, participants in Exp. 10 (N=172) did not produce significantly more theme-first locatives following theme-first fulfilling verbs relative to theme-second fulfilling verbs (75% vs. 75%), β=.04(SE=.12), z=.32, p=.75, 95% CI [-.26, .31], R^2=.43 (Fig. 3.2).

Priming in Exp. 10 was significantly less than priming in Exp. 3+replication (0% vs. 7%), (total N=644) β=.12(SE=.05), z=2.43, p=.02, 95% CI [.02, .23], R^2=.35, but not significantly different from priming in Exp. 5+replication (0% vs. 4%), (total N=644) β=.04(SE=.05), z=.77, p=.44, 95% CI [-.06, .15], R^2=.40.[18]

3.8.3. Discussion

We again observe a replicable drop in priming from one construction that plausibly contains a recipient role to another construction that contains a destination role, in favor of the *narrow roles hypothesis* and against the *broad roles hypothesis*. Specifically, our minds appear to treat destination and recipient roles as distinct constructs, at least for the purposes of priming, rather than as the single coherent construct of goal.

3.9. Experiment 11: Revisiting Bock & Loebell (1990, Exp. 1)

Across ten experiments, we found no evidence for priming between constructions that contain a recipient thematic role (e.g., datives, fulfilling verbs) and those that contain a destination role (e.g., locatives), except for when that priming could be carried by animacy alone (Exps. 8 and 9).

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[18] We were unable to compute the profile likelihood confidence intervals on the maximal model for the comparison between Exps. 10 and 5+replication, so we calculated them instead on a simpler model without the random slopes.

This suggests that recipients and destinations are distinct, in line with the *narrow roles hypothesis*, rather than members of a single monolithic category, as argued for by the *broad roles hypothesis*. Recall, however, that Bock and Loebell (1990, Exp. 1) found equivalent priming of prepositional-object dative targets by motion verb sentences with locative prepositional phrases (e.g., "The wealthy widow drove an old Mercedes to the church") as by other prepositional-object datives (e.g., "The wealthy widow gave an old Mercedes to the church"). This finding challenges our conclusions. While prepositional-object datives and motion verb sentences have the same surface syntax (i.e., NP-V-NP-PP), the former have a recipient thematic role while the latter have a destination or location role. Thus, we would have predicted that there would be significantly more priming for the prepositional-object datives (syntax+thematic roles) than for the motion verb sentences (syntax only), given that structural priming is additive, as demonstrated here (e.g., Exps. 1 vs. 7 vs. 8) and elsewhere (e.g., Bernolet et al., 2009, 2014; Gámez & Vasilyeva, 2015; Griffin & Weinstein-Tull, 2003; Vernice et al., 2012; Ziegler et al., 2017a).

However, as we noted in the Introduction, some of Bock and Loebell's (1990, Exp. 1) motion verb sentences contained non-alternating dative verbs (e.g., *return*), which, arguably, have recipient arguments and not destinations. Thus, priming may have been equivalent because the motion verb primes also shared narrow thematic roles with their targets. To verify this intuition, we ran a norming study on Bock and Loebell's (1990, Exp. 1) original prime sentences on Amazon Mechanical Turk. The paper did not contain the full stimulus set, so we were confined to the examples they provided. These included three each of the double-object dative sentences (3a, 4a, 5a), the prepositional-object dative sentences (3b, 4b, 5b), and the motion verb sentences (3c, 4c, 5c).

(3)   a.   The wealthy widow sold the church an old Mercedes.

          b.   The wealthy widow gave an old Mercedes to the church.

          c.   The wealthy widow drove an old Mercedes to the church.

(4)   a.   IBM offered the Sears store a bigger computer.

           b.   IBM promised a bigger computer to the Sears store.

           c.   IBM moved a bigger computer to the Sears store.

(5)   a.   The hospital sent the patient the bill by mistake.

           b.   The hospital showed the bill to the patient by mistake.

           c.   The hospital returned the bill to the patient by mistake.

Participants (N=117; 61 female, 56 male) were asked to rate, for each of 9 sentences, how likely the dative recipient or motion verb location was to now possess the theme, on a 1 to 7 scale (1=not likely at all, 7=very likely). These sentences were interspersed with the motion verb sentences we created for the current work (see below). Strikingly, Bock and Loebell's (1990) motion verb sentences were rated as being *equally* likely to indicate transfer of possession (4.94[SE=.31]) as their dative sentences (4.99[SE=.20]). Our own motion verb sentences (see below), in contrast, were very unlikely to indicate transfer of possession (2.39[SE=.11]). Thus, we conclude that the absence of a difference in priming in Bock and Loebell (1990) is consistent with the *narrow roles hypothesis*.

To the best of our knowledge, the only within-language replication of this study was conducted by Potter and Lombardi (1998).[19] They used motion verbs that do not seem to encode transfer of possession, and they found greater priming for dative primes than for motion verb primes, as we would predict. However, their stimuli were also confounded in another way: The motion verb sentences had *inanimate* location arguments, while both the dative primes and dative targets had *animate* recipients. As we have seen in Exps. 8 and 9 (see also Bock et al., 1992; Gámez & Vasilyeva, 2015), animacy can exert an independent influence in priming. Thus, these results could

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[19] See fn. 11.

be due to the cumulative influence of syntactic structure+animacy for the dative primes but only syntax for the motion verb primes.

To verify this interpretation and provide a final test of our hypotheses, we performed a preregistered conceptual replication of Bock and Loebell (1990, Exp. 1).[20] Specifically, we created motion verb sentences with animate locations that clearly had destination or location roles rather than recipients. The motion verb sentences were constructed by taking the prepositional-object dative prime sentences from our previous experiments (e.g., Exps. 1 and 5) and changing both the verb and the preposition. For example, "The woman threw the ball to the bird" became "The woman raised the ball above the bird." Thus, the prepositional-object datives and motion verbs have the same syntactic phrase structure (i.e., NP-V-PP) and animacy features, but differ in the thematic role assigned to their animate oblique object (see norming results above).

If thematic priming occurs at the level of broad thematic roles (e.g., goal), then we should see no difference in priming between the prepositional-object datives and motion verbs, as in Bock and Loebell (1990). If, on the other hand, the thematic roles are distinct, as our previous results suggest, then we should see more priming for prepositional-object dative primes relative to motion verb primes.

3.9.1. Materials

Prime and target stimuli for Exp. 11 used the following twelve alternating dative verbs (eight old, four new): *bring*, *feed*, *give*, *hand*, *lend*, *offer*, *pass*, *read*, *sell*, *send*, *show*, and *throw*. Prime stimuli for Exp. 11 also used the following twelve non-alternating motion verbs: *carry*, *drag*, *drop*, *haul*, *lift*, *lower*, *lug*, *move*, *pull*, *push*, *raise*, and *spin*.

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[20] Link to preregistration: https://doi.org/10.17605/OSF.IO/PS7B6.

3.9.2. Results

Participants in Exp. 11 (N=174) produced 73% prepositional-object descriptions following prepositional-object primes, 62% prepositional-object descriptions following motion verb primes, and 49% prepositional-object descriptions following double-object primes, suggesting that all three sentence types were treated differently. Accordingly, the full model revealed a significant main effect of Prime Type (ps<.001), with follow-up pairwise analyses confirming that these effects were driven by double-object dative primes yielding significantly fewer prepositional-object dative productions than either prepositional-object dative primes (49% vs. 73%), β=.75(SE=.09), z=8.41, p<.001, 95% CI [.59, .95], R^2=.41, or motion verb primes (49% vs. 62%), β=-.38(SE=.09), z=-4.14, p<.001, 95% CI [-.60, -.19], R^2=.42, consistent with Bock and Loebell (1990). Crucially, however, prepositional-object dative primes also yielded significantly more prepositional-object dative productions than motion verb primes (73% vs. 62%), β=.35(SE=.09), z=4.01, p<.001, 95% CI [.15, .53], R^2=.45 (Fig. 3.2).

3.9.3. Discussion

We do not directly replicate Bock and Loebell's (1990, Exp. 1) original pattern of results. Indeed, although we find significant priming both for datives and motion verbs alike, consistent with this past work, we also find significantly more priming for datives than for motion verbs (see also Potter & Lombardi, 1998). In Potter and Lombardi (1998), this result was ambiguous: Although priming occurred on the basis of syntax for both sentence types, the decreased priming they observed for their transitive sentences with locative prepositional phrases relative to prepositional-object datives could have been due either to the narrow thematic roles not matching up from prime to target (and therefore not boosting priming) or to animacy (which was not shared between prime and target for their transitive sentences but was for their prepositional-object dative sentences). In contrast, our results are straightforwardly consistent with participants having treated the thematic roles of these

two sets of constructions as distinct: Participants were primed by both sentence types on the basis of syntax but significantly more so for prepositional-object datives, which share a narrow thematic role with the prepositional-object dative targets, than for motion verb sentences, which do not share a narrow role with the prepositional-object dative targets. Crucially, this difference cannot be due to differences in animacy (as in Potter & Lombardi, 1998), since both our motion verb sentences and prepositional-object datives had animate prepositional arguments and inanimate themes (and therefore cannot be the reason why the latter led to more priming than the former). This is the pattern of results expected on the *narrow roles hypothesis*, which our previous experiments have also supported, but not on the *broad roles hypothesis*.

3.10. General Discussion

These experiments investigated the scope of structural priming, using it as a tool to explore the grain size of the thematic mappings that guide language production. Specifically, we were interested in whether destination and recipient thematic roles can be subsumed under a single role, goal, in line with the *broad roles hypothesis* (e.g., Anderson, 1971; Baker, 1996; Harley, 2003; Goldberg, 1995, 2002, 2006; Gruber, 1965; Lakoff & Johnson, 1980; Jackendoff, 1972, 1983; Pylkkänen, 2008), or whether the language processing system treats the two as distinct, consistent with the *narrow roles hypothesis* (e.g., Bresnan & Kanerva, 1989; Pinker, 1989; Rappaport Hovav & Levin, 2008). Our overall pattern of results speaks against the *broad roles hypothesis*: We did not find priming between recipients and destinations across distinct constructions, except for when plausibly carried by animacy and/or syntax. For example, there was no priming between locatives and datives (Exps. 4 and 5) or between locatives and fulfilling verbs (Exp. 10) when the datives and fulfilling verbs had animate recipients and the locatives had inanimate destinations. However, we did find priming from locatives to datives when there was an animacy distinction in the locative primes that could influence animacy ordering in the dative targets (Exps. 8 and 9). In addition, we found

significantly greater priming between dative primes and dative targets than between motion verb primes and dative targets (Exp. 11), where the key difference was in the composition of their thematic roles (recipients for datives, destinations for motion verbs). Our results therefore support the *narrow roles hypothesis*, in which destinations and recipients are distinct.

Importantly, our results cannot be reduced to priming on the basis of animacy alone. First, in some cases, animacy cannot have contributed at all (e.g., Exps. 2-5 and 10). We found robust priming among locatives when neither animacy nor syntax provided any clues as to the relative ordering of the post-verbal arguments (Exps. 2 and 3), confirming that purely thematic priming is possible. Second, animacy cannot explain the differences in the magnitude of priming we observed among Exps. 1, 7, and 8 or within Exp. 11. Specifically, we found significantly less priming in Exp. 7 than in Exp. 1 and significantly more priming in Exp. 7 than in Exp. 8. Since the configuration of animate and inanimate arguments in all three cases was the same, animacy cannot account for these differences. Instead, the reason we see the most priming among datives (Exp. 1) is because animacy, syntax, and thematic role ordering are all contributing; the reason we see intermediate priming from fulfilling verbs to datives (Exp. 7) is because both animacy and thematic role ordering (but not syntax) are contributing; and the reason we see the least priming from locatives with animate destinations to datives (Exp. 8) is because only animacy (but neither syntax nor thematic role ordering) is contributing (see Table 3.1). Similarly, we found significantly less priming between motion verb sentences with locative prepositional phrases and datives than between datives and other datives (Exp. 11) precisely because only animacy and syntax contributed to the former, while animacy, syntax, and thematic role ordering all contributed to the latter (see Table 3.1).

Nevertheless, although not reducible to animacy, these results broaden our understanding of the contribution of animacy to structural priming in important ways. For example, we found priming between locatives and datives only when there was an animacy distinction in the locative primes that could influence animacy ordering in the dative targets (Exps. 8 and 9). This occurred both when the

thematic roles were broadly aligned (locative themes with dative themes, locative destinations with dative recipients) and when they were not (locative themes with dative recipients, locative destinations with dative themes). These results confirm that animacy is an independent contributor to priming separate from the influences of either thematic roles or syntax (see also Bock, Loebell, & Morey, 1992; Gámez & Vasilyeva, 2015) and extend animacy priming to a new pair of constructions (locatives and datives).

In the remainder of this discussion, we consider, in turn, (1) the influence of syntax on priming, (2) how current models of priming might account for these results, (3) what the representations underlying thematic priming are likely to be, (4) whether our results speak to a further subdivision of dative verbs, (5) the role of animacy in argument realization, and (6) how to reconcile the centrality of the notion of goal in human cognition with the present results.

3.10.1. Independent influence of syntax on structural priming

Everyone agrees that syntax can be primed (e.g., Branigan, 2007; Branigan & Pickering, 2017; Mahowald et al., 2016; Pickering & Ferreira, 2008; Tooley & Traxler, 2010). We contribute to this consensus additional evidence for the role of syntax as an independent source of priming. Recall that we found no differences in priming between locatives and datives on the basis of thematic structure (Exps. 4 and 5). However, locatives as a class only share the same surface phrase structure with prepositional-object datives (NP-V-NP-PP) and not double-object datives (NP-V-NP-NP). This leaves open the possibility that *both* locative types may have led to an increase in prepositional-object dative productions relative to double-object dative primes, on the basis of shared syntax with the former but not the latter. To test this prediction, we conducted a follow-up analysis combining Exps. 1 and 4 (same dative targets) in a separate logistic mixed-effects model (N=224), with Prime Type (Prepositional-object Dative, Double-object Dative, Locative) as an effect-coded (1, -1) fixed effect and the same maximal random effects structure as before. The model revealed a significant

main effect of Prime Type (ps<.002), with follow-up pairwise analyses confirming a significant difference between locatives and double-object datives (67% vs. 44%), β=-.85(SE=.19), z=-4.49, p<.001, but not between locatives and prepositional-object datives (67% vs. 74%), β=-.03(SE=.17), z=-.16, p=.87. Thus, participants appear to have treated locatives and prepositional-object datives similarly, consistent with priming at the level of syntax (independently of thematic roles and animacy).

3.10.2. Implications for models of priming

Models that instantiate structural priming as implicit learning have gained a lot of traction in recent years (e.g., Branigan & McLean, 2016; Chang et al., 2006; Jaeger & Snider, 2013; Reitter, Keller, & Moore, 2011). One such model, Chang et al.'s (2006) Dual-Path Model, makes explicit use of thematic role information and offers an interesting perspective on the present findings. The Dual-Path Model is a model of sentence production. It uses supervised learning to link sentence forms to messages, and then is tested on how well it creates an accurate grammatical surface structure for a new message. To simulate priming, the model is exposed to a prime sentence word-by-word, adjusts its message-to-sentence weights on the basis of how well it predicted each subsequent word in the sentence, and then uses these adjusted weights to produce a new target sentence from an event representation. If the target sentence matches the structure of the prime, it counts as priming, otherwise it does not.

The Dual-Path Model has the ability to learn two types of syntactic representations: purely structural representations (syntactic phrase structure) and structural representations imbued with meaning (thematic roles) (Chang et al., 2006). Which representation is learned varies across constructions, though syntax is privileged. Specifically, if the model can distinguish two variants of an alternation on the basis of phrase structure alone, as in the case of the dative alternation, it learns a purely syntactic representation: NP-V-NP-NP vs. NP-V-NP-P-NP. If syntax alone does not

differentiate them, as in the case of the locative alternation, then the model learns a syntactic representation supplemented with broad thematic roles: AGENT-V-THEME-P-GOAL vs. AGENT-V-GOAL-WITH-THEME.

Given that the representations learned by the model for these two sets of constructions are different, Chang et al.'s (2006) model correctly predicts that locatives will not prime datives (Exp. 4) and datives will not prime locatives (Exp. 5). Furthermore, the authors found that the model exhibited priming from motion verbs with locative prepositional phrases to prepositional-object datives (p. 249), consistent with our significant difference in Exp. 11 between motion verbs and double-object datives (also Bock & Loebell, 1990; Potter & Lombardi, 1998). Elsewhere (pp. 250-251), Chang et al. (2006) tried a version of the model with thematic roles that are similar to our *narrow roles hypothesis* and again found significant motion-verb-to-dative priming. However, they also found that the magnitude of this priming was reduced by using these narrow roles, which is consistent with the significant difference between motion verbs and prepositional-object datives we observed in Exp. 11 (also Potter & Lombardi, 1998). Further work is needed to see whether this model could explain the full range of data in this paper, although we suspect that narrow roles will also be needed to capture the priming pattern of fulfilling verbs (Exps. 7 and 10).

3.10.3. Role of animacy in argument realization

Our findings also bear on questions about the relationship between thematic roles and the animacy of the arguments that fill those roles. Many thematic roles are typically animate (e.g., agent, recipient, experiencer) or inanimate (e.g., patient, theme). Thus, it is tempting to assume that animacy affects syntactic argument realization solely via thematic role selection. Our results are inconsistent with this assumption. To understand this more fully, we have to consider two hypotheses about how animacy might influence priming.

On the hypothesis where animacy solely affects role selection, we would have to posit an

underspecified broad goal role that becomes a recipient by virtue of the animacy of the filler noun that takes that role. If that were the case, we expect that changing the animacy of the filler of the non-theme role in the locatives should have created a recipient rather than destination, thereby also yielding equivalent priming between locatives with animate destinations and datives (Exp. 8) as that between fulfilling verbs and datives (Exp. 7). This hypothesis can in no way account for the priming we saw in Exp. 9, however, in which theme-first locatives with animate themes resulted in more double-object over prepositional-object dative responses. To do so, we would have to posit themes as also changing to recipients by virtue of the animacy of their fillers.

Thus, our results lead us to a second hypothesis, in which both thematic roles and the links between animacy features and syntactic positions can be primed independently of one another. On this hypothesis, there are cases of pure thematic priming (e.g., Exp. 2), which cannot be explained by any other factors. There are also cases where priming is mediated solely by mappings between animacy and syntactic position (e.g., Exp. 9). This hypothesis is fully consistent with our results.

