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Event structure influences language production: Evidence from structural priming in motion event description

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ABSTRACT

This priming study investigates the role of conceptual structure during language production, probing whether English speakers are sensitive to the structure of the event encoded by a prime sentence. In two experiments, participants read prime sentences aloud before describing motion events. Primes differed in (1) syntactic frame, (2) degree of lexical and conceptual overlap with target events, and (3) distribution of event components within frames. Results demonstrate that conceptual overlap between primes and targets led to priming of (a) the information that speakers chose to include in their descriptions of target events, (b) the way that information was mapped to linguistic elements, and (c) the syntactic structures that were built to communicate that information. When there was no conceptual overlap between primes and targets, priming was not successful. We conclude that conceptual structure is a level of representation activated during priming, and that it has implications for both Message Planning and Linguistic Formulation.

Introduction

During the process of language production, the message that a speaker wants to convey passes through several distinct levels of linguistic representation before it is realized as an utterance (e.g., Bock & Levelt, 1994; Levelt, 1989; Levelt, Roelofs, & Meyer, 1999). At each level, speakers make rapid, often implicit decisions about how elements from a conceptual representation of their message—the idea they want to convey—map onto linguistic representation. At the level of Message Planning, sometimes called "Conceptualization" because it interfaces with conceptual representations (Levelt, 1989), the content of the utterance is determined. Here speakers select both the information they will communicate and the perspective from which they want to present that information, and arrange these semantic elements in some linear order. At the level of Linguistic Formulation, the form of the utterance is determined as speakers select lexical items, assemble them into syntactic constituents, and engage in phonological and articulatory encoding.

The process of language production is subject to various linguistic constraints and language-specific biases that may influence both the content of an utterance and the form that the utterance takes. The way that a speaker resolves choices during both Message Planning and Linguistic Formulation is affected, in part, by the speaker's competing goals of informativeness and processing efficiency (e.g., Grice, 1975; Qian & Jaeger, 2011). Speakers may, for example, underspecify certain details of a conceptual representation in a related utterance to reduce formulation costs (Smith, 2000), for instance, omitting information about one or more components of a complex event. Linguistic Formulation may also be guided by a desire to emphasize different parts of a message, with the effect that different formulation choices may result in utterances that convey roughly the same information but that differ in their pragmatic implications (e.g., Smith, 2000; Talmy, 2000).

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In addition to these higher-level influences, the form of an utterance may be shaped by the emerging linguistic representation itself. The choice of a particular verb, for example, imposes both syntactic (e.g., Levelt, 1992; Levin, 1993; Melinger & Dobel, 2005; Pinker, 1989) and semantic (e.g., Medina, 2007; Merlo & Stevenson, 2001; Pinker, 1989; Resnik, 1996; Scott & Fisher, 2009) constraints on the rest of the utterance, determining both the number of argument positions available in the grammatical structure and the semantic features of the elements that may be chosen to occupy those positions. Moreover, language-specific grammatical encoding biases may lead to systematized differences in the way that conceptual representations are mined for linguistic purposes (e.g., Bock, 1995; Levelt, 1989; Slobin, 1996, 2003). Slobin (1996) refers to this process as "thinking for speaking," arguing that a speaker's experience with the way his/her native language tends to encode various conceptual elements may affect the way that early decisions about Message Planning are made.

Very little research has targeted the Message Planning stage of language production, either in terms of how information is selected for inclusion in a message, how the structure of a conceptual representation shapes the utterances that may be formulated to convey it, or what the downstream implications of Message Planning are for later levels of linguistic processing (though see, e.g., Bock, Irwin, Davidson, & Levelt, 2003; Gleitman, January, Nappa, & Trueswell, 2007). The current study was designed to probe the way that this level of representation comes into play during language production. In particular, we are interested in the way that speakers take the conceptual structure of an event into account as they formulate an utterance to describe it.

Event conceptualization and description

When encoding information about the complex and continuous activity occurring in the environment, the human mind creates structured representations of events that capture abstract spatial, temporal, and causal information about the world. The conceptual representation of a given event includes information about the entities that participate in the event, certain characteristics of those entities, and the relations among them. The relations between event participants are defined in terms of conceptual/semantic features (e.g., motion, contact, causation, transfer) that facilitate generalization, allowing events to be grouped into classes on the basis of their *event structure*—that is, a schematic of the types of participants in an event (e.g., agent, causer, recipient) and the types of relations that hold among them (e.g., Jackendoff, 1990; Pinker, 1989; Rappaport Hovav & Levin, 1998; Talmy, 1985a, 2000). Examples of event classes include *motion events*, in which an event participant undergoes a change in location by moving in some particular way (e.g., events of walking, driving, or entering), *causative events*, in which an event participant performs some activity that causally affects another (e.g., events of externally caused breaking, opening, or soaking), and *transfer events*, in which an event participant experiences a change in location or possession between two other participants (e.g., events of sending, giving, or donating).