What this hypothesis fails to explain is why particular thematic roles seem to require, or at least strongly prefer, animate fillers. For instance, I cannot send New York the package, unless New York is meant to refer to something like the New York office rather than the place (Goldberg, 1995; Pesetsky, 1995; Pinker, 1989; Rappaport Hovav & Levin, 2008). While our data clearly show independence of thematic roles and animacy, they leave open several means of accounting for these tendencies. First, some but not all roles could place restrictions on their contents. Experiencers, for instance, are probably always animate. Likewise, recipients, though not always animate, do strongly prefer to be (though cf. examples like "give the house a coat of paint"; Rappaport Hovav & Levin, 2008, fn. 10; see also McIntyre, 2006). Second, animacy in these cases could be an inference rather than a restriction. Particular verbs (e.g., *give*) or particular sub-predicates in the thematic structure (e.g., CAUSE, HAVE) could imply things about their arguments that are only true of animate entities. Critically, whatever the explanation for these animacy requirements is, it cannot account for our

priming between animacy and syntactic positions independent of thematic roles (Exp. 9).

The animacy priming we observed provides evidence that the features of filler nouns can play an independent role in syntactic argument realization. This is challenging for theories in which argument realization depends entirely upon thematic roles (or predicate decompositions; for discussion, see Levin & Rappaport Hovav, 2005). While it is not clear how to integrate these independent animacy mappings into our theory of argument realization (though for competing accounts see Branigan, Pickering, & Tanaka, 2008; Chang, 2009), this is not the first or only piece of evidence that suggests such a step will be necessary. For example, Irish allows only animate entities to be subjects (Guilfoyle, 1995, 2000; for discussion, see Levin & Rappaport Hovav, 2005). In other cases, animacy has probabilistic effects. In the dative alternation, for instance, animate recipients typically favor the double-object construction, while inanimate recipients typically favor the prepositional-object construction (Bresnan, Cueni, Nikitina, & Baayen, 2007; Bresnan & Nikitina, 2009; Collins, 1995; Evans, 1997; Gries, 2003; Thompson, 1990). Ultimately, our theory of argument realization will need to account for both types of influences (thematic roles *and* animacy) in order to capture the entire range of findings to date.

3.10.4. Sub-dividing dative verbs

Throughout this paper, we have treated alternating dative verbs as a monolithic class. Many theorists, however, have pointed out that there are systematic differences between different subclasses of datives (e.g., Jackendoff, 1990; Rappaport Hovav & Levin, 2008). For example, Rappaport Hovav and Levin (2008) argue for a three-way distinction among *give*-type verbs, *send*-type verbs, and *throw*-type verbs. They propose that all three subclasses are consistent with a transfer of possession meaning. However, the *send*- and *throw*-type verbs in the prepositional-object variant are also consistent with a caused motion meaning, while the *give*-type verbs are not. If we translate

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this hypothesis into thematic role terminology, it implies that while *give*-type datives always have a recipient, *send-* and *throw*-type datives can have either a recipient or a destination.

This proposal adds a possible wrinkle to the interpretation of our findings. We have assumed that all of the dative sentences we constructed for these experiments had a recipient role in both the double-object and prepositional-object constructions. If they had destinations or locations, it is unclear how we could account for the observed priming patterns. To explore this possibility, we did three things. First, we classified our verbs based on the verb classes described in Rappaport Hovav and Levin (2008). We discovered that nine of our verbs are *give*-type verbs (i.e., *feed*, *give*, *hand*, *lend*, *offer*, *pass*, *read*, *sell*, and *show*), which are expected to have recipients in all cases. Three of our verbs, however, were *send-* or *throw*-type verbs (i.e., *bring*, *send*, and *throw*), which could potentially have a destination role.

Second, we tested whether participants interpreted our stimulus sentences as having recipients in a norming study on Amazon Mechanical Turk that was identical in structure to the one we performed for Exp. 11. Participants (N=118; 59 female, 57 male, 2 other) were asked to rate, for each of 9 dative sentences, how likely the recipient was to now possess the theme, on a 1 to 7 scale (1=not likely at all, 7=very likely). The prepositional-object variants of *bring*, *send*, and *throw* were rated as being *equally* likely to indicate transfer of possession (4.65[SE=.23]) as their double-object counterparts (4.57[SE=.24]); crucially, no differences were observed between these sentences and the prepositional-object and double-object variants of the *give*-type verbs (prepositional-object: 4.73[SE=.15]; double-object: 4.69[SE=.14]), all ps>.85.[21] Thus, all our dative sentences seem to have recipient thematic roles.

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[21] For this analysis, we entered Prime Type (Prepositional-object vs. Double-object), Verb Type (Give vs. Send/Throw), and their interaction as fixed effects into a linear mixed-effects model (lme4 package) in R, with random intercepts for participant and item (verb) and random slopes for Prime Type within both participants and items. Neither the main effects for Prime Type, β=-.01(SE=.07), t=-.18, p=.86, and Verb Type, β=.06(SE=.44), t=.14, p=.89, nor the interaction was significant, β=.01(SE=.08), t=.10, p=.92.

Finally, we conducted a follow-up analysis on the combined results of Exps. 4 and 8 (locative-to-dative priming), to see whether priming between locatives and *send-/throw*-type datives might have been greater than that between locatives and *give*-type datives. If so, this would be evidence that our *send-* and *throw*-type dative sentences included at least some destination roles.[22] We found no evidence for differential priming (interaction) by dative subtype (Give: 6% priming; Send/Throw: 4% priming), (total N=944) β=.01(SE=.08), z=.07, p=.94.[23]

While it is clear from the experiments in this paper that our dative sentences with recipient roles did not prime locative sentences with destination roles, we cannot determine from these data whether there are dative sentences with destination roles and whether such datives would prime locative sentences (or vice versa). Clearly, the theory presented in this paper predicts that if such sentences exist, and if animacy is controlled, then priming of this type should occur.

3.10.5. "Goals" in linguistics and cognitive development

The term "goal" is used widely both in research on linguistic representation (e.g., Goldberg, 1995; Harley, 2003; Levin & Rappaport Hovav, 2005; Jackendoff, 1990) and in research on pre-linguistic cognitive development (e.g., Hamlin, 2015; Liu, Ullman, Tenenbaum, & Spelke, 2017; Woodward, 1998). This raises the question of how the respective notions relate to each other, if at all. We see three broad possibilities consistent with the present findings.

One possibility is that (a) there is a single domain-general representation of events which the pre-linguistic infant studies are tapping into, and which will ultimately come to guide semantic encoding for language production in adults, and (b) this domain general system represents a single

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[22] We could not look in the opposite direction (dative-to-locative priming), however, due to the nature of our trial structure (i.e., two primes for every target), because *send-* and *throw*-type datives were frequently paired with *give*-type datives as priming doublets in the relevant experiment (Exp. 5).

[23] This analysis included Prime Type (Prepositional-object vs. Double-object), Verb Type (Give vs. Send/Throw), and their interaction as fixed effects in a logistic mixed-effects model (lme4 package) in R, with random intercepts for participant and item (verb) and random slopes for Prime Type within both participants and items.

broad role of goal. If this is the case, what our data suggest is that the adult linguistic system also has notions of recipient and destination, that are perhaps subcategories of goals, and it is these narrower notions that contribute to priming. The question then becomes: Where do these narrower roles come from? Are they constructed in the course of language acquisition? Or are they part of our innate linguistic endowment?

A second possibility is that there is a single domain-general system for event representation, but that this system represents recipients and destinations as separate discrete roles. To the best of our knowledge, there are no studies in the infant event perception literature which show that babies treat recipients and destinations as a single construct. There are experiments showing that infants represent possession, or at least desire (e.g., Woodward, 1998), and there are experiments showing that they encode destinations (e.g., Lakusta, Spinelli, & Garcia, 2017). But we know of no work that shows that they generalize across these constructs. Until such evidence is available, it is plausible that this broad notion of goal that is available to theorists is not available either to infants or to the language production system.

A third and final possibility is that there are two separate domain-specific systems for event representation: one which guides infants' analysis of action and another which guides argument realization in language production. On this hypothesis, the existence of a broad notion of goal in early action understanding has no bearing on the question of whether there is a broad notion of goal in the linguistic system. This may seem counterintuitive; after all, both literatures use the word goal. However, what the word goal refers to in each case seems very different. The term goal in the pre-linguistic infant literature typically refers to the mental objects of intention or desire (for reviews, see Spelke & Kinzler, 2007; Woodward, 2009). In contrast, goal in the linguistics literature refers to an entity that is the endpoint of an action, either the destination in a motion event or the recipient in a transfer-of-possession event. Thus, while the toy bear that the hand reaches for in Woodward's (1998) classic study is called a goal, most linguists would consider it to be a theme or a patient.

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Cross-cutting these issues of domain-specificity is the question of whether narrower and broader roles can coexist within the linguistic system. Such coexistence would be consistent with the semantic architectures proposed by Dowty (1989, 1991) and within the tradition of Role and Reference Grammar (e.g., Van Valin & LaPolla, 1997). For example, Van Valin and LaPolla (1997) propose two relevant levels of thematic role representation. On the one hand, there are the traditional thematic roles like agent, recipient, theme, and destination. On the other hand, there is also a level of representation that captures generalizations *across* these traditional roles, known as macroroles. Dowty (1989, 1991) also proposes a hierarchy of narrow (verb-specific) and mid-sized (agent- and patient-level) roles, in addition to even broader prototype notions (i.e., proto-roles) that serve a similar function as macroroles. With respect to this question, what our data suggest is that this broader level of representation, if it exists, isn't involved in priming.

Another approach that invokes multiple kinds of roles is one in which narrower roles are subsumed in broader roles. Several researchers have noted, for instance, that the set of events that can be described with double-object syntax (e.g., double-object datives), which necessarily entails a recipient role, are a subset of those events that can be described with prepositional-object syntax (e.g., prepositional-object datives, theme-first locatives), entailing either a recipient role or a destination role (e.g., Beavers, 2011; Pesetsky, 1995; Rappaport Hovav & Levin, 2008; though cf. Harley, 2005). On this type of approach, goal would refer to the endpoint (spatial or metaphorical) of an action, and recipient would refer to a specific type of endpoint (specified for possession). Recipients would inherit both the meaning and form of the broader notion of goal. But the goal role would inherit nothing from the narrower specification of recipient. This theory makes the prediction that recipients will prime goals (i.e., dative-to-locative priming in Exp. 5), but that goals will not necessarily prime recipients (i.e., locative-to-dative priming in Exp. 4; for similar subsumption arguments regarding benefactives and datives, see, e.g., Goldberg, 1995; Pappert & Pechmann,

2013). We found no evidence for unidirectional priming of this sort, and thus, this relationship, if it exists, is not manifest in priming.

3.11. Conclusion

We found no evidence that speakers treat the recipient role in dative or fulfilling verb sentences as equivalent to the destination role in locative or motion verb sentences. These results speak against the *broad roles hypothesis*, which states that the thematic roles destination and recipient form a broad class, goal, and instead are more in line with the *narrow roles hypothesis*, in which destinations and recipients are distinct. We also observed an independent influence of animacy on priming in the absence of thematic role overlap. Our findings are consistent with a picture of conceptual and semantic representation in which thematic structure and animacy comprise distinct constraints on argument realization. The complexity of these results challenges our desire for a parsimonious theory in which structural priming is solely syntactic (see also Ziegler, Snedeker, & Wittenberg, 2017b). A full theory of the mental architecture of language production requires that we account for (at least) syntactic-, thematic-, and animacy-based priming.

Chapter 4

[Paper 3]

How abstract is syntax? Evidence from structural priming

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Under review

Abstract

In 1990, Bock and Loebell found that passives (e.g., *The 747 was radioed by the airport's control tower*) can be primed by intransitive locatives (e.g., *The 747 was landing by the airport's control tower*). This finding is often taken as strong evidence that structural priming occurs on the basis of a syntactic phrase structure that abstracts across lexical content, including prepositions, and is uninfluenced by the semantic roles of the arguments. However, all of the intransitive locative primes in Bock and Loebell contained the preposition *by* (*by*-locatives), just like the passive targets. Therefore, the locative-to-passive priming may have been due to the adjunct headed by *by*, rather than being a result of purely abstract syntax. The present experiments investigate this possibility. In Exp. 1, we show that passives and intransitive *by*-locatives are equivalent primes, while intransitive locatives with other prepositions (e.g., *The 747 has landed near the airport control tower*) do not prime passives. In Exp. 2, we find that the presence of a *by*-phrase in active *transitive* sentences (e.g., *The 747 made a sudden stop by the airport control tower*) is sufficient to prime passives, despite the differences in global phrase structure. We conclude that a shared abstract, content-less tree structure is neither sufficient (Exp. 1) nor necessary (Exps. 1 and 2) for passive priming to occur.

4.1. Introduction

When we speak to one another, we must take our ideas (our messages), convert them into words, and combine those words to form utterances. It is easy to conceive of the lexical and combinatorial processes as separable, and many early linguistic and psycholinguistic models argued that words and syntax were generated by wholly distinct systems (Chomsky, 1994; Frazier & Fodor, 1978). At the same time, we have long recognized that lexical and syntactic representations are often

intimately related, with each representation constraining the other (Chomsky, 1965; Culicover, 1999; Fillmore, 1968; Jackendoff, 1975; Lakoff, 1970; Levelt, 1993; MacDonald, Pearlmutter, & Seidenberg, 1994; Trueswell, Tanenhaus, & Garnsey, 1994).

One powerful tool used to explore the relationship between word choice and syntactic structure has been *structural priming*, which describes the tendency for speakers to reuse previously encountered sentence structures (Bock, 1986; for meta-analysis and reviews, see Branigan, 2007; Branigan & Pickering, 2017; Ferreira & Bock, 2006; Mahowald, James, Futrell, & Gibson, 2016; Pickering & Ferreira, 2008; Tooley & Traxler, 2010; Traxler & Tooley, 2012). For instance, Bock (1986) showed that speakers were more likely to describe a picture with a *to*-dative (e.g., *The man is reading a story to the boy*) after using a different *to*-dative (e.g., *A rock star sold some cocaine to an undercover agent*) than after using a double-object dative (*A rock star sold an undercover agent some cocaine*). Within the structural priming literature, there is evidence that structural priming is increased when the prime and target sentences share a content word (i.e., the *lexical boost*; Cleland & Pickering, 2003; Pickering & Branigan, 1998). But we know that structural priming occurs even when prime and target do not overlap in content or function words (Bock, 1986, 1989).

Critically, structural priming has been argued to *only* require shared abstract syntax, occurring even in the absence of shared argument types (*semantic roles*), shared discourse-related properties, *or* shared words (Bock, 1986, 1989; Bock & Loebell, 1990). In other words, structural priming has been thought to reflect the priming of abstract, content-less tree structures (for discussion, see Branigan, 2007; Branigan & Pickering, 2017; Branigan, Pickering, Liversedge, Stewart, & Urbach, 1995; Chang, Dell, & Bock, 2006). For this reason, the effect is often referred to as *syntactic priming*, rather than the more neutral term, *structural priming*, that we adopt here.

A key piece of evidence that has been used to argue in favor of fully abstract syntactic priming is, on closer examination, ambiguous. Bock and Loebell (1990, Exp. 2) found that participants produced as many passive sentences following intransitive locative sentences (*The 747*

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was landing by the airport's control tower) as they did after other passives (*The 747 was alerted by the airport's control tower*). While passives and intransitive locatives appear to share the same abstract syntax (following, e.g., Emonds, 1976; though see section 4.4.1 for alternative analyses), their semantics is clearly distinct. In a passive sentence like *The 747 was alerted by the airport's control tower*, the control tower is the actor of the action and the 747 is the undergoer of the action; in the intransitive locative, *The 747 was landing by the airport's control tower*, the 747 is the argument that is acting and the control tower is a location. Thus, this data point seems to demonstrate that abstract phrase structures can be primed. This study, however, contains a lexical confound: All of the intransitive locative primes contained the preposition *by* and the auxiliary *be*, just like the passive targets, while none of the actives did. Therefore, the locative-to-passive priming that was found may have been due, in part or in whole, to the shared lexical material.[24] If locative-to-passive priming requires lexical overlap, it would remove the strongest evidence we have that priming can occur on the basis of fully abstract syntactic representations (for discussion, see, e.g., Desmet & Declercq, 2006; Ferreira, 2003; Goldberg, 2006, ch. 6.10; Hare & Goldberg, 1999; Hartsuiker, Kolk, & Huiskamp, 1999, fn. 3). Bock and Loebell (1990) acknowledged this concern. Their conclusion that the locus of this priming was purely syntactic rested on evidence from another construction and the assumption that all argument structure alternations are primed in the same way.

Specifically, Bock (1989) had shown previously that *for*-datives (e.g., *The secretary is baking a cake for her boss*) are just as good at eliciting *to*-dative target descriptions (e.g., *The girl is handing the paintbrush to the man on the ladder*) as other *to*-dative primes (e.g., *The secretary is taking a cake to her boss*; see also Chang, Bock & Goldberg, 2003; Ziegler & Snedeker, 2018). *For*-to-*to*-

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[24] Likewise, Messenger, Branigan, McLean, and Sorace (2012) found that children (ages 3-4) and adults produced more passives after passives that were quite different semantically. In particular, they found that children were more likely to produce undergoer-agent passives (e.g., *A girl is being hit by a sheep*) after experiencer-theme passives (e.g., *A girl is being shocked by a sheep*) than after actives. Putting aside the possibility that in both cases causer and theme arguments might be involved, all of the primes again included the word *by*.

dative priming, however, is also ambiguous. Critically, the two dative constructions have common *semantic properties* which could be responsible for the priming. Specifically, the semantic structures ascribed to *to*-datives and *for*-datives are closely related (e.g., Jackendoff, 1972, 1983; Lakoff & Johnson, 1980), and critically, are distinct from the semantic structure of double-object datives, which is the same regardless of whether the sentences can be paraphrased using *to* or *for* (Goldberg, 2002; Green, 1974). At the time Bock and Loebell (1990) presented their findings, there was no evidence that semantic structure could be primed. Now, however, there is ample evidence for this form of priming in dative and closely related constructions (see, e.g., Cai, Pickering, & Branigan, 2012; Chang et al., 2003; Cho-Reyes, Mack, & Thompson, 2016; Hare & Goldberg, 1999; Köhne, Pickering, & Branigan, 2014; Pappert & Pechmann, 2014; Salamoura & Williams, 2007; Yi & Koenig, 2016; Ziegler & Snedeker, 2018; Ziegler, Snedeker, & Wittenberg, 2018).

For example, Chang et al. (2003) found that location-theme locative sentences (e.g., *The maid rubbed the table with polish*) led to more location-theme responses (e.g., *The farmer heaped the wagon with straw*), which share a semantic structure, as compared to theme-location locatives (e.g., *The maid rubbed polish onto the table*), which have a different semantic structure (see also Yi & Koenig, 2016; Ziegler & Snedeker, 2018; for evidence of locative priming in Brazilian Portuguese, see Ziegler, Morato, & Snedeker, under review). Critically, this priming occurred independently of syntax and animacy, which were the same across prime types. Similarly, Ziegler et al. (2018) showed that compositional dative primes (e.g., *The culprit gives the attorney a check*) yielded greater priming on compositional dative targets (e.g., *The boy gives the cowboy a rope*) than did either idiomatic dative primes (e.g., *The audience gives the performer his due*) or light verb dative primes (e.g., *The boy gives the girl a hug*; see also Griffin & Weinstein-Tull, 2003, for a semantic boost in clausal complement constructions). The compositional dative primes and targets were matched on syntactic phrase structure, semantic structure, and syntax-animacy mappings, while the idiomatic and light verb dative primes had only the same syntactic phrase structure and syntax-animacy mappings, thus

implicating semantic structure as the locus of the difference in priming (for further discussion of the involvement of semantics in priming, see section 4.4.4).

Thus, *for*-to-*to*-dative priming cannot distinguish between priming on the basis of syntax and priming based semantic structure, or some combination of these factors.[25] This observation makes it all the more important to determine whether the locative-to-passive priming reported by Bock and Loebell (1990) was truly the result of priming a fully abstract phrase structure, or whether it depended critically on the shared lexical content (the use of *by* and the same auxiliary, *be*). Passive-to-passive priming is a well-replicated phenomenon (see Mahowald et al., 2016). However, to the best of our knowledge, no study rules out the lexical hypothesis (including, e.g., Messenger, Branigan, & McLean, 2011), a point we will elaborate on in the general discussion.

The experiments reported in this paper therefore have two primary goals. First, we aimed to replicate Bock and Loebell's (1990, Exp. 2) original finding with a much larger sample of participants and updated statistical tools, as the study has been a theoretical lynchpin in priming research for almost 30 years. Save for the confounding inclusion of *by* and *be*, the fact that the intransitive locative condition primed passives has stood as the strongest evidence in favor of fully abstract syntax. And yet we are unaware of any published replications. In addition, and more relevantly for the current discussion, we set out to determine whether the locative-to-passive priming in Bock and Loebell (1990) was based, in whole or in part, on shared abstract syntax devoid of lexical content. Specifically, we ask whether passives are primed by intransitive locatives that do not contain the preposition *by* or the same auxiliary. Therefore, in Experiment 1, we added a fourth condition to Bock and Loebell's (1990) design: intransitive locatives that did not contain *by* or *be* (e.g., *The 747 has landed near the airport control tower*). If we find that these sentences are equally

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[25] Alternatively, the *for*-to-*to*-dative priming could be the result of animacy priming. We know that the order of animate and inanimate arguments can be primed (Bock, Loebell, & Morey, 1992; Gámez & Vasilyeva, 2015; Ziegler & Snedeker, 2018). Such priming could also ensure that *to*-datives would prime *for*-datives over the alternative double-object option.

good primes for passive sentences as intransitive *by*-locatives, it would provide strong evidence in favor of fully abstract syntax.

To preview our results, we find that participants were as likely to produce passives after intransitive *by*-locatives as they were to produce passives after passives, replicating Bock and Loebell (1990). But we also find that participants were *not* more likely to produce passives after intransitive non-*by*-locatives (and with *have* replacing *be* as the auxiliary), despite their shared constituent structure. In Experiment 2, we investigate the locus of the *by*-locative-to-passive priming in Exp. 1 and Bock and Loebell (1990, Exp. 2). Is repetition of the same abstract syntax (i.e., NP Aux-V PP$_{by}$) required, or might it instead be carried by the *by*-phrase alone? To investigate this question, we constructed a final condition that included the preposition *by* but did not have the same global syntactic structure as the passives. This condition included *transitive* sentences with a clause-final *by*-phrase adjunct but no auxiliary verb (e.g., *The 747 made a sudden stop by the airport control tower*). If we find that these *by*-transitives prime passives, it would suggest that the shared *by*-phrase is sufficient for priming passives, and that shared abstract syntax is not necessary.

In the general discussion, we situate the current findings in a broader context by reviewing a range of prior work that has argued in favor of abstract syntactic priming. While we do not and cannot rule out the possibility that abstract syntactic priming exists, we suggest that the majority of previous results allow the possibility that the effects reported required shared lexical content, shared semantic structure, shared information structure, shared prosody. As discussed there, it could be that different factors are more or less relevant for different types of constructions.

4.2. Experiment 1

4.2.1. Methods

4.2.1.1. Participants

300 native English speakers recruited from Amazon Mechanical Turk participated in Exp. 1 (166 female, 129 male, 4 trans, 1 unreported; mean age=36, SD=11, range=18-73). All participants provided written consent (in accordance with the guidelines of the Committee on the Use of Human Subjects at Harvard University) prior to participating and received $4.50 in compensation.

4.2.1.2. Materials

Exp. 1 consisted of 32 critical trials interspersed with 68 filler trials, for a total of 100 trials. All trials included a sequence of one prime sentence, presented as text to be read out loud, followed by a target picture, described below. The sentence primes were 32 sets of transitive sentences in each of four priming conditions: full passive (Passive; e.g., *The 747 was radioed by the airport control tower*), active transitive (Active; e.g., *The 747 radioed the airport control tower*), intransitive locative with a *by*-phrase (*By*-locative; e.g., *The 747 was landing by the airport control tower*), and intransitive locative with a non-*by*-phrase (Non-*by*-locative; e.g., *The 747 has landed near the airport control tower*). Some of the intransitive verbs came from the original Bock and Loebell (1990) stimuli; the remainder were chosen with the requirement that they made sense and were grammatical in the intransitive locative construction (with *by* and at least one other preposition). We represent the structure of active transitive sentences in Fig. 4.1a, and the structure of the other sentence types, including passive, intransitive *by*-locative, and intransitive non-*by*-locative sentences, in Fig. 4.1b (the possibility that the representation in Fig. 4.1b is invalid is addressed in section 4.4.1). (For a full list of all prime sentences by experiment, see Appendix C.).
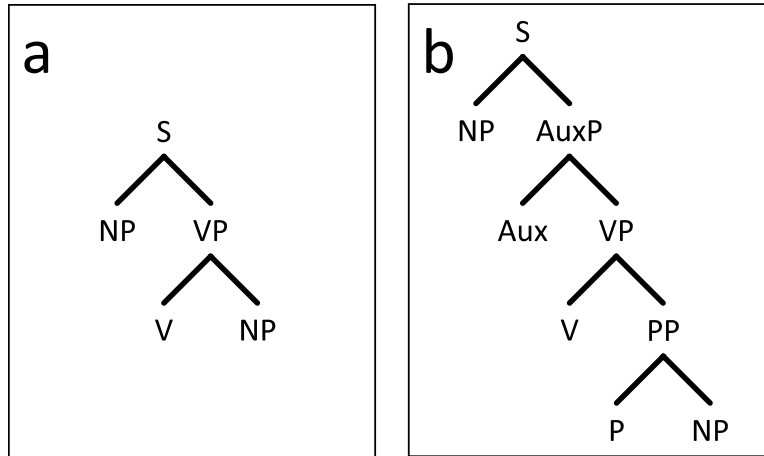
Figure 4.1. Constituent structure for (a) active transitives and (b) passives or intransitive locatives.

In the Active primes, an agent of the action appeared in the subject NP (e.g., *747*), the verb was expressed in past tense in the active voice (e.g., *radioed*), and a direct object NP contained an undergoer argument (e.g., *airport control tower*). In the corresponding Passive primes, the undergoer appeared in the subject NP (e.g., *747*), the verbal predicate included the auxiliary *be* and a past participle (e.g., *was radioed*), and the agent of the action appeared in a PP headed by the preposition *by* (e.g., *by the airport control tower*). In the *By*-locative primes, the agent of the action appeared in the subject NP (e.g., *747*), the verbal predicate included the auxiliary *be* and a progressive intransitive verb (e.g., *was landing*), and the PP contained the locative preposition *by* followed by the object NP (e.g., *by the airport control tower*). The semantic role of the oblique noun (e.g., *airport control tower*) was that of location. Finally, in the Non-*by*-locative primes, the agent of the action appeared in the subject NP (e.g., *747*), the verbal predicate included the auxiliary *have* and a past participle (e.g., *has landed*), and the PP was identical to its *By*-locative counterpart except for the presence of a different preposition (e.g., *near the airport control tower* vs. *by the airport control tower*).[26] We used *be* in our *By*-locatives in order to replicate Bock and Lobell (1990), who had

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[26] On average, our Non-*by*-locative prepositions were less frequent than *by* (1,293,156 vs. 2,068,768; values from the Corpus of Contemporary American English [COCA], Davies, 2008; see Appendix C), *V*=20, *p*=.02 (two-tailed,

consistently used *be*. We used *have* in our Non-*by*-locatives in order to make them as similar to passives as possible while eliminating any shared lexical content. See Table 4.1 for example prime stimuli.

Table 4.1. Sample prime stimuli used in each of the four conditions of Exp. 1.			
Active	The 747	radioed	the airport control tower
Passive	The 747	was radioed	**by** the airport control tower
By-locative	The 747	was landing	**by** the airport control tower
Non-*by*-locative	The 747	has landed	**near** the airport control tower

Each priming sentence was paired with one of 32 experimental pictures. The pictures were line drawings that depicted events involving two participants, typically an inanimate or non-human agent or initiator of the action (e.g., *wrecking ball*) and an animate or inanimate undergoer of the action (e.g., *building*). Sixteen of the scenarios depicted were from the original Bock and Loebell (1990) experiment. Fourteen of the experimental pictures (44%) had the agent on the left, another fourteen (44%) had the agent on the right, and four (12%) were neutral as to the orientation of the agent relative to the undergoer on the horizontal plane (in all four, the agent was above the undergoer). All 32 experimental pictures were previously normed on Amazon Mechanical Turk (N=195) by asking participants to describe 6-10 assorted pictures using only one sentence each, yielding a 91% median use of active or passive transitive sentences (range=36-100%) and, among these, a 23% mean proportion of passives. (For a full list of all target pictures, see Appendix C.)

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one-sample Wilcoxon signed-rank test, for non-normal data). The relative infrequency of these other prepositions can be expected to increase their *surprisal*, which in turn predicts stronger priming effects for Non-*by*-locatives than *By*-locatives (e.g., Jaeger & Snider, 2013). Thus, if we find no priming in Non-*by*-locatives, it cannot be explained by these differences in frequency. We also considered how likely each preposition was *given* the verb (conditional probability). These values did not differ between the *By*-locatives and Non-*by*-locatives (.04 vs. .06; values calculated from COCA; see Appendix C), V=250, p=.80 (two-tailed, paired-sample Wilcoxon signed-rank test, for non-normal data). Thus, any differences we see in priming between the two conditions also cannot be attributed to differences in conditional probability.

Prime sentences and target pictures were randomly paired across participants. Verbs did not repeat from prime to target.

We used 42 filler sentences and 40 filler pictures. One function of these filler items was 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. For this purpose, we repeated 26 of the 42 filler sentences and 28 of the 40 filler pictures, yielding a total of 68 filler sentences and 68 filler pictures. The 42 unique filler sentences instantiated a wide variety of constructions, such as clefts (e.g., *It was an old lady who discovered the weapon*), existentials (e.g., *There is a red spot on Jupiter*), resultatives (e.g., *The girl laughed herself silly*), datives (e.g., *The singer gave the piano player a wave*), generics (e.g., *All humans are mammals*), intransitives (e.g., *The graceful young girl danced*), and clausal complements (e.g., *The man admitted that he was wrong*). None of the filler sentences were passives. The 40 unique filler pictures depicted a variety of events involving one or more participants, typically described with intransitive sentences (e.g., boy shivering in cold, two bikes leaning on fence, girl running toward house, cat hiding behind chair, two skiers skiing). Care was taken to not select filler pictures that elicited transitive (active or passive) descriptions. In total, each participant saw 100 sentences (including the 32 primes) and 100 pictures (including the 32 targets). Filler trials were interspersed randomly between critical trials, with the constraint that the first five trials be fillers and at least one but not more than two filler trials intervene between critical trials.

4.2.1.3. 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. They were given only a single opportunity to make each recording, and a microphone check preceded the

task. See Fig. 4.2 for procedure and example materials. Participants were told to not use pronouns, to mention every depicted character, and to be as precise as possible.

For the distractor memory task, participants indicated 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. A post-test questionnaire confirmed that none of the participants doubted the cover story or realized the true purpose of the experiment. The whole experiment lasted approximately 45 minutes.
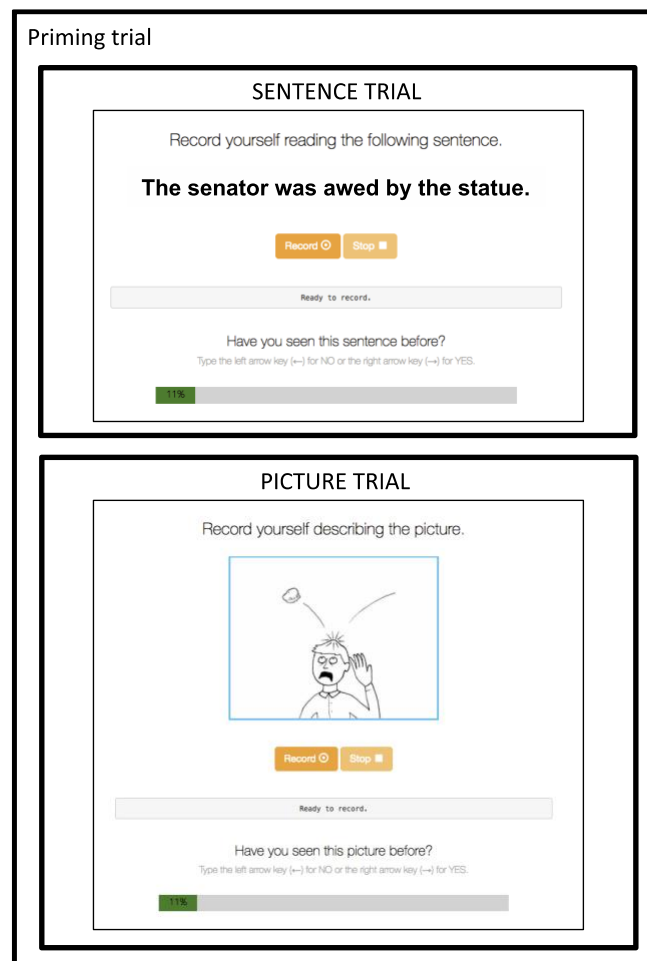
Figure 4.2. Procedure and example materials for Exp. 1.

4.2.1.4. Design

We used a 3 × 2 mixed design, with Prime Condition (Passive, *By*-locative, Non-*by*-locative) as a between-subjects factor and Prime Type (Non-active, Active) as a within-subjects factor. Thus, each participant saw exactly 2 conditions, 16 prime sentences of each. We manipulated Prime Condition between subjects to maximize the likelihood of observing priming in the Non-*by*-locative condition. This gave us ~94% power to detect priming in each condition (at a Cohen's *d* of .28 without lexical overlap; see Mahowald et al., 2016, p. 21), and ~87% power to detect interactions between conditions (at a Cohen's *d* of .28; see Mahowald et al., 2016, p. 21). Participants were randomly assigned to the three Prime Conditions and then to one of eight counterbalanced lists within each Prime Condition. The dependent measure was the number of passive sentences produced by participants (coded as 1, with actives coded as 0), out of all transitive responses (passive/active+passive). In presenting the production cell means (for descriptive purposes), we have aggregated over both participants and items.

4.2.1.5. Coding

The descriptions of the experimental pictures were scored for syntactic structure. If the description consisted of more than one sentence, only the first complete sentence containing both the agent and the undergoer was scored. If participants hesitated, stuttered, or produced a false start, the final form of the utterance was scored. Responses were divided into one of the three categories: Active, By-Passive, and Other.

To be scored as an Active, a target description had to provide an appropriate description of the transitive event in the target picture; had to contain the agent or initiator of the event in subject position, a verb in the active voice, and the undergoer of the event in object position; and had to be expressible in the alternative form (i.e., as a passive). To be scored as a By-Passive, a description had to be a complete sentence that appropriately described the target picture's event; had to contain the

undergoer role in subject position, an auxiliary verb (*be* or *get*), a main transitive verb, and a prepositional *by*-phrase with an agentive object; and had to be expressible in the alternative form (i.e., as an active). Transitive sentences with prepositional particles (e.g., *crash into*) were included in the analysis, so long as they could occur in both the active and the passive form. All other descriptions (including truncated, lexical, or instrumental passives; datives; intransitives; and incomplete, inaudible, or unintelligible utterances) were scored as Other. In total, 7,473 of the 8,770 produced target descriptions (85.2%) were transitive responses (i.e., Active or By-Passive) and thus entered into the analysis. Ten percent of the target responses were independently coded by a second coder, with an intercoder reliability of 99% (Cohen's κ=.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 Condition (Passive, *By*-locative, Non-*by*-locative), Prime Type (Non-active, Active), and their interaction as fixed effects. We started with the maximal random effects structure appropriate for our experimental design (Barr, Levy, & Scheepers, 2013). However, this model failed to converge. The final model included random intercepts for participant and item (target picture), a random slope for Prime Type within participants, and a random slope for Prime Condition within items. 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 4.2 summarizes the results of these comparisons. Planned pairwise analyses were run on the full model minus the relevant level of Prime Condition.

　　In addition, we calculated Bayes factors for the effect of priming in each condition. Unlike *p*-values, which only provide evidence for how unexpected the data are under the null hypothesis, Bayes factors allow us to compare the likelihood of the data fitting under the null hypothesis with the

likelihood of the data fitting under the alternative hypothesis. The higher a Bayes factor (BF_{01}), the more evidence in support of the null hypothesis; the inverse of this value thus tells us how likely the data are to occur under the alternative hypothesis (BF_{10}). We calculated our Bayes factors using Bayesian Information Criteria (BIC; Jarosz & Wiley, 2014; Wagenmakers, 2007). We first extracted the BIC for each hypothesis by fitting and comparing two separate regression models: one that characterizes the alternative hypothesis (H_1: including an effect for Prime Type, plus random intercepts for both participant and item) and one that characterizes the null hypothesis (H_0: same model without the effect for Prime Type). We then found the difference of these values:

$$\Delta BIC_{10} = BIC_{H_1} - BIC_{H_0}$$

Finally, we transformed this into a Bayes factor:

$$BF_{01} = e^{\Delta BIC_{10}/2}$$

And we took the inverse to quantify the odds in favor of H_1:

$$BF_{10} = 1/BF_{01}$$

Table 4.2. Stepwise forward model comparisons for fixed effects in Exp. 1.				
Fixed effect term	AIC (ΔAIC)	df (Δdf)	χ^2	$p=$
Base model: Random intercepts for participant and item + random slope for Prime Type within participants + random slope for Prime Condition within items	5522.7 (---)	10 (---)	---	---
+ Prime Type (PT)	5479.4 (-43.3)	11 (1)	45.28	<.001*
+ Prime Condition (PC)	5466.6 (-12.8)	13 (2)	16.82	<.001*
+ PT × PC	5459.2 (-7.4)	15 (2)	11.41	.003
*Significant at the $p < .05$ level.				

4.2.2. Results

Accuracy on the distractor memory task was high (94%), with no differences by Prime Condition.