There is robust evidence that abstract event representations have implications for language, since the meanings assigned to linguistic expressions that encode events (mostly, but not exclusively, verbs) are tied very closely to the underlying conceptual representations of events (Jackendoff, 1990; Levin & Rappaport Hovav, 1995; Pinker, 1989; Talmy, 2000). Here we ask whether and how the class of event that a speaker is describing during language production influences Message Planning and Linguistic Formulation. We focus on motion events, a relatively well-studied class of events in the linguistic and psycholinguistic literature (e.g., Allen et al., 2007; Naigles, Eisenberg, Kako, Highter, & McGraw, 1998; Papafragou, Hulbert, & Trueswell, 2008; Papafragou, Massey, & Gleitman, 2002; Slobin, 1996, 2003; Talmy, 1985b, 2000).

Following Talmy (1985b, 2000), we define a motion event as one in which a Figure experiences a change in location with respect to some Ground object. The details of a motion event may be elaborated by optionally specifying the Manner in which the Figure moves (e.g., bounce, drive) or the trajectory, or Path, that the Figure takes in relation to the Ground object (e.g., circle, enter, down). When describing a motion event, speakers may make choices about which of these event components they want to mention and how they want to package information about those components in the sentence they produce. Imagine, for example, an event in which an alien drives a car into the mouth of a cave, as depicted in Fig. 1.

Some examples of possible descriptions of this motion event in English are given in (1): note that information provided about both the manner (drive) and the path (enter, into) of motion may be encoded in a variety of different structural positions, if these components are mentioned at all.

(1) a. The alien drove.
b. The alien drove into the cave.
c. The alien entered the cave.
d. The alien entered the cave, driving.
e. The driving alien entered the cave.

English speakers usually prefer to use sentences like (1a) and (1b) when describing motion events, with information about manner of motion encoded early in the sentence (usually in the verb) and path information mentioned later (usually in a post-verbal prepositional phrase) or not at all. However, this is a language-specific bias, not a requirement of English, and different languages demonstrate different biases for motion event encoding (Talmy, 1985b).

The description of motion events illustrates the range of decisions faced by speakers during language production. At the level of Message Planning, speakers need to select which conceptual components (e.g., manner, path, among others) of a motion event to include in their description. Speakers also need to make a choice at the interface of Message Planning and Linguistic Formulation about how to order motion information (e.g., manner or path first?) and what kinds of grammatical elements to encode that

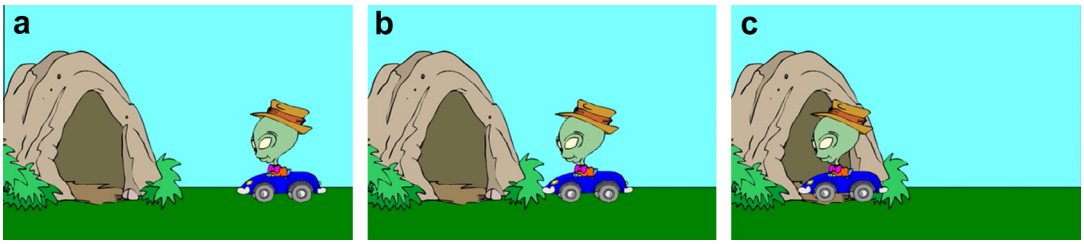

Fig. 1. Depictions of the (a) beginning, (b) middle, and (c) end of a motion event.

information in (e.g., in verbs vs. nouns vs. modifiers, as in (1a–e)). Finally, at the level of Linguistic Formulation, speakers need to choose lexical items to express this motion information and organize these items in a syntactic frame that satisfies the morpho-syntactic requirements of their language.

Crosslinguistic variation in the encoding of motion event components may be realized at the levels of both Message Planning and Linguistic Formulation. For example, because of constraints on the use of resultative phrases (e.g., Giannakidou & Merchant, 1999), speakers of Greek tend to talk more than English speakers about the paths of motion events and to encode information about paths in verbs followed, optionally, by post-verbal phrases that describe manners (Papafragou et al., 2002; Slobin, 1996; Talmy, 1985b). Greek speakers, then, would prefer the Greek equivalent of sentence (1c) or (1d), as in (2).