Fig. 4.3 shows the pattern of results for Exp. 1. The model comparisons revealed a significant main effect of Prime Type, such that passives were produced significantly more often after Non-active (Passive, *By*-locative, Non-*by*-locative) primes than after Active primes (26.0% vs. 22.0%), independent of condition, $\chi^2(1)$=45.28, *p*<.001. However, this was in the context of a significant Prime Type by Prime Condition interaction, $\chi^2(2)$=11.41, *p*=.003. Planned pairwise comparisons revealed that priming for Passives was significantly greater than that for Non-*by*-locatives (7.1% vs. -0.8%), *β*=.16(SE=.04), *z*=3.51, *p*<.001, but did not significantly differ from that for *By*-locatives (7.1% vs. 5.9%), *β*=.04(SE=.05), *z*=.89, *p*=.38, and that priming for *By*-locatives was significantly greater than that for Non-*by*-locatives (5.9% vs. -0.8%), *β*=.11(SE=.05), *z*=2.35, *p*=.02. There was also a significant main effect of Prime Condition, $\chi^2(2)$=16.82, *p*<.001. The planned pairwise comparisons revealed that significantly more passives were produced in the Passive condition as compared to either the *By*-locative condition (27.2% vs. 24.4%), *β*=.17(SE=.09), *z*=2.00, *p*=.046, or the Non-*by*-locative condition (27.2% vs. 20.4%), *β*=.36(SE=.11), *z*=3.24, *p*=.001, but the proportion of overall passive responses in the *By*-locative condition was not significantly different from that in the Non-*by*-locative condition (24.4% vs. 20.4%), *β*=.19(SE=.12), *z*=1.64, *p*=.10.[27]

Our Bayes factor analysis suggested that the data in the Passive condition were >150 times more likely to occur under a model including Prime Type (=priming) than a model without it (=no priming). The data in the *By*-locative condition were >150 times more likely to occur under a model

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[27] We wanted to see whether this held for the Active primes as well as the Non-active primes. In a post-hoc analysis, we ran the same pairwise comparisons on the Active primes only (without Prime Type in the model): Although significantly more passives were produced following Active primes in the Passive condition as compared to the Non-*by*-locative condition (23.7% vs. 20.8%), *β*=.26(SE=.13), *z*=2.06, *p*=.04, the proportion of overall passive responses following Active primes in the *By*-locative condition was not significantly different from that in either the Passive condition (21.4% vs. 23.7%), *β*=.18(SE=.12), *z*=1.45, *p*=.15, or the Non-*by*-locative condition (21.4% vs. 20.8%), *β*=.12(SE=.14), *z*=.87, *p*=.39.

including Prime Type (=priming) than a model without it (=no priming). Lastly, the data in the Non-*by*-locative condition were .02 times more likely to occur under a model including Prime Type (=priming) than a model without it (=no priming), or in others words, ~44 times more likely to occur under a model *without* Prime Type (=no priming) than a model with it (=priming). Thus, by standard analysis (e.g., Jeffreys, 1961; Raftery, 1995), there is very strong or decisive evidence *in support of* priming in both the Passive and *By*-locative conditions, and conversely, strong or very strong evidence *against* priming in the Non-*by*-locative condition.
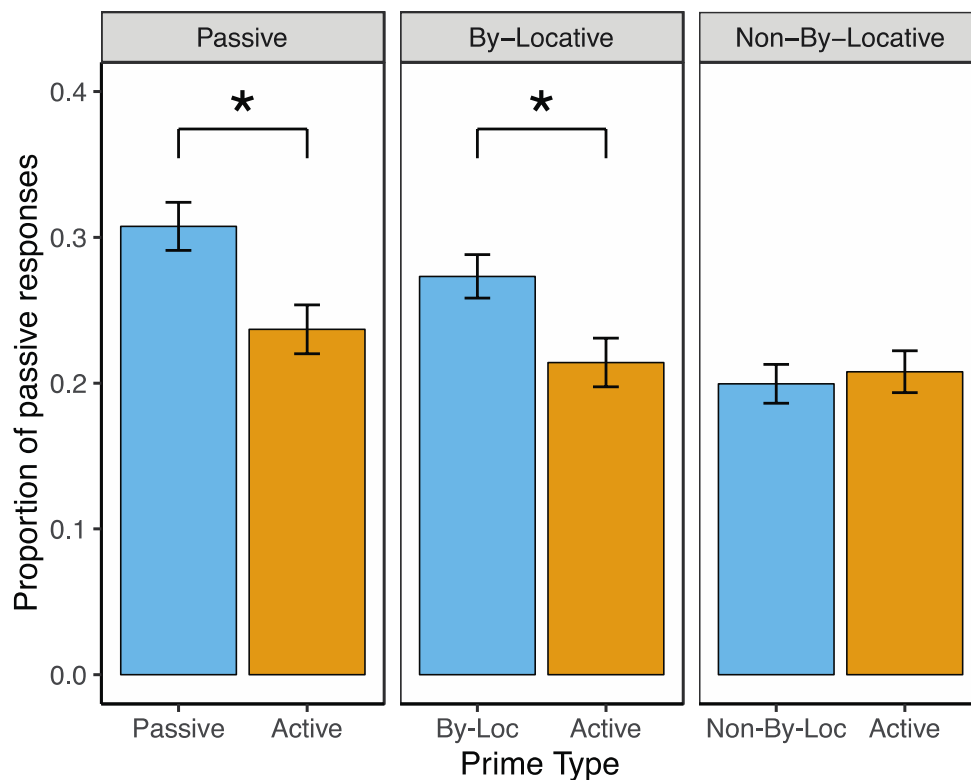
Figure 4.3. Overall proportion of passive productions in Exp. 1 by Prime Type by Prime Condition. Error bars reflect by-subject standard errors. By-Loc=*By*-locative; Non-By-Loc=Non-*by*-locative.

4.2.3. Discussion

We have three clear findings from Exp. 1. First, like in much past work, we replicated priming from passives to other passives, relative to active controls (see Mahowald et al., 2016). Second, we replicated Bock and Loebell's (1990) finding of (equivalent) passive priming from *by*-locatives. Third and critically, however, we failed to find any evidence of priming from non-*by*-locatives to passives. Our Bayes factor analysis further confirmed these findings. Together, these data provide strong evidence that the priming of passives by *by*-locatives is due, at least in part, to the presence of shared lexical content (*by*, *be)*, and not to an abstract, content-less phrase structure.

However, a final question remains. Thus far, we have established that repetition of the abstract syntactic phrase structure is not *sufficient* for passive priming: Priming of passives required lexical overlap. But is repetition of the passive phrase structure even *necessary*? In all cases so far, the global phrase structure between our primes and targets has been identical: NP Aux-V PP. It is therefore an open question as to whether priming would persist even if the phrase structure were different, so long as the *by*-phrase itself still gets repeated. This would further call into question the widespread assumption that structural priming depends crucially on shared constituent structure across prime and target.

To address this question, we considered an additional sentence type in Exp. 2: transitive sentences that contain clause-final *by*-phrase adjuncts (e.g., *The 747 made a sudden stop by the airport control tower)*. If the sentence's global phrase structure (including the *by*-phrase) is critical, then we should not expect *by*-transitives to prime passives. Moreover, auxiliaries were not included in the *by*-transitive stimuli, so if we find that *by*-transitives *do* prime passives, it will implicate the *by*-phrase as the locus of priming. We return to a within-subjects design for Exp. 2 because of the baseline difference across conditions in Exp. 1.

4.3. Experiment 2

4.3.1. Methods

4.3.1.1. Participants

200 native English speakers recruited from Amazon Mechanical Turk participated in Exp. 2 (104 female, 87 male, 9 unreported; mean age=34, SD=10, range=19-64). All participants provided written consent (in accordance with the guidelines of the Committee on the Use of Human Subjects at Harvard University) prior to participating and received $4.50 in compensation.

4.3.1.2. Materials

Exp. 2 used the same materials as Exp. 1, except for the following changes. We replaced the Non-*by*-locative condition with a condition in which a *by*-phrase was included in transitive rather than intransitive sentences (*By*-transitive; e.g., *The 747 made a sudden stop by the airport control tower*). We had no other criteria for transitive verb selection other than that they could be used with a *by*-phrase.[28] We assume the structure in Fig. 4.4 for these sentences. All *By*-transitive primes contained simple past tense verbal morphology (e.g., *made*) and the preposition *by*. (For a full list of all prime sentences by experiment, see Appendix C.)

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[28] Some of the verbs were light verbs. As we've shown elsewhere, light verbs behave differently in priming with respect to their semantics but not their syntax (Ziegler et al., 2018). Since we were interested here in syntax and not semantics, this is unlikely to have affected our results. However, if we were wrong, and light verbs also have weaker syntactic priming effects, we would predict that the proportion of passive responses after *By*-transitive primes (which were often light verbs) would be smaller than after Passive and *By*-locative primes. This is not what we see.
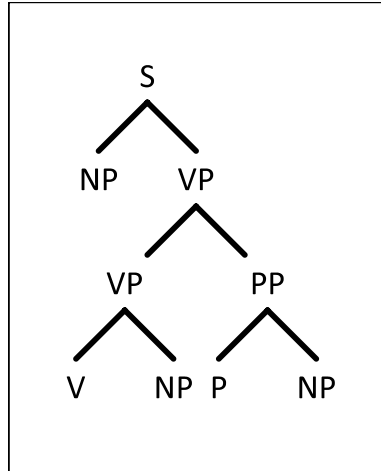
Figure 4.4. Constituent structure for active *by*-transitives.

4.3.1.3. Procedure

Exp. 2 was administered in the exact same way as Exp. 1.

4.3.1.4. Design

We used a within-subjects design with four levels of Prime Type (Passive, *By*-locative, *By*-transitive, Active). This gave us 94% power to detect priming between any two levels of Prime Type (at a Cohen's *d* of .28 without lexical overlap; see Mahowald et al., 2016, p. 21). Participants were randomly assigned to one of eight counterbalanced lists. The dependent measure was the number of passive sentences produced by participants (coded as 1, with actives coded as 0), out of all transitive responses (passive/active+passive). In presenting the production cell means (for descriptive purposes), we have aggregated over both participants and items.

4.3.1.5. Coding

Participants' recorded responses were coded as in Exp. 1. In total, 5,173 of the 5,927 produced target descriptions (87.3%) were transitive responses (i.e., Active or By-Passive) and thus

entered into the analysis. Ten percent of the target responses were independently coded by a second coder, with an intercoder reliability of 99% (Cohen's κ=.98).

4.3.1.6. Data analysis

We analyzed the data for Exp. 2 with a logistic mixed-effects model in the lme4 package in R, with Prime Type (Passive, *By*-locative, *By*-transitive, Active) as a fixed effect. We started with the maximal random effects structure appropriate for our experimental design. However, this model failed to converge. The final model included random intercepts for participant and item (target picture) and a random slope for Prime Type within participants. The fixed effect was effect coded (1, -1). As before, we performed a forward model comparison to determine the significance of our fixed effect. Table 4.3 summarizes the results of this comparison. Planned pairwise analyses were run on the full model minus the relevant levels of Prime Type. In addition, we calculated Bayes factors for the simple effect of priming for (1) Passives vs. Actives, (2) *By*-locatives vs. Actives, and (3) *By*-transitives vs. Actives (see section 4.2.1.6 for details).

Table 4.3. Stepwise forward model comparison for fixed effect in Exp. 3.				
Fixed effect term	AIC (ΔAIC)	df (Δdf)	χ^2	$p=$
Base model: Random intercepts for participant and item + random slope for Prime Type within participants	3787.3 (---)	12 (---)	---	---
+ Prime Type (PT)	3783.7 (-3.6)	15 (3)	9.58	.02*
*Significant at the $p < .05$ level.				

4.3.2. Results

Accuracy on the distractor memory task was high (94%).

Fig. 4.5 shows the pattern of results for Exp. 2. The model comparison revealed a significant main effect of Prime Type, $\chi^2(3)=9.58$, $p=.02$. Planned pairwise comparisons revealed that significantly more passives were produced in the Passive priming condition as compared to the Active control condition (24.7% vs. 22.0%), $\beta=.19(SE=.07)$ $z=2.80$, $p=.005$, but not as compared to either the *By*-locative condition (24.7% vs. 25.8%), $\beta=.03(SE=.06)$ $z=.42$, $p=.67$, or the *By*-transitive condition (24.7% vs. 24.1%), $\beta=.08(SE=.06)$ $z=1.25$, $p=.21$. The proportion of passives produced in the *By*-locative priming condition was significantly greater than the proportion of passives produced in the Active control condition (25.8% vs. 22.0%), $\beta=.19(SE=.07)$ $z=2.76$, $p=.006$, but did not significantly differ from the proportion of passives produced in the *By*-transitive condition (25.8% vs. 24.1%), $\beta=.04(SE=.07)$ $z=.61$, $p=.55$. Finally, the proportion of passives produced in the *By*-transitive condition was also significantly greater than the proportion of passives produced in the Active control condition (24.1% vs. 22.0%), $\beta=.16(SE=.07)$ $z=2.28$, $p=.02$.

Our Bayes factor analysis suggested that the data for Passives vs. Actives were .28 times more likely to occur under a model including Prime Type (=priming) than a model without it (=no priming). The data for *By*-locatives vs. Actives were .33 times more likely to occur under a model including Prime Type (=priming) than a model without it (=no priming). Lastly, the data for *By*-transitives vs. Actives were .08 times more likely to occur under a model including Prime Type (=priming) than a model without it (=no priming). Thus, our evidence for priming in Exp. 2 is decidedly less strong, and we must interpret these results with caution.
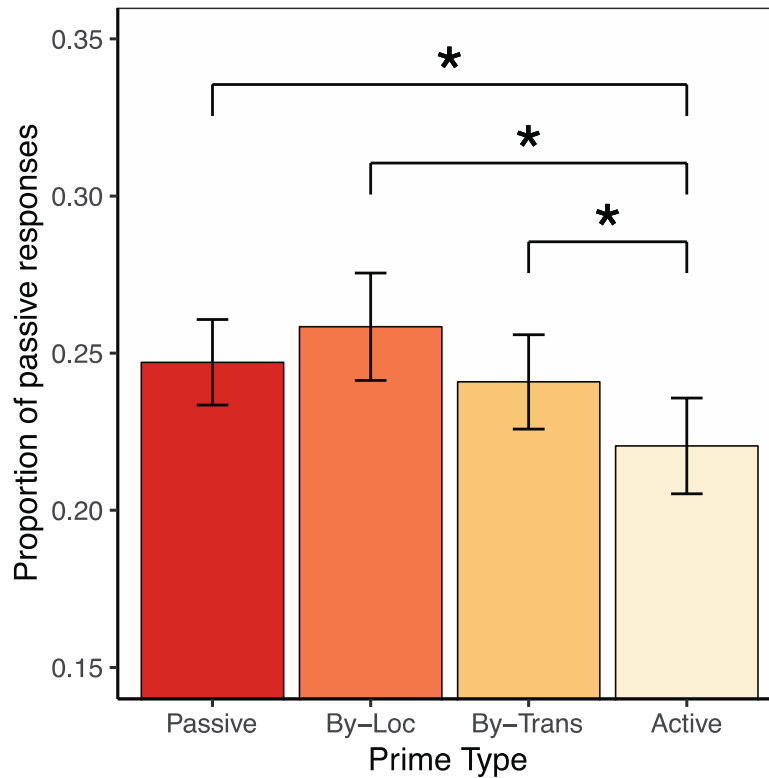
Figure 4.5. Overall proportion of passive productions in Exp. 2 by Prime Type. Error bars reflect by-subject standard errors. By-Loc=*By*-locative; By-Trans=*By*-transitive.

4.3.3. Discussion

In Exp. 2, we replicate several of our central findings: Both passive primes and *by*-locative primes increased passive production (to the same degree), relative to active primes, confirming the findings of Exp. 1 and Bock and Loebell (1990). Critically, we also found that *by*-transitives primed passive responses. Thus, the *by*-phrase itself is sufficient to induce priming of passives regardless of whether it appears in an intransitive sentence (Exps. 1 and 2) or a transitive sentence (Exp. 2), demonstrating that the global syntactic phrase structure is neither sufficient nor necessary for passive priming to occur. However, the effects in Exp. 2 were not as strong as those in Exp. 1, as confirmed by our Bayes factor analysis. We will return to this point in the general discussion.

At the same time, simple changes in verbal morphology did not significantly reduce the priming of passive structures. Note that our passives and *by*-locatives always contained an auxiliary, while our actives and *by*-transitives did not. If this piece of structure mattered for priming, we should have expected reduced (or no) priming in *by*-transitives as compared to either passives or *by*-locatives (this also predicts that we should have seen non-zero priming in the non-*by*-locatives in Exp. 1). But this is not the case. This result suggests one parallel between passive priming and dative priming, where verbal morphology is also irrelevant (Pickering & Branigan, 1998).

4.4. General Discussion

We revisited a key finding in the structural priming literature that has been widely used to argue for bare constituent tree priming: that intransitive locative sentences prime passives (e.g., Bock & Loebell, 1990). We asked whether this effect was in fact due to a tendency to repeat fully abstract syntactic phrase structures, or if it might instead reflect the priming of something less abstract: an adjunct *by*-phrase. In two experiments, we replicated Bock and Loebell's (1990) finding that *by*-locatives prime passives (Exps. 1 and 2). Critically, however, we find that locative-to-passive priming is limited to cases in which the preposition *by* is repeated from prime to target (cf. non-*by*-locatives; Exp. 1). Finally, we discovered that priming of passives persists even when the *by*-phrase occurs in a different global syntactic structure: *By*-transitives prime passives even though their global phrase structure is more similar to actives (due to the presence of a direct object; Exp. 2).

Notably, we also replicated Bock and Loebell's (1990) finding that semantic roles do *not* contribute to passive priming. That is, across both experiments, we found no evidence that the magnitude of priming from passives to passives was greater than that from *by*-locatives to passives. Instead, priming in this task appears to be driven solely by the presence of the *by*-phrase, regardless of its semantic interpretation (agent vs. location) or the constituent structure of the clause. We discuss this finding in greater detail below.