(2) O eksogiinos bike sti spilia (odigontas)
'the alien entered the cave (driving)'

A recent study demonstrated effects of motion event structure on Message Planning and Linguistic Formulation. Papafragou et al. (2008) tracked speaker eyegaze while adult speakers of English and Greek viewed and described motion events. They found that adult speakers of each language directed their attention differently to motion event components when engaged in linguistic and nonlinguistic tasks, providing evidence for conceptual motion event structures that are independent of linguistic processes. In addition, they found crosslinguistic differences in the selection and linguistic encoding of motion event components during language production that illustrate a connection between Message Planning and Linguistic Formulation. Specifically, they found that adult speakers of English and Greek not only show differences in the way that they describe paths and manners of motion events, but when engaged in the task of language production, they also exhibit language-specific patterns of attention to those events, with speakers of each language turning their attention very early to visual representations of the event component (manner or path) that they plan to encode in the verb of their event description. These findings illustrate that event structure is a level of representation that is relevant during language production (for similar findings in children see Bunger, Trueswell, & Papafragou, 2012a), but leave open questions about the way that information is accessed and the way it imposes downstream effects on Message Planning and Linguistic Formulation. Our goal in the current study is to continue to fill in these gaps in our understanding by using structural priming as a tool to probe the different levels of linguistic representation that are at play during language production.

Structural priming

The structural priming paradigm provides a useful means for probing the representations that speakers access during language production. This paradigm builds on the observation that speakers tend to repeat linguistic structures that they have recently used or observed others using. Priming is a robust, spontaneous, crosslinguistic phenomenon that is well-documented in corpora of natural speech (e.g., Gries, 2005): in natural conversation, speakers tend to repeat structures used by their interlocutors as well as structures that they themselves have used. Experimental work has shown that speakers can be induced (or "primed") to repeat particular structures in controlled settings as well (e.g., Bock, 1986; Bock & Loebell, 1990; Hartsuiker, Kolk, & Huiskamp, 1999; Pickering & Branigan, 1998; Potter & Lombardi, 1998; see Pickering & Ferreira, 2008, for an overview).

In an early demonstration of the priming phenomenon (Levelt & Kelter, 1982), researchers in the Netherlands called a shop and asked the person who answered the phone what time the shop closed using the Dutch equivalent of one of the two sentences in (3).

(3) a. What time does your shop close?
b. At what time does your shop close?

Their results demonstrated that shopkeepers tended to repeat the structure of the question in their answer, so that those who had been presented with the question in (3b) tended to include a preposition in their answer (e.g., "at 4 o'clock"), but those who had been presented with the question in (3a) did not (e.g., "4 o'clock"). Priming has been argued to make both production (Levelt, 1992; Smith, 2000) and comprehension (Pickering & Garrod, 2004) of language more efficient through the recycling of recently activated lexical items and syntactic frames between interlocutors.

For present purposes, knowledge of the kind of abstract structures that speakers tend to repeat is informative about the nature of the representations that are accessed during language production. That is, the linguistic features

that are found to be susceptible to priming are taken to be part of the representations that speakers construct or access when they are producing language. Bock and Loebell (1990, Experiment 2) demonstrated, for example, that speakers are more likely to produce a passive sentence like "The church was struck by lightning" when they are first asked to repeat another unrelated passive sentence, like (4a), or an unrelated active sentence that shares the same surface syntax as the passive, like (4b), than when they are primed with an unrelated active sentence that does not share the syntactic structure of the passive, like (4c).

(4) a. The construction worker was hit by the bulldozer.
b. The construction worker was walking by the bulldozer.
c. The construction worker drove the bulldozer.

These findings are widely accepted as evidence that speakers can be primed to produce a particular syntactic structure independent from the meaning it conveys, and hence, that syntactic structure is an independent level of representation accessed by speakers during language production.

According to current lexicalist theories of the mechanisms that underlie structural priming (e.g., Bock & Levelt, 1994; Cleland & Pickering, 2003; Levelt et al., 1999; Pickering & Branigan, 1998; Scheepers, 2003), a prime sentence activates lemmas at the level of Linguistic Formulation, along with the local syntactic constituents (variously referred to in terms of rules, procedures, or combinatorial nodes) that are associated with those lemmas. Lingering activation of primed elements is argued to make them more accessible for language processing, making it more likely, for example, that speakers will use activated elements when producing a new sentence. Activation of lemmas and associated structures is cumulative, and the effect of priming on the repetition of syntactic structure can be enhanced when primes and targets share (open-class) lexical items (Gries, 2005; Pickering & Branigan, 1998). Pickering and Branigan (1998) demonstrated, for example, that use of the same verb in primes and targets provides a "lexical boost" to structural priming. In their study, participants who had been asked to complete sentence fragments consisting of a subject and a dative verb (e.g., "The patient showed...") as either a double-object or a prepositional dative were more likely to repeat the structure of a prime sentence if the prime had included the same verb presented in the target ("The racing driver showed the torn overall...") rather than a different dative verb ("The racing driver gave the helpful mechanic...").

The effects of priming are not limited to the level of Linguistic Formulation, however. Lemma activation may spread upward to associated concepts at the level of Message Planning, and activation at this level may spread across related concepts and back down to the lemmas associated with those concepts. Given this characteristic of the priming mechanism, it is not surprising that syntax is not the only type of representation that gets primed by linguistic input. Cleland and Pickering (2003) demonstrated, for example, that spreading of primed activation across related lexical concepts enhances repetition of syntactic structures. In their study, speakers were more likely to produce a target phrase like "the sheep that's red" (vs. the more canonical "the red sheep") after hearing a prime with a semantically related head noun, like "the goat that's red," than after a prime with an unrelated head noun, like "the knife that's red." Priming can also affect the mapping of semantic constituents (e.g., thematic roles) onto structural positions (e.g., Bernolet, Hartsuiker, & Pickering, 2009; Cai, Pickering, & Branigan, 2012; Chang, Bock, & Goldberg, 2003; Griffin & Weinstein-Tull, 2003; Hare & Goldberg, 1999; Hartsuiker et al., 1999). In an investigation of priming by object-control, subject-control, and object-raising constructions, Griffin and Weinstein-Tull (2003) demonstrated that priming is effective only when the valency of primes and targets (i.e., the number of arguments/thematic roles they encode) is the same. Chang et al. (2003) demonstrated, moreover, that when syntactic structure is held constant across primes and targets, the order in which thematic roles are mapped to structural locations may be primed. In their study, participants were more likely to accurately remember a target sentence that included a spray/load verb like (5a) when it was preceded by a prime sentence with a spray/load verb in which the Theme (Th) and Location (Loc) were mapped onto the same syntactic positions, as in (5b), versus a similar prime sentence in which the order of the Theme and Location were reversed, as in (5c).

(5)	a. The farmer heaped straw onto the wagon.	Th–Loc target
	b. The maid rubbed polish onto the table.	Th–Loc prime
	c. The maid rubbed the table with polish.	Loc–Th prime

Together, these studies demonstrate that the influence of a linguistic prime is not shallow: priming affects a participant's access not only to the syntactic level of representation but also to lexical and semantic information encoded in the prime. Observations such as these have led numerous researchers to posit that the effects of a prime run as deep as the conceptual representation of a speaker's message, and moreover, to point out that what looks like priming of syntactic structure may sometimes be the result of downstream effects of the priming of conceptual structure (e.g., Bock, 1986; Bock & Griffin, 2000; Garrod & Anderson, 1987; Goldwater, Tomlinson, Echols, & Love, 2011; Griffin & Weinstein-Tull, 2003; Potter & Lombardi, 1998; Scheepers, 2003; Schober, 1993). For example, several studies of spatial description in discourse situations have shown that alignment of spatial models between interlocutors have implications for language use: specifically, the spatial model or perspective that interlocutors choose places constraints on the set of linguistic structures that they may use when describing a given spatial array (e.g., Garrod & Anderson, 1987; Schober, 1993). Bock (1986) suggests, moreover, that priming of the conceptual features (specifically, the animacy) of subjects

and objects may influence whether speakers produce active or passive sentences, and Bock, Loebell, and Morey (1992) provide evidence for independent effects of syntactic and conceptual priming on the structure of output sentences. More recently, Tanaka, Branigan, McLean, and Pickering (2011) demonstrated that the conceptual accessibility of noun arguments affects the way they are mapped to linguistic structures (cf. Bock, Irwin, & Davidson, 2004; Bock & Warren, 1985; Bock et al., 1992; Onishi, Murphy, & Bock, 2008). They found that for Japanese speakers, animacy influenced both the order and the syntactic positions in which arguments were recalled, with animate arguments more likely to be mentioned first as well as to be mapped to subject positions. Finally, a recent study by Goldwater et al. (2011) described an effect of event type in priming of syntactic structure during language production in children. They found that 4-year-old children who were primed with dative sentences (double-object or prepositional dative) that were matched with pictures of transfer events were more likely to describe target transfer events not only with the particular dative frame that had been primed, but to increase their use of *both* dative frames in target event descriptions. Goldwater and colleagues interpret this finding as evidence for priming of the relational structure consistent with transfer events, which results in priming of the use of dative frames in general, in addition to priming of a specific syntactic structure.