One possible interpretation of the results is that the *by*-phrases in the prime sentences activate stored pieces of lexically-specified syntax, rather than an abstract prepositional phrase schema that can have any preposition slotted into it. This level of description is consistent with linguistic traditions that reject a strict division between syntax and the lexicon and allow for (and in fact predict) the existence of intermediate generalizations: linguistic entities that combine abstract schematic knowledge with more concrete and lexically-specified knowledge (e.g., Croft, 2001; Fillmore, 1985; Goldberg 1995, 2006; Jackendoff, 2002, 2007; Langacker, 1987; O'Donnell, 2015; Oehrle, Bach, & Wheeler, 2012; Pollard & Sag, 1994; Schabes, Abeillé, & Joshi, 1988). It is alternatively possible that what's doing all the work is the lexical item *by* on its own, rather than the full prepositional phrase which it heads.[29] One reason why we might favor the stored structure account is that prior data, using different constructions, found no evidence for the priming of function words independent of their interpretation (Bock & Loebell, 1990, Exp. 3; Ferreira, 2003). For example, Ferreira (2003) found a greater increase in *that*-complementization (e.g., *The mechanic mentioned **that** the car could use a tune-up*) following other *that*-complementization structures (e.g., *The company insured **that** the farm was covered for two million dollars*) than following a complementization structure without *that* (e.g., *The company insured ___ the farm was covered for two million dollars*). Critically, there was no increase in *that*-complementization following transitive sentences with the functionally distinct deictic *that* (e.g., *The company insured **that** farm for two million dollars*). Likewise, Bock and Loebell (1990, Exp. 3) found no influence of infinitive *to* (e.g., *Susan brought a book to study*) on *to*-dative productions (e.g., *The girl is handing a paintbrush to the boy*). If the same processes are at work in complement priming, dative priming, and passive priming, then we should not expect *by* on its own to prime passives. At the same time, there are good reasons to believe that priming varies systematically across constructions depending on the representational

[29] One fact that makes this a distinct possibility is that *by* contains a diphthong vowel, making it bimoraic: [bai]. Thus, it is a strong (and memorable) syllable.

basis of the alternation (see section 4.4.4). For this reason, we are reluctant to draw strong

conclusions from these prior findings. Thus, it remains to be seen whether this priming is due to the

by-phrase or *by* on its own.

In sum, the central message of the present findings is that passive priming does not result

from the repetition of abstract constituent structure alone (cf. Bock & Loebell, 1990; Branigan &

Pickering, 2017). In the remainder of this discussion, we situate our results in the context of the

wider structural priming literature. We first discuss our assumptions about syntax (section 4.4.1) and

the strength of our priming effects (section 4.4.2). We then review the evidence that has been offered

in favor of content-less tree priming to determine whether it can be integrated with the present

findings (section 4.4.3). Finally, we consider how to reconcile our findings with how priming works

in other alternations, particularly locatives and datives, in which semantic event structure plays a role

(section 4.4.4).

4.4.1. A note on passive syntax

While the simplified syntactic structure in Fig. 4.1b led to the prediction that intransitive

locatives should prime passives, in reality, there is little agreement about passive syntax. More

elaborate syntactic structures have been proposed in order to represent unexpressed aspects of

semantics and discourse structure. For example, an influential proposal by Baker, Johnson, and

Roberts (1989) treats passive sentences as underlyingly transitive (see Fig. 4.6). This proposal

captures the idea that the subject argument of a passive corresponds to the direct object argument of

an active sentence. On this theory, the distinct discourse function of the passive construction is

represented by the inclusion of a passive morpheme "argument," represented in Fig. 4.6 by *–en*, and

the lack of a causer argument.
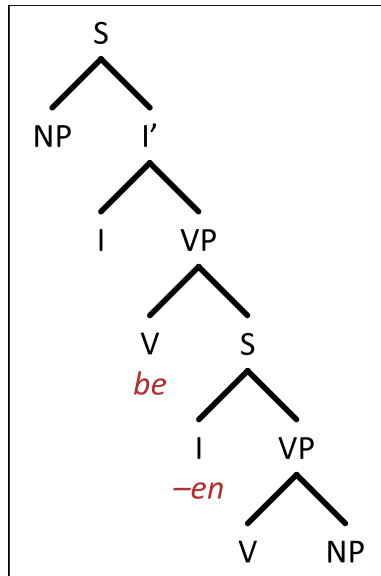
Figure 4.6. Schematic (underlyingly) transitive representation of the passive proposed by Baker, Johnson, and Roberts (1989).

Other frameworks have treated the passive as a construction (e.g., Culicover & Jackendoff, 2005; Ginzburg & Sag, 2001) or as surface projections of individual verbs (e.g., Bresnan, 1982; Pollard & Sag, 1987). These proposals consider the passive to be syntactically intransitive, with semantics and discourse structure represented by other means. Researchers have also debated whether the *by*-phrase should be treated as an adjunct (e.g., Legate, 2014), an argument (e.g., Koenig, Mauner, & Bienvenue, 2003), or something in between (e.g., Grimshaw, 1990).

But importantly, no one has proposed that passives share the same abstract syntax with *both* intransitive and transitive sentences, or that distinct abstract tree configurations are required for sentences solely on the basis of the inclusion of distinct locative prepositions such as *by* vs. *near*. In order for the current set of results to be explained by syntactic priming, both of these assumptions would be needed. Thus, the main conclusion we draw remains valid: The fact that intransitive *by*-locatives prime passives does *not* provide evidence in support of abstract syntactic priming.

4.4.2. A note on effect sizes and online data collection

At first blush, our priming effects might appear smaller than other priming effects. But, in fact, our results are well within the range typically observed. In their meta-analysis of structural priming, Mahowald et al. (2016) report the average Cohen's *d* of priming across 138 experiments in 69 papers to be .29 (small to medium). However, since we know that different representations contribute to the priming of different constructions (see section 4.4.4), it makes sense to compare our study to previous studies of active-passive priming. For these studies (N=74), the average reported value is also .29; however, the inferred value, according to Mahowald et al. (2016), is approximately .17 (see their Fig. 2). Our effects in Exp. 1 (where we see priming) are very close to this inferred value: .20 in the Passive condition and .15 in the *By*-locative condition. Moreover, our Bayes factor analysis suggested very strong or decisive evidence in favor of priming in the Passive and *By*-locative conditions and strong or very strong evidence against priming in the Non-*by*-locative condition. Thus, we have confidence in the results of Exp. 1.

In contrast, our effects in Exp. 2 are notably smaller: .08 for Passives vs. Actives, .09 for *By*-locatives vs. Actives, and .06 for *By*-transitives vs. Actives. In this case, the Bayes factor analysis did not provide strong support for either hypothesis. Thus, we must interpret these results more cautiously. Nevertheless, Exp. 1 provides strong evidence that *by*-locatives prime passives as much as passives do, replicating Bock and Loebell (1990), and strong evidence that non-*by*-locatives do *not* prime passives. Thus, these results support the conclusion that priming between intransitive *by*-locatives and passives does *not* provide evidence in support of abstract syntactic priming.

Of course, one salient difference between our study and the relevant past work on passive priming is the use of online (vs. in-lab) data collection. The concern is that by virtue of using a remote platform we have less control over what participants are doing (or who participates, for that matter), and remote participants might therefore not pay attention or engage as fully as participants brought into the lab. However, it is unlikely that this adversely influenced our results, for three

reasons. First, lapses in attention would predict consistently smaller effect sizes in the online studies, but our effects in Exp. 1 closely paralleled prior in-lab studies (see above). Second, we have successfully used Amazon Mechanical Turk in other papers and consistently found robust priming across a variety of different constructions and experimental procedures (Ziegler & Snedeker, 2018; Ziegler et al., 2018, under review). Third, in a within-subjects pilot study for Exp. 1 conducted in the lab, we found small effects parallel to those in Exp. 2 (which is in part what motivated us to move online in the first place; see Appendix C). In sum, our results are robust, replicable, and unlikely to have been influenced by the decision to collect data online.

4.4.3. Is there unambiguous evidence for the priming of abstract, content-less syntactic trees?

In addition to Bock and Loebell (1990), there are several other findings which have been argued to demonstrate that content-less phrase structure can be primed. The challenge in every case is to isolate this level of representation, given that most of the alternations we study will also vary in their lexical content, semantic event structure, information structure, and/or syntax-animacy mappings. Here we explore whether there is any priming result that *must* be attributed to the priming of phrase structure, with no potential confounds. We first review priming in passives, and then we branch out to other constructions.

As we can see in Table 4.4, the vast majority of passive priming studies are confounded by lexical content (rows 1-3), as was the case in Bock and Loebell (1990, Exp. 2). However, there are two kinds of studies where this is not the case. The first is cross-linguistic studies, in which bilingual participants are primed in one language and asked to generate target descriptions in another language (Chen, Jia, Wang, Dunlap, & Shin, 2013; Hartsuiker, Pickering, & Veltkamp, 2004; rows 4 and 5). Since the morphemes used to mark passives are distinct in the two languages, these studies appear to rule out lexicalized representations as the locus of priming. The second is a study by Messenger et al. (2011), in which participants were primed by short passives that did not contain an agentive *by-*

phrase (e.g., *The girls are being shocked*) and produced full passives with the *by*-phrase (e.g., *The king is being scratched by the tiger*; row 6). While none of these studies allows for lexical priming (though see fn. 32), they all have at least one potential locus of priming other than content-less phrase structure (see Table 4.4): information structure, or the way information is "packaged" within a sentence (e.g., Lambrecht, 1994). Some evidence for information structural priming comes from Vernice, Pickering, and Hartsuiker (2012), who found a tendency for Dutch-speaking participants to produce more passive sentences (e.g., *De jongen wordt geraakt door de bal* "The boy is hit by the ball"), which make the undergoer argument the sentence topic, following a cleft sentence with a topicalized undergoer (e.g., *Degene die hij slaat is de cowboy* "The one who he is hitting is the cowboy") than one with a topicalized agent (e.g., *Degene die hem slaat is de cowboy* "The one who is hitting him is the cowboy"), despite differences in surface syntax (for other evidence, see, e.g., Bernolet, Hartsuiker, & Pickering, 2009; Fleischer, Pickering, & McLean, 2012; Heydel & Murray, 2000; Ziegler & Snedeker, 2019).[30] Thus, none of the passive priming studies provide unambiguous evidence for the priming of abstract syntax (vs. lexicalized syntax, lexical content on its own, information structure, or some combination thereof).

Table 4.4. Review of possible contributors to priming in passives.					
Study	**Prime structure**	**Target structure**	**Shared phrase structure?**	**Shared lexical item?**	**Shared information structure?**

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[30] Bernolet et al. (2009) examined the priming of English passives by variants of the Dutch passive: namely, Dutch passives with the *by*-phrase positioned sentence-initially, -medially, or -finally. Results demonstrated that the medial and final cases serve a function analogous to the English passive in emphasizing the patient argument (see also Cornelis, 1996), and they both primed English passives. However, statistically stronger priming was found for the variant that shared with English both information structure and constituent structure (passives with sentence-final *by*-phrase) over just information structure alone. At face value, this might suggest a role for the contribution of abstract syntax to priming. However, this pattern could also be due to a deeper difference in information structure between the two variants (which likely "differ in the emphasis given to the agent […] because it takes a different sentence position"; Bernolet et al., 2009, p. 302) or, as we suggest for other cases below, differences in prosody.

Bock & Loebell (1990, Exp. 2); many others (for references, see Mahowald et al., 2016)	The 747 was alerted by the airport's control tower	A golfer was struck by lightning	✓	✓ (by)	✓
Bock & Loebell (1990, Exp. 2)	The 747 was landing by the airport's control tower	A golfer was struck by lightning	✓	✓ (by)	✗
Messenger et al. (2012)	A girl is being shocked by a sheep	A king is being scratched by a tiger	✓	✓ (by)	✓
Hartsuiker et al. (2004)	El camión es perseguido por el taxi "The truck is chased by the taxi"	A bottle is hit by a bullet	✓	✗	✓
Chen et al. (2013)	杯子被小猫打破了 "cup by cat broken"	Boxes were knocked over by a ball	✗	✗	✓
Messenger et al. (2011)	The girls are being shocked	A king is being scratched by a tiger	✓ (partial, unless covert)	✗ (unless covert)	✓

As mentioned previously, there is reason to think that priming varies by construction depending on the representations involved (we return to this point in section 4.4.4). Thus, evidence that abstract, content-less trees can be primed in *some* cases would not provide evidence that they can be primed in *all* cases. Above, we reviewed passive priming and found no unambiguous evidence for

the influence of abstract, content-less phrase structure. We next consider candidate evidence for abstract tree structure priming in other constructions, summarized in Table 4.5.[31]

Several of these studies (rows 1-4) build on another experiment in Bock and Loebell (1990, Exp. 1) in which motion verb sentences with locative prepositional phrases (e.g., *The wealthy widow drove an old Mercedes to the church*) were shown to prime *to*-datives (e.g., *The girl is handing a paintbrush to the boy*; row 1). While all of the motion verb primes and dative targets contained the preposition *to* in the original experiment, leaving open a lexical explanation (see also Potter & Lombardi, 1998), subsequent studies eliminated the preposition as the locus of priming (Fox Tree & Meijer, 1999, Exp. 1; Salamoura & Williams, 2007, Exp. 3; Ziegler & Snedeker, 2018, Exp. 11; rows 2-4). Nevertheless, these studies all had a common feature which suggests another possible locus of priming. Specifically, in each case, the alternative prime against which the motion verb sentences were compared was the double-object dative (e.g., *Sue gave the dog a bone*). Double-object datives differ from both motion verbs and *to*-datives in their information structure, semantic structure, and syntax-animacy mappings. Thus, priming at any of these levels of representation could have resulted in the observed difference between the prime conditions (i.e., double-object dative primes may be pulling *to*-dative production down, rather than *to*-dative primes pulling it up).

Several other findings that manipulated the order of information in the sentence are summarized in rows 5-7. Hartsuiker et al. (1999) found that scrambled Dutch sentences in which the subject followed the verb led to more productions in which the subject followed the verb than did canonical subject-first orderings (row 5). But this type of word order difference is known to predict differences in information structure in Germanic and other languages (Hinterhölzl & Petrova, 2009; Lambrecht, 1994). Cleland and Pickering (2003) showed that relative-clause modification in English

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[31] Another common case that has been used to argue for abstract syntax is the priming of attachment ambiguities (e.g., Desmet & Declercq, 2006; Scheepers, 2003). However, this type of priming is always confounded with differences in semantic interpretation. We therefore do not discuss it further.

led to more relative clause productions than did prenominal attributive modification (row 6; see also Bernolet, Hartsuiker, & Pickering, 2007), but there is evidence that predicative modification (by a relative clause) differs from attributive modification, both semantically and in terms of information structure (e.g., Bolinger, 1967). Bernolet, Hartsuiker, and Pickering (2013) found priming between *of*-genitives in Dutch and *of*-genitives in English, relative to the Dutch equivalent of *s*-genitives (row 7), and yet here, too, there are likely information structural and semantic differences since such differences exist between the analogous constructions in English (e.g., Stefanowitsch, 2003). Thus, none of these cases provides unambiguous evidence for pure tree priming.

There are two final results that are not easily attributed to lexical or information structural differences. Konopka and Bock (2009; see also Gries, 2005) have found priming of verb-particle placement in English: Participants produced more verb-particle constructions with the direct object intervening (e.g., *The high prices scared the customers off*) following configurations with the same ordering (e.g., *The burglars broke the door down*) than configurations in which the particle occurred right after the verb and before the direct object (e.g., *The burglars broke down the door*; row 8). The ordering of the particle and direct object is conditioned by various semantic and information structural factors (Gries, 1999), but the priming effect was found even when these factors were controlled for (Konopka & Bock, 2009) or taken into account (Gries, 2005).

Another intriguing finding comes from Hartsuiker and Westenberg (2000), who found priming of auxiliary placement in Dutch: Participants were more likely to place the finite auxiliary verb in a subordinate clause before the participle (e.g., *had gebroken*) following a prime with the same order (e.g., *was geblokkeerd*) than after a prime with verb-final ordering (e.g., *geblokkeerd was*; row 9), regardless of whether responses were verbal or written. While differences in constituent ordering commonly reflect differences in information structure, as noted above, information structure does not appear to condition this difference (for discussion, see Hartsuiker & Westenberg, 2000; Pappert & Pechmann, 2014). Instead, the variation is conditioned by dialect, choice of auxiliary, and

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prosody (rhythm; De Sutter, 2009; Swerts & van Wijk 2005). Intriguingly, the ordering of direct

object and verb-particle—which also shows somewhat mysterious priming effects—has rhythmic

correlates as well (Dehé, 2005). The possibility of rhythmic priming in language has not been widely

studied, and the evidence that does exist is mixed: While no evidence has been found for priming of

pauses within sentences (Tooley, Konopka, & Watson, 2014, 2018), and one study found no

evidence of lexical stress priming (Bock & Loebell, 1990, Exp. 3), other work that used tone

sequences found rhythmic priming for word lists (Cason & Schön, 2012) and for sentences with

matching rhythmic structure (Cason, Astésano, & Schön, 2015). Clearly, more work is needed to

determine whether (explicit or implicit) rhythmic structure, or any of the other factors besides syntax

in Table 4.5, is responsible for the priming in each case.

Critically, the key contribution of the current work is that passive priming is reliant on

information structure (see above) or lexicalized representations. We have demonstrated that the *by*-

phrase itself is sufficient to induce priming of passives regardless of whether it appears in an

intransitive sentence (Exps. 1 and 2) or a transitive sentence (Exp. 2), demonstrating that the global

syntactic phrase structure is neither sufficient nor necessary for passive priming to occur.

Table 4.5. Review of possible contributors to priming in other constructions.						
Study	**Prime structure**	**Target structure**	**Shared phrase structure?**	**Shared lexical item?**	**Shared information structure?**	**Shared semantics?**
Bock & Loebell (1990, Exp. 1); also Potter & Lombardi (1998)	The wealthy widow drove an old Mercedes to the church	The girl is handing a paintbrush to the boy	✓	✓ (to)	✓ (of alternative double-object structure)	✓ (of alternative double-object structure)
Ziegler & Snedeker	The girl dragged the	The boy brought the	✓	✕	✓ (of alternative double-	✓ (of alternative double-

Study	Prime/Example 1	Prime/Example 2				
(2018, Exp. 11)	bucket around the doctor	keys to the camel			object structure)	object structure)
Fox Tree & Meijer (1999, Exp. 1)	The musician needs to borrow a microphone from his friend tonight	While the poet traveled in France, she wrote many letters to her family	✓	✗	✓ (of alternative double-object structure)	✓ (of alternative double-object structure)
Salamoura & Williams (2007, Exp. 3)	Ο πρόεδρος φύλαξε το χρυσό μετάλλιο μέσα στο συρτάρι "The president kept the gold medal in the drawer"	The hotel receptionist gave [a key to the guest]	✓	✗	✓ (of alternative double-object structure)	✓ (of alternative double-object structure)
Hartsuiker et al. (1999)	Op de tafel ligt een bal "On the table lies a ball" (vs. Een bal ligt op de tafel "A ball lies on the table")	Naast het hok zit een hond "Beside the kennel sits a dog"	✓	✗	✓	✗
Cleland & Pickering (2003); also Bernolet et al. (2007)[32]	The square that's red (vs. The red square)	The square that's green / The diamond that's red	✓	✓ (that)	✓	✓
Bernolet et al. (2013)	het hemd van de jongen "the	the egg of the nurse	✓	✗	✓	✓

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[32] Bernolet et al. (2007) found differential priming for attributive vs. predicative constructions within English, within Dutch, and between Dutch and German, but not between Dutch and English. We know that translation-equivalents boost priming (Bernolet, Hartsuiker, & Pickering, 2012; Cai, Pickering, Yan, & Branigan, 2011; Schoonbaert, Hartsuiker, & Pickering, 2007), which would predict equivalent priming between Dutch and English as between Dutch and German. However, Bernolet et al. (2012) have found that priming across languages increases with phonological overlap in the syntactic head (in this case, the relativizer *that/die/der*). The greater phonological similarity between *die* and *der* could predict greater priming between Dutch and German than between Dutch and English. Therefore, consistent with the current findings, partially lexicalized translation equivalents (Rel$_{die/der}$ Adj V) may result in more priming than translation equivalents with less analogous morphosyntax (Rel$_{that}$ V Adj).

	shirt of the boy" (vs. de jongen zijn hemd "the boy his [=boy's] shirt")					
Konopka & Bock (2009); also Gries (2005)	The burglars broke the door down (vs. The burglars broke down the door)	The high prices scared the customers off	✓	✗	✓ (?)	✗
Hartsuiker & Westenberg (2000)	… omdat de weg geblokkeerd was "because the road blocked was" (vs. omdat de weg was geblokkeerd "because the road was blocked")	…omdat hij zijn been gebroken had "because he his leg broken had"	✓	✗	✗	✗

4.4.4. Semantic event structure matters for locative and dative priming but not passive priming

The priming behavior we have observed for passives is different from what has been observed for locatives and datives. In particular, recall that we found no influence of semantic structure on passive priming, replicating Bock and Loebell (1990): Sentences with a locative *by*-phrase primed passives just as much as passives did. In contrast, both locatives and datives appear to be sensitive to differences in semantic event structure in their priming behavior (see introduction).