The current study

In the current study, we use priming as a tool to investigate the online involvement of abstract event structures during language production in adults. Given evidence that the production of particular linguistic elements may be driven not only by priming of those elements themselves, but also by priming of the conceptual structure associated with a given input, we take a closer look at the downstream effects of event structure priming. As mentioned already, we use motion events, which offer an event structure that allows for a relatively flexible mapping between event components and structural positions (like the examples in (1)). In this way, we avoid selecting prime and target stimuli that are bound to each other by a strict mapping between event structure and syntactic behavior.

We ask two questions about the influence of motion event structure on language production. First, we ask whether activation of motion event structure influences the Message Planning level of language production, including the selection of motion (path/manner) information to talk about and the choice of a perspective from which to present that information. Success in priming the kind of information that speakers report when they are describing motion events and the way that they distribute that information within a sentence will demonstrate that priming influences not only the way that a message is structured in the output, but also the way the message itself is selected. Second, we ask what implications the priming of conceptual motion structure has for the grammatical encoding phase of Linguistic Formulation, including both lexical selection and syntactic assembly. In general, evidence that motion event structure is activated during priming will demonstrate (1) that priming influences the accessibility of abstract conceptual representations and (2) that event structure is a level of representation that is relevant for online language production.

To probe the effects of overlap of event structure between primes and targets, we ask adult speakers to provide descriptions of dynamic motion events preceded by prime sentences. Specifically, participants were presented with motion events like the one in Fig. 1, which can be described in several possible ways (as illustrated in the sentences in (1)). Across two experiments, we primed these descriptions by preceding each motion event with one of three different kinds of prime sentences. *Verb + Event Type* prime sentences mentioned both the manner and the path of a motion event that was unrelated to the target event with which they were paired and, critically, included a verb that could be used to describe the target. For example, the Verb + Event Type prime sentence that preceded the event in Fig. 1 included the verb "entering," which could also be used to describe the path of the driving alien. *Event-Type Only* prime sentences also described the manner and path of an unrelated motion event, but did not include a verb that could be used to describe the target event. For example, the Event-Type Only prime sentence that preceded the event in Fig. 1 included the verb "circled," which does describe a path of motion, but not the one taken by the alien. Finally, *No-Overlap* prime sentences did not describe a motion event, nor did they provide a verb that could be used to describe the target event. The No-Overlap prime sentence that preceded the event in Fig. 1 included the verb "baked," which describes neither the activity of the alien nor a motion event in general.

The content and structure of motion event descriptions produced in these priming conditions was compared to descriptions of the same events provided in a control condition in which no prime sentences were presented. If the event structure evoked in a prime sentence can increase the conceptual accessibility of a related event structure, we expect to see alignment between primes and targets that is independent of lexical and syntactic priming. Specifically, for conditions in which participants were provided with prime sentences that described motion events, we expect to see evidence of priming at the levels of Message Planning, i.e., in the mention and distribution of motion event components, and Linguistic Formulation, i.e., in the syntactic structures in which those components are encoded.

Event-structure priming at the level of Message Planning should be evident in the motion event components that speakers choose to talk about. That is, when participants are presented with prime sentences that describe both the manner and the path of a motion event (as they are in the Verb + Event Type and Event-Type Only conditions), we expect them to mention both the manner (driving) and the path (entering) of our example event involving the alien more often than they do in the absence of event-structure overlap between primes and targets (No-Overlap and control conditions). This pattern should be observed not only when prime sentences describe events that involve the *same* kind of motion as that seen in target videos (Verb +

Event Type condition), but also when prime sentences describe motion events that involve a *different* kind of motion than the target (Event-Type Only condition).

If event-structure priming extends to the interface of Message Planning and Linguistic Formulation, we also expect to see priming of the way that participants distribute information about the manners and paths of target events in their event descriptions that is independent of the particular lexical items chosen to convey that information. That is, if speakers are primed with sentences in which path information is given in a verb and manner information in a modifier (as they are in the Verb + Event Type and Event-Type Only conditions), we expect them to describe the event in Fig. 1 with a sentence like "The alien entered the cave driving," in which information about the alien's path of motion is given in the verb and information about his manner of motion is given in a modifier. We do not expect to see priming of the distribution of motion event information in conditions that do not provide prime sentences that describe motion events (No-Overlap and control conditions).

Finally, to the extent that Message Planning has downstream implications for the mapping of semantic elements to structural positions during Linguistic Formulation, we also expect to see an increase in the use of the particular syntactic frames used in prime sentences when event structures are primed. This kind of priming should lead to an increase in repetition of the syntactic structure of prime sentences in conditions in which prime sentences describe motion events (Verb + Event Type, Event-Type Only conditions) compared to conditions with no motion event priming (No-Overlap and control conditions). For primes that provide verbs that can actually be used to describe targets (Verb + Event Type condition), we may also see the influence of a lexical (Pickering & Branigan, 1998) or conceptual (Cleland & Pickering, 2003) boost to repetition of primed syntactic structures. Repetition of the syntax of a prime sentence in the absence of lexical or conceptual overlap between primes and targets (as in the No-Overlap condition) would provide evidence of message-independent priming of syntactic structure.

Experiment 1

The goal of this experiment was to determine how the type of event being evoked by a prime sentence affects Message Planning and the grammatical encoding phase of Linguistic Formulation during event description. Using a no-priming control and three between-subjects priming conditions, we assessed alignment of informational content and perspective as well as repetition of syntactic structure when there was (1) lexical (and, *a fortiori*, event) overlap between prime sentences and target pictures, (2) overlap between primes and targets only in event structure, and (3) no lexical or conceptual overlap between primes and targets.

Methods

Participants

Data were collected from 70 adult native speakers of American English. Participants were students at the University of Delaware or the University of Pennsylvania and received either $8 or course credit as compensation for participation. Data were excluded from 15 additional participants for the following reasons: participant demonstrated difficulty in reading prime sentences aloud ($n = 1$), participant was not a native speaker of English ($n = 2$), participant withdrew before the end of the study ($n = 1$), participant did not produce event descriptions that could be coded using our rubric ($n = 4$), and experimenter or equipment errors ($n = 7$).

Materials

Two kinds of stimulus items were constructed: (1) dynamic videos for elicitation of motion event descriptions (targets) and (2) prime sentences to be presented before each video.

Videos were created by animating clip-art images. Target events depicted 12 simple motion events in which an animate agent used an instrument or vehicle to move in a particular manner to a visible path endpoint. The pictures in Fig. 1 depict a sequence of still frames from the beginning, middle, and end of one of the target events: in the animation these frames are taken from, an alien sits in a car as it moves across the screen and into the mouth of a cave. Nineteen filler videos depicted animate agents involved in events that did not include a specific endpoint, like flying a kite.

The production task used in this experiment is similar to that used by Bock (1986), Bock and Griffin (2000), Hartsuiker et al. (1999), *inter alia*, with the exception that videos were shown instead of still images to elicit event descriptions. Using animations rather than still images allowed us to ensure that there was no ambiguity about either the manner or path of motion in target stimuli. Manners of motion and path endpoints in each target event were represented by visible elements within the scene. In every event, the manner of motion was associated with a motile instrument or vehicle (e.g., car, roller skates, parachute, hot air balloon). All paths were bounded by some visible stationary endpoint (e.g., cave, tree, building). In each video the agent moved with the aid of the instrument toward the endpoint and into some definite spatial relationship with it (e.g., on, in, next-to). Trajectories of motion were never marked by visible paths like winding roads or jet streams. A full list of target events can be found in the appendices.

In all videos, movement lasted for 3 s, at which time the animation froze and a beep sounded. Except for this beep, videos were silent. After the beep, the final frame of the video remained visible for an additional 2 s.

To create these videos, clipart animations were first assembled in Microsoft PowerPoint and then converted to Audio Video Interleave (avi) files using a conversion program. Timing was verified using video editing software.

A set of three prime sentences was created to precede each target event, one for each of the categories of content restrictions defined below, giving a total of 36 prime sentences across items and conditions. Prime sentences followed the same syntactic structure across conditions. In all prime sentences, the noun (N) that labeled the agent of the event (i.e., the subject) was modified by a

Table 1
Types of prime sentences used in Experiment 1.