How can we account for this discrepancy? Elsewhere, we have argued that the semantic representations involved in structural priming for locatives and datives are event structures rather than a list of semantic roles and their syntactic positions (Ziegler et al., 2018). Semantic roles are

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traditionally viewed as atomic elements that define the participant roles in a sentence and are ordered in a hierarchy which controls their syntactic realization (e.g., Baker, 1988; Fillmore, 1968; Gruber, 1965; see also Jackendoff, 1972). In contrast, event structures consist of decomposed verbal predicates (ACT, BECOME, CAUSE, HAVE, etc.) that capture the relational structure among arguments (e.g., Goldberg, 1995; Harley, 2003; Jackendoff, 1990, 2002; Levin & Rappaport Hovav, 2005; Pinker, 1989; Rappaport Hovav & Levin, 1998, 2011; for a related proposal, see Davis & Koenig, 2000). On this theory, the surface syntactic expression of arguments is based on these relational semantic structures, not on isolated semantic roles: Arguments higher in the semantic structure appear higher in the syntactic tree. Thus, the same semantic role—e.g., recipient—can appear as subject (e.g., *She received the package*), as the first object in a double-object dative construction (e.g., *He gave her a package*), or as an object of one of at least two prepositions (e.g., *He gave the book to her* or *He baked a cake for her*) depending on its place in the event structure. Likewise, an undergoer argument can appear as subject (e.g., *The stick broke*), as direct object (e.g., *She broke the stick*), or as the second argument in a double-object dative construction (e.g., *She threw him the stick*).

Thinking of semantic structural priming in terms of event structures provides a potential explanation for the difference between locatives/datives and passives. The two syntactic realizations of locatives and datives are typically argued to differ from one another on the basis of their underlying event structures (e.g., Anderson, 1971; Beck & Johnson, 2004; Bruening, 2010; Goldberg, 1995; Harley, 2003; Levin & Rappaport Hovav, 2005; Pinker, 1989; Rappaport & Levin, 1988; Rappaport Hovav & Levin, 2008).[33] The active-passive alternation, on the other hand, is

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[33] The distinction relies on the fact that while, e.g., double-object and *to*-dative sentences can both describe the same event in the world they nevertheless capture different construals of, or perspectives on, that event (Goldberg, 1995, 2006; Jackendoff, 1990; Levin & Rappaport Hovav, 2005; Pinker, 1989). To see the point, note that the double-object dative requires that the recipient be construed to be animate (Goldberg, 1995; Pinker, 1989; Rappaport Hovav & Levin, 2008): *She sent that place a package* vs. *She sent a package to that place*.

typically considered to result from a single semantic representation rather than two (e.g., Baker, 1988; Bresnan, 1978, 1982; Chomsky, 1957, 1965; Katz & Postal, 1964; though cf. Pinker, 1989; for discussion, see Culicover & Jackendoff, 2005; Levin & Rappaport Hovav, 2005). Actives and passives, instead, are differentiated by their information structure (specifically *voice*): Passive sentences allow the argument which would be the object in an active sentence to become the topic, and the argument which would normally be the subject argument in an active sentence to be less topical or even omitted (Fox & Hopper, 1994; Givón, 1994; Shibatani, 1985). Accordingly, while the two syntactic realizations of locatives and datives reflect differences in underlying event representation (event construal), passivization takes a given event structure and changes the surface order of its arguments to fulfill a different discourse function without necessitating any change in meaning.[34]

To see that event structure is not relevant to the function of passives in English, notice that passivization is available as an option for almost any semantically transitive verb (though not all; cf. *cost*, *have*, etc.). Non-agentive arguments can be "demoted" to the *by*-phrase in passives (e.g., *She is always pleased by good weather*), and even the dummy-*it* argument may appear as the subject (e.g., *It was believed to be the case*). In fact, the passive can be combined with either locative construction (e.g., *Paint was smeared on the wall* or *The wall was smeared with paint*) and either dative construction (e.g*., The dog was given a bone* or *A bone was given to the dog*).

Thus, when we choose one version of a locative or dative structure, we choose one of two competing event structures, opening up the possibility of priming future utterances at this level. For example, double-object datives have [X CAUSE [Z HAVE Y]] structures which prime other [X CAUSE [Z HAVE Y]] structures but do not prime the [X CAUSE [Y BE AT Z]] structures that underlie *to-*

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[34] Passives and actives famously *can* differ in meaning, as in *Two languages are known by every linguist* vs. *Every linguist knows two languages* (Ziff, 1966), but this difference arguably stems from the difference in information structure, since the more topical argument tends to have wider scope (Goldberg, 2006, ch. 8; Kurtzman & MacDonald, 1993).

datives. Conversely, since both the active and passive version of a sentence have the same underlying event structure, we do not see semantic priming: Passive transitive [X ACT Z] structures equally prime both active transitive [X ACT Z] and passive transitive [X ACT Z] structures, resulting in no differential influence on one over the other.

4.5. Conclusion

Priming is a powerful tool for studying linguistic representation (e.g., Branigan & Pickering, 2017). In this paper, we questioned a key argument underlying claims that structural priming is based on tree structures devoid of meaning and morphology. In particular, we asked whether the priming Bock and Loebell (1990) observed between intransitive *by*-locatives and passives was driven by an abstract syntactic phrase structure, as has commonly been assumed (e.g., Bock & Griffin, 2000; Branigan & Pickering, 2017; Branigan et al., 1995; Chang et al., 2006; Pickering & Branigan, 1998; Pickering et al., 2002; Pickering & Ferreira, 2008; Rowland, Chang, Ambridge, Pine, & Lieven, 2012). We found that priming did not occur when the locatives did not contain the preposition *by*. This forces us to reexamine the priming literature. In doing so, we observe that the loci of structural priming vary across constructions in ways which correspond to our theories of the representational bases of the alternations involved. These data highlight the importance of revisiting old conclusions with attention to the full range of factors that may be relevant for the selection of various types of grammatical patterns or constructions (for discussion, see Ziegler, Snedeker, & Wittenberg, 2017).

Chapter 5

CONCLUSION

This thesis has been an examination of the format and content of the semantic representations that underlie natural language understanding and use. In three papers, I showed that semantic event structures provide greater empirical coverage of the available and relevant data than atomic semantic roles do. I have also begun to better characterize the inventory and scope of primitive predicates that compose event structures. Below, I discuss the implications of these findings for the structural priming literature, for our theories of language representation more broadly, and for language acquisition.

5.1. Implications for structural priming

As the field has grown, evidence has mounted that priming can occur at multiple levels (syntactic, semantic, lexical, conceptual, information structural; e.g., Papers 2 and 3; Bock & Loebell, 1990; Bock, Loebell, & Morey, 1992; Chang, Bock, & Goldberg, 2003; Pickering & Branigan, 1998; Vernice, Pickering, & Hartsuiker, 2012; Ziegler & Snedeker, 2019; for reviews, see Branigan & Pickering, 2017; Pickering & Ferreira, 2008). Yet priming is *still* often characterized as largely syntactic, with these other forms of priming being treated as secondary, interface phenomena (e.g., Branigan, 2007; Branigan & Pickering, 2017; Branigan, Pickering, Liversedge, Stewart, & Urbach, 1995; Branigan, Pickering, McLean, & Stewart, 2006; Chang, Dell, & Bock, 2006; for discussion, see Ziegler, Snedeker, & Wittenberg, 2017b). My work not only reaffirms that semantic structure is a powerful driver of priming, but it also suggests that the syntactic representations that *do* contribute to priming are decidedly less abstract than is usually assumed. In Paper 2, I demonstrated priming for semantic structure in a variety of cases, even though priming did not occur between BE

AT and BE POSSESSED AT predicates. In Paper 3, participants did not produce more passives after intransitive locatives with prepositions other than *by*—that is, when only the abstract phrase structure was shared but not the lexical content.

Moreover, I have argued that thinking of structural priming in terms of event structures correctly predicts when semantic representations ought to influence priming, depending on the representational basis of the alternation. Recall that semantic structure did *not* contribute to priming of the passive construction in Paper 3. If actives and passives derive from a single event structure rather than two, this is exactly what we would predict: A passive transitive [X ACT Z] structure should equally prime both the active transitive [X ACT Z] and passive transitive [X ACT Z] structures, resulting in no differential influence on one over the other. In contrast, when the event structure is different for two constructions, we expect a semantic influence on priming: e.g., the [X CAUSE [Z HAVE Y]] structure of a double-object dative should prime other [X CAUSE [Z HAVE Y]] structures but not the [X CAUSE [Y BE POSSESSED AT Z]] structure of a *to*-dative. This is precisely the pattern of data we see across Papers 2 and 3.

Priming is clearly a powerful means for studying linguistic representation (e.g., Branigan & Pickering, 2017). Yet in many common examples (e.g., datives, passives), priming could result from any number of influences. Researchers often draw strong conclusions from such data as to the nature of *one* type of representation without consideration for the other(s). It's precisely this ambiguity and lack of precision that I believe has led to the syntax-dominant view of structural priming. 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 (for further discussion, see Ziegler et al., 2017b). In my work, I have been careful to do just that. I hope others will follow suit.

5.2. Implications for linguistic representation

We often crave theoretical simplicity. For example, as I just mentioned in section 5.1, many structural priming researchers like to think of syntax as the primary driver of priming, with all other representations acting only secondarily (e.g., Branigan, 2007; Branigan & Pickering, 2017; Branigan et al., 1995, 2006; Chang et al., 2006). Or another example: In the history of language research more generally, many early linguistic and psycholinguistic models argued that words and syntax are generated by wholly distinct systems (e.g., Chomsky, 1994; Frazier & Fodor, 1978), even while we have long recognized that lexical and syntactic representations are often mutually constraining (e.g., Chomsky, 1965; Culicover, 1999; Fillmore, 1968; Jackendoff, 1975; Lakoff, 1970; Levelt, 1993; MacDonald, Pearlmutter, & Seidenberg, 1994; Trueswell, Tanenhaus, & Garnsey, 1994). Contra this desire for simplicity, my work and survey of the literature have revealed a more complex picture of the linguistic architecture. I will demonstrate what I think are the key processes and representations (and open questions) through the lens of production: going from message to sentence.

(1) We first conjure an event structure (e.g., "a girl throwing a ball to a dog": [girl CAUSE [ball BE AT dog]]$_{throw}$). My work has begun to better characterize the predicates that compose these event structures. For one, we appear to have a CAUSE predicate that is highly abstract and spans many different classes of verbs (Paper 1). Yet we also have narrower predicates, like BE POSSESSED AT, that likely occur in only a very limited range of verbs (perhaps even a single class; Paper 2). (I suspect BE AT, like CAUSE, is more general and applies to several classes rather than just one, though this remains to be tested.) It's reassuring that our methods are sensitive enough to reveal both commonalities and divergences in structure, which is crucial to gaining a better understanding of what these representations are like. A caveat, however: The evidence I have brought to bear on these event predicates comes from distinct processing pathways: comprehension for the former (Paper 1) and production for the latter (Paper 2). It's an open question as to whether this will make a difference for how we understand either the format or content of these representations.

(2) At the same time as, or shortly after, selecting an event structure, the arguments in this

representation get ordered with respect to their accessibility and the conventional options our

language affords us, where accessibility is determined by given vs. new status, animacy, heaviness,

relative salience, and frequency (e.g., girl > ball > dog). This is where I would situate standard

information-ordering phenomena like passivization, topicalization (e.g., *That pizza, I won't eat*),

cliticization (e.g., *It's the sky that's falling*), heavy-NP shift (e.g., *Bill put on the table the book that*

he had inherited from his grandmother; e.g., Hawkins, 2004; Wasow, 2002), and scrambling (in

languages like German with freer word order; e.g., *Die Kellnerin übergibt die Tasse dem Clown* "The

waitress gives the clown the cup," literally "The waitress gives the cup the clown"; example from

Köhne, Pickering, & Branigan, 2014). The existing priming evidence (including my own elsewhere:

Ziegler & Snedeker, 2019[35]; see also Bernolet, Hartsuiker, & Pickering, 2009; Cai, Pickering, &

Branigan, 2012; Fleischer, Pickering, & McLean, 2012; Heydel & Murray, 2000; Köhne et al., 2012;

Pappert & Pechmann, 2014; Pickering, Branigan, & McLean, 2002; Salamoura & Williams, 2007;

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[35] In visual-world eye tracking, participants primed by a double-object dative (e.g., *Now, he's gonna feed the baby the apple*) usually look to possible animate referents that fulfill the recipient role prior to disambiguation in the target sentence, and vice versa for prepositional-object datives (e.g., *Now, he's gonna feed the bagel to the girl*) to possible inanimate referents that fulfill the theme role (e.g., Arai, van Gompel, & Scheepers, 2007; Thothathiri & Snedeker, 2008). This could be due either to priming at the level of syntax or to priming at the level of event structure. However, in Ziegler and Snedeker (2019), I found the opposite pattern: Following a double-object dative, participants looked more to possible *themes* than possible recipients, and following a prepositional-object dative, they looked more to possible *recipients* than to possible themes. Although at odds with priming on the basis of syntax or event structure, this finding is compatible with priming at the level of information structure. The final argument of a sentence is more likely to be new information (Gundel, 1988). It is also often given default stress and is frequently heavier in terms of both its phonological form and its semantic content (Gundel, 1988; Quirk, Greenbaum, Leech, & Svartvik, 1972). Finally, by virtue of being at the end of the sentence, it benefits from recency effects, making it more memorable (Deese & Kaufman, 1957). All of these factors conspire to draw attention to the inanimate themes of the double-object sentences and to the animate recipients of the prepositional-object sentences. To the extent that this contrast in themes vs. recipients persists across trials, it could drive attention toward other objects that could fulfill the same functions on the target trials.

One puzzle this finding raises is why I found an effect of information structure when the prior work had not (cf. Arai et al., 2007; Thothathiri & Snedeker, 2008). I think this has to do with an unintentional feature of my stimuli. In both of these past studies, the target sentences described isolated events or gave instructions, without any unifying discourse features or goals to link the utterances from one trial to the next. In this study, however, I embedded all of my stimuli—primes, targets, and fillers—within an extended narrative about a single character, John, thus creating a discourse that linked the utterances together. I suspect that having this coherent story led participants to focus more on the information structure of the sentences as they attempted to integrate each new piece of information into their developing understanding of John.

Shin & Christianson, 2009; Vernice et al., 2012) is consistent with this being a distinct step/level of representation from either event structure selection (step 1) or syntactic constituent assembly (step 3 below), and acts over event structures rather than elements in surface syntax (hence step 2 and not later). Critically, this conceptual-level planning already determines, to a large extent, the word order or combination of constructions in a sentence (see, e.g., Levelt, 1989).

(3) We next select the syntactic chunks, or constructions, that express the relationships determined in steps 1 and 2 (e.g., [The girl]$_{NP}$ [[to the dog]$_{PPto}$ [the ball]$_{NP}$]$_{VP}$; Bock & Levelt, 1994; Garrett, 1975, 1980; Kempen & Hoenkamp, 1987; Levelt, 1989). My work in Paper 3 suggests that these structures aren't completely abstract given that priming didn't occur between intransitive locatives and passive transitives when only the abstract phrase structure was shared but the preposition *by* was not. Thus, one possibility is that these chunks are lexical-syntactic structures that are both partly abstract and partly lexicalized (like a *by*-phrase). It's also possible that we have mischaracterized the phrase structures for intransitive locatives and passive transitives such that they actually aren't as similar as we think. If this is the case, these syntactic chunks could well be highly abstract after all, and the priming I observed in Paper 3 could have been carried solely by the word *by*.[36] My data do not rule out this possibility, and the exact grain size of these chunks remains an open question.

(4) Thus far, the global structure of the syntactic tree has been largely determined. However, we must also organize the elements *within* these larger constituents. Here I have included phenomena like verb-particle placement (e.g., *throw out the trash* vs. *throw the trash out*) and auxiliary-participle ordering (e.g., *geblokkeerd was* vs. *geblokkeerd was* "was blocked"). In part, this is due to the distinction I have drawn between priming that appears to be lexically dependent (step 3) or heavily influenced by event conceptualization and information structure (steps 1 and 2) and priming that does

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[36] Although it's still curious that we as a field don't have any direct positive evidence for fully abstract syntactic priming when there's plenty of evidence for robust priming at other levels.

not appear to be subject to any of these constraints (see discussion in Paper 3). But it is also guided

by the distinction made in many models of production which separates out this type of within-

constituent linearization from constituent assembly proper (step 3) (see, e.g., De Smedt, 1990;

Garrett, 1975, 1980; Gazdar & Pullum, 1981; Kempen & Hoenkamp, 1987; Pollard & Sag, 1994).

More work is needed to fully suss out whether this division is warranted.

In sum, language is a complex system of representations that are both distinct and mutually

constraining. The ones listed above are just the structural representations beyond the level of the

word; there are still more at the levels of morphology and phonology that are not accounted for here.

In this thesis, I have begun to better characterize some of these structures. Careful investigation is

needed to further characterize the rest.