Type of overlap	Prime sentence
Target event: An alien drives a car into a cave	
Verb + Event Type	The zebra on the motorcycle entered the garage
Event-Type Only	The man in the helicopter circled the tower
No-Overlap	The nurse with the freckles baked a pie

All of these prime sentences were matched with the event pictured in Fig. 1. No-Overlap primes used the same syntactic frame as Verb + Event Type and Event-Type Only primes, but did not describe motion events.

prepositional phrase (PP), e.g., "The zebra on the motorcycle..." This complex subject phrase was then followed by a verb (V) and a post-verbal phrase. The three prime sentences created for each target event differed in the degree to which they overlapped in content with that target event. Table 1 lists the three prime sentences that were created to accompany the motion event pictured in Fig. 1. *Verb + Event Type* prime sentences overlapped with target events in two ways: they described an unrelated event that shared the event structure of the associated target video (a motion event; event-type overlap), and they included a verb that could also be used to describe the target event (verb overlap). So, for example, given the target event in which the alien drives his car into a cave, the Verb + Event Type prime sentence "The zebra on the motorcycle entered the garage" not only describes a motion event, but also includes a path verb, "enter," that can also be used to describe the target event. *Event-Type Only* prime sentences also overlapped with targets in event structure, i.e., they also described unrelated motion events, but the verb in these sentences could never be used to describe the target. The Event-Type Only prime sentence "The man in the helicopter circled the tower" describes a motion event, but the verb "circle" does not provide an appropriate description of the driving-alien target event with which it is matched. *No-Overlap* primes used the same syntactic frames as Verb + Event Type and Event-Type Only primes, but described events that did not overlap with the target either in event structure (they did not describe motion events) or in the particular verb used. A full list of the prime sentences associated with each target event in Experiment 1 is given in Appendix A.

For primes that described motion events (Verb + Event Type and Event-Type Only primes), we always used the same distribution of manner and path elements to structural positions. Subject noun phrases (NPs)[1] always identified the animate agent of the event, and the prepositional phrase that modified the subject NP identified an instrument or vehicle that determined the agent's manner of motion. The verbs in these sentences always encoded information about the path of motion, and post-verbal phrases always identified a Ground object. These mapping choices resulted in prime sentences that preserved the manner-before-path ordering of information used in canonical English motion event descriptions, but encoded each element in a nonca-

[1] "Noun phrase" is used rather than "determiner phrase" throughout for transparency. Assuming a different syntactic structure for phrases containing nouns would not impact our findings.

nonical structural position, with path encoded in verbs and manner in the subject. In No-Overlap prime sentences, subject NPs also identified animate agents and were modified by prepositional phrases that identified various non-instrument attributes of the agents, e.g., physical features, articles of clothing, or occupation. Verbs in No-Overlap primes encoded non-motion activities, and post-verbal phrases identified either patients (e.g., "baked a pie") or co-agents ("sang with his wife") of the activity.

The path verbs that were chosen to fill these frames dictated the syntactic form of the post-verbal phrase: for eight sets of prime sentences, the post-verbal phrase was an NP, as in sentence (6a), and for the remaining four sets, it was a PP, as in sentence (6b).

(6) a. The zebra on the motorcycle entered the garage. [N_PP]_V_NP
b. The nurse in the helicopter landed on the mountain. [N_PP]_V_PP

Every prime sentence that was assigned to a particular target event followed the same syntactic structure, so that if an event was assigned a prime sentence like (6a), all three of the primes in the set associated with that event would follow the [N_PP]_V_NP structure.

Two prime sentences were created to accompany each filler event, one with a verb that could be used to describe the filler event and one with a verb that could not be used to describe the event. For example, for a filler event in which a monkey swings from a tree, the prime sentence with a matching verb was "The acrobat swung from the trapeze" and the prime sentence with a mismatching verb was "The children danced on the stage." Filler prime sentences with verbs that matched the associated video event were used in the Verb + Event Type condition, and filler sentences with mismatching verbs were used in the Event-Type Only and No-Overlap conditions. Prime sentences associated with filler events varied in their syntactic structure.

Procedure and design

Participants were run individually, seated at a distance of approximately 60 cm from a computer screen on which pairs of prime sentences and dynamic events were presented. A single experimenter was present during the session to begin the display of stimuli and to record data.

Sixty participants were pseudo-randomly assigned to one of three experimental conditions that were distinguished by the type of prime sentence (Table 1) presented before video stimuli: Verb + Event Type, Event-Type Only, and No-Overlap. Instructions were the same across the three priming conditions. Participants were told that they would see a set of items that included both sentences and animated videos, and that when they saw a sentence they should read it aloud and when they saw a video they should first watch it and then provide a description of it when they heard the beep. To encourage them to pay attention to both the video and sentence stimuli, participants in the priming conditions were informed that they would be asked to participate in a memory task after

viewing all of the stimuli, in which they would be asked to identify the items they had seen before.[2] The remaining 10 participants were assigned to a control condition, in which no prime sentences were presented before videos were viewed and described. Participants in the control condition were told that they would see a series of animated clips and were instructed to describe what happened in each clip as soon as the beep sounded.[3] Participants in the control condition were not informed in advance about the memory test.