5.3. Implications for language acquisition

One fascinating and enduring observation at the intersection of linguistic representation and

cognitive development is that many of the same primitives invoked in theories of semantic event

representation appear in theories of infants' prelinguistic conceptualization of events (agents vs.

objects, goal-directedness, causation; e.g., Spelke & Kinzler, 2007). This suggests a natural

hypothesis about the developmental origins of language—specifically, that the primitive units of

event representation derive directly from our prelinguistic conceptual categories (e.g., Brown, 1973;

Pinker, 1984, 1989, 2007; Strickland, 2016; for discussion, see Hartshorne et al., 2016; Kline et al.,

2017).

This hypothesis has consequences for language acquisition. In the absence of any constraints

(extreme empiricism; e.g., Skinner, 1957), a child learning her first language would have to

simultaneously figure out what the relevant syntactic representations are, what the relevant semantic

representations are, and how to link the two together. With so many moving parts, this would be a

difficult problem to solve indeed (for relevant critique, see Chomsky, 1959). However, if our

prelinguistic conceptual representations form the basis of argument structure in language, then this significantly reduces the complexity of the learning problem: Children need only parse the syntactic input around them and link it to these already existing structures.

This of course is still no small feat. But here event structures provide a clear advantage over traditional atomic role theories. On these earlier accounts, children would need dozens of rules that map particular semantic roles to specific syntactic arguments. However, because event structures represent meaning as a series of hierarchically embedded predicates, this myriad of rules can be replaced by a single, simpler principle: Map arguments high in the predicate structure to phrases high in the syntactic tree (i.e., preserve prominence; Bouchard, 1995; Grimshaw, 1990; Hartshorne et al., 2016; Jackendoff, 1990; Wechsler, 1995; for review and discussion, see Levin & Rappaport Hovav, 2005). This, in turn, substantially reduces the distance between the viable nativist and empiricist theories of language acquisition. Rather than dozens of innate rules, the nativist infant need only expect prominence to be preserved. Similarly, the empiricist infant need only be alert to broad generalizations about how meaning maps to form; she can discover prominence preservation in the process of learning her first verbs.

One prediction of this framework is that children should exhibit broad semantic generalization at the earliest ages that we can test for it. Once a child has learned a few verbs and either taps into an innate program for prominence preservation or discovers it empirically, she now has the ability to take any new syntactic structure and extract a verb meaning (syntactic bootstrapping; Gleitman, 1990) or predict the syntactic structure of a new verb based on its similarity to existing verbs (semantic bootstrapping; Pinker, 1984). This prediction holds empirically: Children as young as 15 months of age have been shown to use syntax to learn the meanings of novel verbs (Jin & Fisher, 2014).

My work offers several obvious future directions for how to further test the predictions of this framework. For example, we know that very young infants are capable of distinguishing caused

motion events from non-causal events (Kotovsky & Baillargeon, 2000; Leslie, 1982; Leslie & Keeble, 1987). Does this early ability form the basis of the CAUSE predicate I find evidence for in Paper 1? Similarly, in Woodward's (1998) classic study, we call the toy bear that the hand reaches for a "goal." How does this notion relate to the BE AT and BE POSSESSED AT predicates I explored in Paper 2, whose arguments are both often also described as "goals"? Either (1) there is an initial broad category that splinters by adulthood, (2) there are actually two distinct categories in early infancy, one that represents possession, or at least desire (e.g., Woodward, 1998), and another that represents destination (e.g., Lakusta, Spinelli, & Garcia, 2017; for reviews, see, e.g., Spelke & Kinzler, 2007; Woodward, 2009), or (3) these are two separate systems entirely: one which guides infants' analysis of action and another which guides argument realization in language production.

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Appendix A

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

https://doi.org/10.17605/OSF.IO/C67NQ.

Supporting Methods

Materials and Procedure. We selected our emotion verbs and physical event verbs on the basis of the classifications provided by Levin (1993). The training trials for *frighten* and *fear* verbs each included 72 declarative sentences (80%) and 18 questions (20%). Forty-five (50%) of the items (per class) were in the past tense, 36 (40%) of the items were in the present tense, and 9 (10%) of the items were in the future tense. Nine (10%) of the items (per class) contained a deictic, and 27 (30%) of the items (including all future-tense items and all questions) contained an auxiliary verb. All arguments (subjects and objects) were animate. The *frighten*- and *fear*-verb test trials (using trained and untrained verbs) contained none of the same nouns as those in the training trials, but they varied along the same dimensions and in the same proportions, and contained only animate arguments. The transitive (causal) and intransitive (non-causal) physical event trials each included 7-8 declarative sentences (70-80%) and 2-3 questions (20-30%), counterbalanced across participants (see below). Six (60%) of the items (per class) were in the past tense, 3 (30%) of the items were in the present tense, and 1 (10%) of the items was in the future tense. One (10%) of the items (per class) contained a deictic, and 4-5 (40-50%) of the items (including all future-tense items and all questions) contained an auxiliary verb. All patients were inanimate, and most (though not all) agents were animate (14 out of 20).

Sentences were normed on Amazon Mechanical Turk to equate for valence (how positive or negative each sentence was) across the causal and non-causal sentences in each set of items. We asked 95 participants (35 female, 60 male; mean age=35, SD=11, range=18-72) to rate how positive

or negative each of 30 sentences was on a scale from 1 (extremely negative) to 7 (extremely positive). Pairwise linear regression models (with random intercepts for participant and item) indicated that there were no differences between *frighten*-type and *fear*-type training items (4.22 vs. 4.21), $t=.09$, $p=.93$, trained *frighten*- and *fear*-verb test items (4.43 vs. 4.32), $t=.02$, $p=.98$, untrained *frighten*- and *fear*-verb test items (4.23 vs. 4.12), $t=-.04$, $p=.97$, or causal (transitive) and non-causal (intransitive) physical event items (3.56 vs. 3.72), $t=-.79$, $p=.43$.

We constructed four experimental lists, each with five blocks. The first block contained only training trials (30 *frighten* verbs and 30 *fear* verbs). Pilot data suggested that sentence valence was a salient dimension for participants. To deter them from forming the hypothesis that valence was the critical predictor, the first 10 training trials in block 1 contained our most negative sentences from the top 5 unique *frighten* verbs and top 5 unique *fear* verbs, randomly ordered, and the next 10 training trials contained our most positive sentences from the remaining unique *frighten* and *fear* verbs, randomly ordered. The additional 40 trials in block 1 (20 *frighten*-type, 20 *fear*-type) were randomly selected from the 160 remaining training trials and presented in random order.

The next four blocks each contained 30 training trials (15 *frighten* verbs and 15 *fear* verbs, randomly selected). These were randomly interspersed with 20 test trials in each block. In the second and third blocks, there were 5 trained *frighten*-verb test trials, 5 trained *fear*-verb test trials, 5 untrained *frighten*-verb test trials, and 5 untrained *fear*-verb test trials. The fourth and fifth blocks each contained 5 untrained *frighten*-verb test trials, 5 untrained *fear*-verb test trials, 5 causal (transitive) physical event test trials, and 5 non-causal (intransitive) physical event test trials. The causal and non-causal physical event trials were counterbalanced across lists, such that two of the lists had 8 declarative sentences (80%) and 2 questions (20%) and the other two lists had 7 declarative sentences (70%) and 3 questions (30%). Across lists, each verb (independent of construction) appeared once as a question and thrice as a declarative.

We also collected intentionality ratings (how deliberate the agent's actions were) for our sentences. We asked 131 participants on Amazon Mechanical Turk (48 female, 82 male; mean age=36, SD=11, range=22-70) to rate for each of 20-24 sentences how likely it is that someone or something acted intentionally, on a scale from 1 (not at all likely) to 7 (extremely likely). Our causal (transitive) physical event sentences were judged to be significantly more intentional than our non-causal (intransitive) physical event sentences (4.64 vs. 3.17), t=4.19, p<.001, and our test sentences with trained *frighten* verbs were judged as significantly more intentional than the parallel *fear* sentences (5.32 vs. 4.27), t=2.64, p=.02 (linear regression models with random intercepts for participant and item). At first blush, these results suggest that participants could be generalizing the training on the basis of intentionality rather than causation. However, the ratings for the training trials are not consistent with this hypothesis: There was no difference between our *frighten* and *fear* training sentences (4.53 vs. 4.34), t=1.55, p=.12. Furthermore, these ratings revealed that our test sentences with untrained *frighten* verbs were actually *less* intentional than the parallel *fear* sentences (3.96 vs. 4.68), t=-2.42, p=.02. Thus, the differences we see in our test trials cannot be the result of training on differences in intentionality in our training trials. We return to this issue below.

Supporting Results

Mouse Clicks. The mouse clicks were analyzed with logistic mixed-effects models using the lme4 package in R. We coded clicks to the *frighten*-verb side as 1 and clicks to the *fear*-verb side as 0. No trials were excluded. As before, we analyzed the three sets of test trials separately. Each model had Condition as an effect-coded fixed effect (1, -1) and the maximal random effects structure appropriate for this experimental design (Barr et al., 2013), including random intercepts for participant and item (target sentence) and a random slope for Condition within participants.

Confidence intervals were computed by running the `confint` function on the glmer model in the R stats package.

The results of this analysis are reported in Fig. S1. In each case, the click data supported our findings from the eye-tracking data. Participants were more likely to click on the *frighten*-verb side following a trained *frighten* verb than following a trained *fear* verb (.58 vs. .41), β=.46 (SE=.13), z=3.53, p<.001, 95% CI [.20, .72], they were more likely to click on the *frighten*-verb side following an untrained *frighten* verb than following an untrained *fear* verb (.61 vs. .42), β=.51 (SE=.12), z=4.06, p<.001, 95% CI [.26, .76], and they were more likely to click on the *frighten*-verb side following a causal (transitive) physical event than following a non-causal (intransitive) physical event (.57 vs. .43), β=.33 (SE=.08), z=4.11, p<.001, 95% CI [.17, .50].
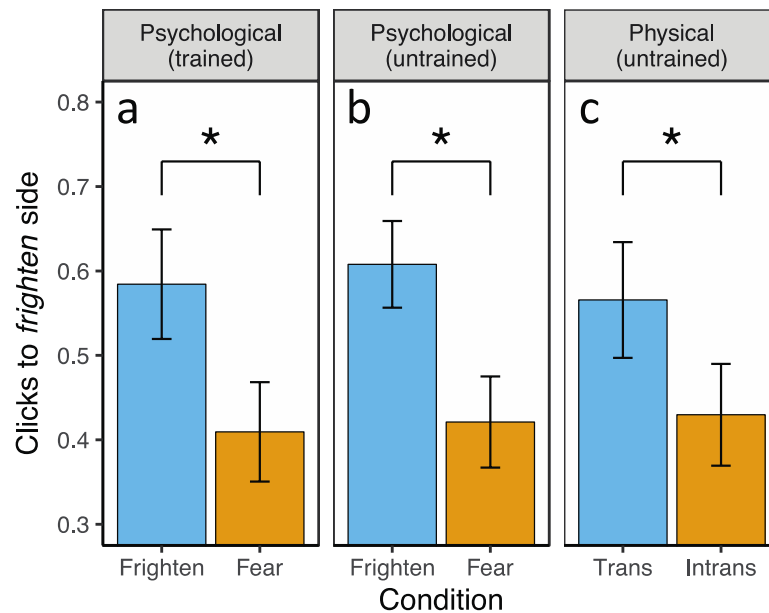
Figure S1. Proportion of clicks to *frighten* side. The differences between trained *frighten* and *fear* verbs (a), untrained *frighten* and *fear* verbs (b), and causal (transitive) and non-causal (intransitive) physical events were all significant. Error bars reflect by-subject standard errors. Trans=transitive; Intrans=intransitive.

Exploratory Analyses. In addition to the above preregistered analyses, we also conducted two exploratory analyses on our data.

Subset Analysis. A post-test questionnaire revealed that two of the participants explicitly identified the correct rule for generalization. This suggests that naïve participants can become aware of the common conceptual link between *frighten* verbs and physical causation. However, our findings do not depend on this explicit awareness: Excluding these two participants from the analysis (adjusted N=62) did not change the overall pattern of results: We found equally large clusters of divergence between the trained *frighten* and *fear* verbs (400-3,000 ms, summed t statistic for cluster=86.88, $p<.001$), untrained *frighten* and *fear* verbs (100-3,000 ms, summed t statistic for cluster=151.41, $p<.001$), and causal and non-causal physical events (900-3,000 ms, summed t statistic for cluster=65.80, $p<.001$).

Intentionality. Recall that our causal (transitive) physical events were judged as more intentional, or more deliberate, than our non-causal (intransitive) physical events (see above). We conducted a follow-up analysis to rule out the possibility that participants were relying on intentionality rather than causality to sort these items. In particular, we asked whether the difference between causal and non-causal physical events would still stand when controlling for intentionality. We first extracted the values at each time point in the cluster of significant activity identified in the main text. We then averaged these values for each item per participant (yielding a single data point per trial) and binarized them: if greater than .5, then 1; if less than .5, then 0; if neither, then NA. This was the dependent measure. We analyzed these values with a logistic mixed-effects model using the lme4 package in R, with Condition and Intentionality as fixed effects. To create the Intentionality variable, we first z-scored (by participant) our raw intentionality ratings, and then averaged these values by item. Intentionality was treated as continuous; Condition was effect coded (1, -1). We used the maximal random effects structure appropriate for this experimental design, including random

intercepts for participant and item (target sentence) and random slopes for Condition, Intentionality, and their interaction within participants. Confidence intervals were computed by running the `confint` function on the glmer model in the R stats package.

Critically, the model yielded a significant main effect of Condition (.54 causal vs. .40 non-causal), β=.30 (SE=.08), z=3.60, p<.001, 95% CI [.14, .44], but no main effect of Intentionality, β=.10 (SE=.13), z=.81, p=.42, 95% CI [-.15, .46], and no interaction, β=.08 (SE=.13), z=.65, p=.51, 95% CI [-.17, .33]. Thus, our results are not due to differences in intentionality, but instead reflect the intended distinction in causality.

The data associated with this article can be found at https://doi.org/10.17605/OSF.IO/AHFKY.

Prime sentences by experiment.

Datives			Motion verbs (Exp. 11 only)
Exp.	Double-object	Prepositional-object	
1, 5, 11	The girl brought the fish the broom.	The girl brought the broom to the fish.	The girl hauled the broom behind the fish.
1, 5, 11	The woman brought the man the ladder.	The woman brought the ladder to the man.	The woman hauled the ladder behind the man.
1, 5, 11	The girl fed the duck the cheese.	The girl fed the cheese to the duck.	The girl spun the cheese near the duck.
1, 5, 11	The woman fed the goose the strawberry.	The woman fed the strawberry to the goose.	The woman spun the strawberry near the goose.
1, 5, 11	The boy gave the rooster the lamp.	The boy gave the lamp to the rooster.	The boy lugged the lamp past the rooster.
1, 5, 11	The girl gave the cowboy the hammer.	The girl gave the hammer to the cowboy.	The girl lugged the hammer past the cowboy.
1, 5, 11	The man handed the mouse the spoon.	The man handed the spoon to the mouse.	The man moved the spoon beyond the mouse.
1, 5, 11	The woman handed the elephant the eggs.	The woman handed the eggs to the elephant.	The woman moved the eggs beyond the elephant.

1, 5, 11	The boy lent the clown the sled.	The boy lent the sled to the clown.	The boy pulled the sled toward the clown.
1, 5, 11	The woman lent the wolf the chair.	The woman lent the chair to the wolf.	The woman pulled the chair toward the wolf.
1, 5, 11	The girl offered the squirrel the bread.	The girl offered the bread to the squirrel.	The girl dropped the bread by the squirrel.
1, 5, 11	The man offered the alligator the hat.	The man offered the hat to the alligator.	The man dropped the hat by the alligator.
1, 5, 11	The boy passed the chicken the cake.	The boy passed the cake to the chicken.	The boy pushed the cake against the chicken.
1, 5, 11	The man passed the lady the cup.	The man passed the cup to the lady.	The man pushed the cup against the lady.
1, 5, 11	The boy read the bunny the menu.	The boy read the menu to the bunny.	The boy carried the menu alongside the bunny.
1, 5, 11	The woman read the frog the newspaper.	The woman read the newspaper to the frog.	The woman carried the newspaper alongside the frog.
1, 5, 11	The boy sent the butterfly the basket.	The boy sent the basket to the butterfly.	The boy lowered the basket beside the butterfly.
1, 5, 11	The man sent the lion the box.	The man sent the box to the lion.	The man lowered the box beside the lion.
1, 5, 11	The boy showed the penguin the bicycle.	The boy showed the bicycle to the penguin.	The boy dragged the bicycle around the penguin.
1, 5, 11	The girl showed the doctor the bucket.	The girl showed the bucket to the doctor.	The girl dragged the bucket around the doctor.

1, 5, 11	The girl sold the bear the glasses.	The girl sold the glasses to the bear.	The girl lifted the glasses under the bear.
1, 5, 11	The man sold the giraffe the camera.	The man sold the camera to the giraffe.	The man lifted the camera under the giraffe.
1, 5, 11	The man threw the pony the crayon.	The man threw the crayon to the pony.	The man raised the crayon above the pony.
1, 5, 11	The woman threw the bird the ball.	The woman threw the ball to the bird.	The woman raised the ball above the bird.

Locatives

Exp.	Theme-second	Theme-first	
2, 4	The girl loaded the van with the boxes.	The girl loaded the boxes in the van.	
2, 4	The woman loaded the shopping cart with the groceries.	The woman loaded the groceries in the shopping cart.	
2, 4	The girl packed the crate with the apples.	The girl packed the apples in the crate.	
2, 4	The woman packed the basket with the sandwiches.	The woman packed the sandwiches in the basket.	
2, 4	The boy rubbed his hair with the shampoo.	The boy rubbed the shampoo on his hair.	
2, 4	The girl rubbed the table with the polish.	The girl rubbed the polish on the table.	
2, 4	The man smeared the bread with the peanut butter.	The man smeared the peanut butter on the bread.	
2, 4	The woman smeared the cake with the frosting.	The woman smeared the frosting on the cake.	

2, 4	The boy splashed himself with the soup.	The boy splashed the soup on himself.	
2, 4	The man splashed the children with the lemonade.	The man splashed the lemonade on the children.	
2, 4	The boy sprayed the plant with the water.	The boy sprayed the water on the plant.	
2, 4	The man sprayed the barn door with the paint.	The man sprayed the paint on the barn door.	
2, 4	The boy stuffed the chest with the toys.	The boy stuffed the toys in the chest.	
2, 4	The girl stuffed the pillow with the feathers.	The girl stuffed the feathers in the pillow.	
2, 4	The man wrapped the present with the tissue paper.	The man wrapped the tissue paper around the present.	
2, 4	The woman wrapped the pizza with the plastic wrap.	The woman wrapped the plastic wrap around the pizza.	
Locatives (+animate destinations)			
Exp.	**Theme-second**	**Theme-first**	
3, 8	The boy injected the dog with the medicine.	The boy injected the medicine into the dog.	
3, 8	The girl injected the patient with the vaccine.	The girl injected the vaccine into the patient.	
3, 8	The girl loaded the donkey with the bags.	The girl loaded the bags onto the donkey.	
3, 8	The woman loaded the packmule with the luggage.	The woman loaded the luggage onto the packmule.	
3, 8	The girl pumped the lab rat with the steroids.	The girl pumped the steroids into the lab rat.	
3, 8	The woman pumped the athlete with the oxygen.	The woman pumped the oxygen into the athlete.	

3, 8	The boy rubbed the client with the oil.	The boy rubbed the oil on the client.	
3, 8	The girl rubbed the toddler with the lotion.	The girl rubbed the lotion on the toddler.	
3, 8	The boy splashed the trainer with the water.	The boy splashed the water on the trainer.	
3, 8	The man splashed the student with the chemicals.	The man splashed the chemicals on the student.	
3, 8	The man splattered the artist with the paint.	The man splattered the paint on the artist.	
3, 8	The woman splattered the assistant with the grease.	The woman splattered the grease on the assistant.	
3, 8	The boy sprayed the man with the cologne.	The boy sprayed the cologne on the man.	
3, 8	The man sprayed the thief with the mace.	The man sprayed the mace on the thief.	
3, 8	The man wrapped the baby in the blanket.	The man wrapped the blanket around the baby.	
3, 8	The woman wrapped the boy in the towel.	The woman wrapped the towel around the boy.	
Locatives (+animate themes)			
Exp.	**Theme-second**	**Theme-first**	
9	The man crammed the cell with the prisoners.	The man crammed the prisoners into the cell.	
9	The woman crammed the pot with the lobsters.	The woman crammed the lobsters into the pot.	
9	The girl draped the jungle gym with the monkeys.	The girl draped the monkeys on the jungle gym.	
9	The man draped the tree with the sloths.	The man draped the sloths on the tree.	

9	The girl loaded the trailer with the horses.	The girl loaded the horses onto the trailer.	
9	The woman loaded the tank with the dolphins.	The woman loaded the dolphins into the tank.	
9	The boy packed the kennel with the puppies.	The boy packed the puppies into the kennel.	
9	The girl packed the crate with the chickens.	The girl packed the chickens into the crate.	
9	The boy piled the log with the ants.	The boy piled the ants onto the log.	
9	The woman piled the car with the children.	The woman piled the children into the car.	
9	The man stocked the aquarium with the goldfish.	The man stocked the goldfish in the aquarium.	
9	The woman stocked the lab with the rats.	The woman stocked the rats in the lab.	
9	The boy stuffed the box with the kittens.	The boy stuffed the kittens in the box.	
9	The girl stuffed the cage with the pigeons.	The girl stuffed the pigeons in the cage.	
9	The boy wrapped the hook with the worm.	The boy wrapped the worm on the hook.	
9	The man wrapped the pole with the snake.	The man wrapped the snake around the pole.	
Benefactives			
Exp.	**Double-object**	**Prepositional-object**	
6	The woman baked the bird the cake.	The woman baked the cake for the bird.	
6	The woman baked the elephant the soufflé.	The woman baked the soufflé for the elephant.	

Exp.	Theme-second	Theme-first	
6	The boy bought the penguin the bicycle.	The boy bought the bicycle for the penguin.	
6	The boy bought the rooster the lamp.	The boy bought the lamp for the rooster.	
6	The girl fetched the cowboy the hammer.	The girl fetched the hammer for the cowboy.	
6	The girl fetched the fish the broom.	The girl fetched the broom for the fish.	
6	The girl found the doctor the scalpel.	The girl found the scalpel for the doctor.	
6	The woman found the man the ladder.	The woman found the ladder for the man.	
6	The boy got the chicken the box.	The boy got the box for the chicken.	
6	The woman got the goose the strawberry.	The woman got the strawberry for the goose.	
6	The boy made the butterfly the basket.	The boy made the basket for the butterfly.	
6	The man made the mouse the sweater.	The man made the sweater for the mouse.	
6	The man ordered the lady the drink.	The man ordered the drink for the lady.	
6	The man ordered the lady the pizza.	The man ordered the pizza for the lady.	
6	The girl saved the duck the cheese.	The girl saved the cheese for the duck.	
6	The man saved the pig the scraps.	The man saved the scraps for the pig.	
Fulfilling verbs			
Exp.	**Theme-second**	**Theme-first**	

7, 10	The man credited the mayor with the achievement.	The man credited the achievement to the mayor.	
7, 10	The woman credited the man with the success.	The woman credited the success to the man.	
7, 10	The girl entrusted the doctor with the surgery.	The girl entrusted the surgery to the doctor.	
7, 10	The man entrusted the son with the house.	The man entrusted the house to the son.	
7, 10	The boy issued the robber with the citation.	The boy issued the citation to the robber.	
7, 10	The man issued the criminal with the warning.	The man issued the warning to the criminal.	
7, 10	The man left the lady with the estate.	The man left the estate to the lady.	
7, 10	The woman left the bride with the endowment.	The woman left the endowment to the bride.	
7, 10	The boy presented the athlete with the trophy.	The boy presented the trophy to the athlete.	
7, 10	The woman presented the actor with the award.	The woman presented the award to the actor.	
7, 10	The boy provided the banker with the funds.	The boy provided the funds to the banker.	
7, 10	The boy provided the teacher with the resources.	The boy provided the resources to the teacher.	
7, 10	The girl served the juror with the summons.	The girl served the summons to the juror.	
7, 10	The woman served the witness with the subpoena.	The woman served the subpoena to the witness.	
7, 10	The girl supplied the contractor with the materials.	The girl supplied the materials to the contractor.	

7, 10	The girl supplied the cowboy with the tools.	The girl supplied the tools to the cowboy.	

Target animations by experiment.

Datives	
Exp.	**Description**
1, 4, 6-9, 11	Boy bringing camel keys / keys to camel
1, 4, 6-9, 11	Man feeding girl bagel / bagel to girl
1, 4, 6-9, 11	Man giving dolphin flower / flower to dolphin
1, 4, 6-9, 11	Boy handing fireman teapot / teapot to fireman
1, 4, 6-9, 11	Girl passing cat money / money to cat
1, 4, 6-9, 11	Woman sending horse clock / clock to horse
1, 4, 6-9, 11	Woman showing owl picture / picture to owl
1, 4, 6-9, 11	Girl throwing puppy muffin / muffin to puppy
Locatives	
Exp.	**Description**
2, 3, 5, 10	Boy loading cart with suitcase / suitcase onto cart
2, 3, 5, 10	Man packing backpack with books / books into backpack
2, 3, 5, 10	Man rubbing hands with soap / soap on hands
2, 3, 5, 10	Boy smearing wall with mud / mud on wall
2, 3, 5, 10	Woman splashing floor with water / water onto floor

2, 3, 5, 10	Girl spraying neck with perfume / perfume on neck
2, 3, 5, 10	Girl stuffing closet with shoe / shoe into closet
2, 3, 7, 10	Woman wrapping child's arm with bandage / bandage around child's arm

The data associated with this article, including COCA frequencies and pilot results, can be found at https://www.doi.org/10.17605/OSF.IO/K3TNJ.

Prime sentences by experiment.

Item*	Exp. 1	Exp. 2
*a=Passive; b=Active; c=By-Locative; d=Non-By-Locative; e=By-Transitive		
1a	The senator was awed by the statue.	The senator was awed by the statue.
1b	The senator unveiled the statue.	The senator unveiled the statue.
1c	The senator was speaking by the statue.	The senator was speaking by the statue.
1d	The senator has spoken about the statue.	
1e		The senator gave a speech by the statue.
2a	The woman was stung by the jellyfish.	The woman was stung by the jellyfish.
2b	The woman caught the jellyfish.	The woman caught the jellyfish.
2c	The woman was swimming by the jellyfish.	The woman was swimming by the jellyfish.
2d	The woman has swum into the jellyfish.	
2e		The woman took a photo by the jellyfish.
3a	The escaping prisoner was illuminated by the guard tower.	The escaping prisoner was illuminated by the guard tower.
3b	The escaping prisoner avoided the guard tower.	The escaping prisoner avoided the guard tower.

3c	The escaping prisoner was hiding by the guard tower.	The escaping prisoner was hiding by the guard tower.
3d	The escaping prisoner has hidden below the guard tower.	
3e		The escaping prisoner sought refuge by the guard tower.
4a	The foreigner was confused by the blinking traffic light.	The foreigner was confused by the blinking traffic light.
4b	The foreigner misunderstood the blinking traffic light.	The foreigner misunderstood the blinking traffic light.
4c	The foreigner was loitering by the blinking traffic light.	The foreigner was loitering by the blinking traffic light.
4d	The foreigner has loitered at the blinking traffic light.	
4e		The foreigner found a coin by the blinking traffic light.
5a	The Dalmatian was pursued by the fire truck.	The Dalmatian was pursued by the fire truck.
5b	The Dalmatian chased the fire truck.	The Dalmatian chased the fire truck.
5c	The Dalmatian was running by the fire truck.	The Dalmatian was running by the fire truck.
5d	The Dalmatian has run around the fire truck.	
5e		The Dalmatian wagged its tail by the fire truck.
6a	The secretary was splashed by the drinking fountain.	The secretary was splashed by the drinking fountain.
6b	The secretary cleaned the drinking fountain.	The secretary cleaned the drinking fountain.

6c	The secretary was tripping by the drinking fountain.	The secretary was tripping by the drinking fountain.
6d	The secretary has tripped near the drinking fountain.	
6e		The secretary cleaned her glasses by the drinking fountain.
7a	The construction worker was hit by the bulldozer.	The construction worker was hit by the bulldozer.
7b	The construction worker drove the bulldozer.	The construction worker drove the bulldozer.
7c	The construction worker was digging by the bulldozer.	The construction worker was digging by the bulldozer.
7d	The construction worker has dug with the bulldozer.	
7e		The construction worker ate lunch by the bulldozer.
8a	The new graduate was hired by the software company.	The new graduate was hired by the software company.
8b	The new graduate joined the software company.	The new graduate joined the software company.
8c	The new graduate was driving by the software company.	The new graduate was driving by the software company.
8d	The new graduate has driven around the software company.	
8e		The new graduate made a U-turn by the software company.
9a	The ship was damaged by the pier.	The ship was damaged by the pier.
9b	The ship approached the pier.	The ship approached the pier.
9c	The ship was docking by the pier.	The ship was docking by the pier.

9d	The ship has docked at the pier.	
9e		The ship boarded new passengers by the pier.
10a	The minister was cut by the broken stained glass window.	The minister was cut by the broken stained glass window.
10b	The minister fixed the broken stained glass window.	The minister fixed the broken stained glass window.
10c	The minister was praying by the broken stained glass window.	The minister was praying by the broken stained glass window.
10d	The minister has prayed below the broken stained glass wind	
10e		The minister recited prayers by the broken stained glass window.
11a	The engineers were appalled by the monument.	The engineers were appalled by the monument.
11b	The engineers criticized the monument.	The engineers criticized the monument.
11c	The engineers were conferring by the monument.	The engineers were conferring by the monument.
11d	The engineers have conferred at the monument.	
11e		The engineers took measurements by the monument.
12a	The lumberjack was struck by the giant redwood tree.	The lumberjack was struck by the giant redwood tree.
12b	The lumberjack struck the giant redwood tree.	The lumberjack struck the giant redwood tree.
12c	The lumberjack was resting by the giant redwood tree.	The lumberjack was resting by the giant redwood tree.
12d	The lumberjack has rested inside the giant redwood tree.	

12e		The lumberjack sharpened his ax by the giant redwood tree.
13a	The students were bankrupted by the new sports complex.	The students were bankrupted by the new sports complex.
13b	The students tried the new sports complex.	The students tried the new sports complex.
13c	The students were working by the new sports complex.	The students were working by the new sports complex.
13d	The students have worked in the new sports complex.	
13e		The students held a protest by the new sports complex.
14a	The 747 was radioed by the airport control tower.	The 747 was radioed by the airport control tower.
14b	The 747 radioed the airport control tower.	The 747 radioed the airport control tower.
14c	The 747 was landing by the airport control tower.	The 747 was landing by the airport control tower.
14d	The 747 has landed near the airport control tower.	
14e		The 747 made a sudden stop by the airport control tower.
15a	The missing geologist was smothered by the volcano.	The missing geologist was smothered by the volcano.
15b	The missing geologist underestimated the volcano.	The missing geologist underestimated the volcano.
15c	The missing geologist was wandering by the volcano.	The missing geologist was wandering by the volcano.
15d	The missing geologist has wandered into the volcano.	
15e		The missing geologist discovered a new plant by the volcano.

16a	The Cub Scouts were warmed by the campfire.	The Cub Scouts were warmed by the campfire.
16b	The Cub Scouts enjoyed the camp fire.	The Cub Scouts enjoyed the camp fire.
16c	The Cub Scouts were singing by the campfire.	The Cub Scouts were singing by the campfire.
16d	The Cub Scouts have sung around the campfire.	
16e		The Cub Scouts told ghost stories by the campfire.
17a	The princess was delighted by the palace's old gate.	The princess was delighted by the palace's old gate.
17b	The princess renovated the palace's old gate.	The princess renovated the palace's old gate.
17c	The princess was daydreaming by the palace's old gate.	The princess was daydreaming by the palace's old gate.
17d	The princess has daydreamed under the palace's old gate.	
17e		The princess greeted her countrymen by the palace's old gate.
18a	The stockbroker was sued by the client.	The stockbroker was sued by the client.
18b	The stockbroker impressed the client.	The stockbroker impressed the client.
18c	The stockbroker was sitting by the client.	The stockbroker was sitting by the client.
18d	The stockbroker has sat opposite the client.	
18e		The stockbroker placed a notebook by the client.
19a	The businessman was paged by the airline ticket counter.	The businessman was paged by the airline ticket counter.

19b	The businessman left the airline ticket counter.	The businessman left the airline ticket counter.
19c	The businessman was waiting by the airline ticket counter.	The businessman was waiting by the airline ticket counter.
19d	The businessman has waited behind the airline ticket count.	
19e		The businessman made a scene by the airline ticket counter.
20a	The scientist was inspired by the apple tree.	The scientist was inspired by the apple tree.
20b	The scientist examined the apple tree.	The scientist examined the apple tree.
20c	The scientist was sleeping by the apple tree.	The scientist was sleeping by the apple tree.
20d	The scientist has slept under the apple tree.	
20e		The scientist performed calculations by the apple tree.
21a	The surfer was excited by the stormy sea.	The surfer was excited by the stormy sea.
21b	The surfer watched the stormy sea.	The surfer watched the stormy sea.
21c	The surfer was sprinting by the stormy sea.	The surfer was sprinting by the stormy sea.
21d	The surfer has sprinted along the stormy sea.	
21e		The surfer took a stroll by the stormy sea.
22a	The patron was annoyed by the jukebox in the bar.	The patron was annoyed by the jukebox in the bar.
22b	The patron destroyed the jukebox in the bar.	The patron destroyed the jukebox in the bar.

22c	The patron was drinking by the jukebox in the bar.	The patron was drinking by the jukebox in the bar.
22d	The patron has drunk at the jukebox in the bar.	
22e		The patron threw darts by the jukebox.
23a	The bag lady was caught by the revolving door.	The bag lady was caught by the revolving door.
23b	The bag lady stopped the revolving door.	The bag lady stopped the revolving door.
23c	The bag lady was falling by the revolving door.	The bag lady was falling by the revolving door.
23d	The bag lady has fallen in the revolving door.	
23e		The bag lady tied her shoe by the revolving door.
24a	The dictator was overthrown by the general.	The dictator was overthrown by the general.
24b	The dictator trusted the general.	The dictator trusted the general.
24c	The dictator was standing by the general.	The dictator was standing by the general.
24d	The dictator has stood behind the general.	
24e		The dictator took a seat by the general.
25a	The children were deafened by the church organ.	The children were deafened by the church organ.
25b	The children disliked the church organ.	The children disliked the church organ.
25c	The children were playing by the church organ.	The children were playing by the church organ.
25d	The children have played beside the church organ.	

25e		The children played tag by the church organ.
26a	The fishermen were startled by the buoy.	The fishermen were startled by the buoy.
26b	The fishermen damaged the buoy.	The fishermen damaged the buoy.
26c	The fishermen were fishing by the buoy.	The fishermen were fishing by the buoy.
26d	The fishermen have fished at the buoy.	
26e		The fishermen caught fish by the buoy.
27a	The young woman was calmed by the lake.	The young woman was calmed by the lake.
27b	The young woman admired the lake.	The young woman admired the lake.
27c	The young woman was walking by the lake.	The young woman was walking by the lake.
27d	The young woman has walked along the lake.	
27e		The young woman made a wish by the lake.
28a	The bum was scratched by the bushes.	The bum was scratched by the bushes.
28b	The bum circled the bushes.	The bum circled the bushes.
28c	The bum was napping by the bushes.	The bum was napping by the bushes.
28d	The bum has napped in the bushes.	
28e		The bum hid his belongings by the bushes.
29a	The dog was protected by the fence.	The dog was protected by the fence.
29b	The dog jumped the fence.	The dog jumped the fence.
29c	The dog was barking by the fence.	The dog was barking by the fence.

29d	The dog has barked behind the fence.	
29e		The dog dug a hole by the fence.
30a	The grandmother was pleased by the flowers.	The grandmother was pleased by the flowers.
30b	The grandmother liked the flowers.	The grandmother liked the flowers.
30c	The grandmother was sketching by the flowers.	The grandmother was sketching by the flowers.
30d	The grandmother has sketched near the flowers.	
30e		The grandmother planted seeds by the flowers.
31a	The councilman was impressed by the new building.	The councilman was impressed by the new building.
31b	The councilman opened the new building.	The councilman opened the new building.
31c	The councilman was strolling by the new building.	The councilman was strolling by the new building.
31d	The councilman has strolled past the new building.	
31e		The councilman parked his car by the new building.
32a	The nymphs were soaked by the waterfall.	The nymphs were soaked by the waterfall.
32b	The nymphs saw the waterfall.	The nymphs saw the waterfall.
32c	The nymphs were bathing by the waterfall.	The nymphs were bathing by the waterfall.
32d	The nymphs have bathed under the waterfall.	
32e		The nymphs washed their hair by the waterfall.

Target pictures.

Alarm clock awakening boy
Ambulance hitting policeman
Ball striking boy
Ballerina tripping boxer
Bee stinging man
Boxer punching referee
Boy rescuing girl from water
Car hitting ambulance
Chef tickling prisoner
Crane demolishing building
Devil poking angel
Dog chasing mailman
Firefighter saving baby
Girl kicking boy
Girl kissing boy
Horse kicking cow
Lightening striking golfer
Lightning striking church
Pirate slapping sailor
Rock hitting boy's head
Rock hitting man
Sailor kicking soldier
Shark scaring boy
Tornado destroying barn
Toy startling little girl
Train hitting truck
Truck towing car

Wave engulfing boy
Wave hitting woman
Whale swallowing man
Wind blowing man's hat off
Woman pushing boy in sled