Stimulus presentation in all three priming conditions followed the same progression: participants first viewed three prime–event training pairs to allow them to get used to the task and the self-paced design of the experiment. All items used for training were fillers. After training, participants viewed a sequence of 28 trials consisting of a prime sentence and its paired event (12 prime–target and 16 prime–filler trials). At the beginning of each trial, a prime sentence appeared on the screen. Participants read the sentence aloud, and then hit the spacebar to move on to the next item. After the sentence disappeared from the screen, a crosshair displayed briefly to redirect attention to the center of the screen, and then the video event began. Participants watched the event unfold, and then viewed a still image of the final frame of the animation as they provided a description of the event. The beep that occurred 3 s into each video served as a cue for participants to begin speaking. Event descriptions were recorded by the experimenter using a digital audio recorder. When the video ended, a blank screen appeared. When participants finished describing the event, they hit the spacebar to display the next item. Prime–event pairs were presented in two fixed orders. Half of the participants in each priming condition saw alternating target and filler prime–event pairs in a particular pseudo-random order, and the other half saw the same pairs in the reverse order. Across trial orders, target events were preceded by the same prime sentences; what changed was the order in which particular prime–event pairs appeared in the trial sequence.

In the control condition, display of stimuli was experimenter-controlled. Participants viewed a sequence of 24 events, the same 12 targets presented in the priming conditions and a subset of 12 fillers from the 16 presented in those conditions. As in the priming conditions, participants watched each event, then provided a description when the beep sounded. A recentering crosshair was displayed between each trial. In the control condition, stimuli were presented in a single fixed pseudo-random order, alternating between target and filler items.

Data coding and analysis

Participant descriptions of target events were transcribed and coded by hand. Utterances were assessed for three types of linguistic features: (1) informational content, (2) mapping of event components to linguistic elements, and (3) syntactic structure.

Informational content was assessed by coding for mention of Manner and Path in descriptions of target events. Words or phrases that referred to instruments (e.g., "car") or the agent's manner of motion (e.g., "driver," "driving," "riding") were coded as Manner mentions, and those that referred to either the path endpoint (e.g., "cave"), the agent's trajectory of motion (e.g., "into"), or the relationship between the agent and the path endpoint (e.g., "entering") were coded as Path mentions. For example, the utterance in (7a) was coded as including both Manner and Path, whereas (7b) includes only Manner information and (7c) includes only Path information.

(7) a. An alien in a car goes into a cave. — Manner + Path
b. An alien is driving a car. — Manner only
c. The alien entered the cave. — Path only

Mapping of event components to linguistic elements was assessed by coding for verb use as well as the structural position of first Manner mentions. Main verbs in each event description were coded as providing information about the Manner of a given target event, as in sentence (8a) or the Path, as in (8b).

(8) a. The alien drove into the cave.
b. The alien entered a cave.

In addition, main verbs in target event descriptions were assessed for lexical priming by coding for repetition of the verbs presented in immediately-preceding prime sentences. Manners were coded as appearing in subject position—either as a subject modifier or encoded in the subject itself as in (9a), as the main verb of the sentence as in (9b), or in a post-verbal position as in (9c).[4]

(9) a. Manner in subject
The alien in the car . . ./The driver . . .
b. Manner in verb
The alien drove . . .
c. Post-verbal Manner
The alien entered the cave in a car.

For assessment of priming of syntactic structure, data are presented for the production of the frames used in the prime sentences that were associated with each event, as illustrated in the sentences in (6). Priming was coded separately for VPs and subject NPs. Utterances were only coded as repetitions of a primed structure if the frame used in the event description matched the one used in the prime

[2] The design and results of the memory task are not discussed here because they do not contribute to our understanding of the issues raised in this paper. Only memory for videos was tested: mean accuracy at identifying changes to target events across conditions was 89%, with no significant differences in accuracy across conditions.

[3] The control condition was originally run as the Linguistic task in Bunger, Trueswell, and Papafragou (2012b). In the current paper, we present a new and significantly expanded linguistic analysis of the event descriptions collected in that earlier study.

[4] While it is true that neither of sentences (9a) or (9c) provide explicit encoding of the manner of the motion event described (i.e., in both cases the alien could be trapped in the trunk of a moving car rather than driving it), in both sentences manner of motion can be inferred from the information provided about the instrument.

sentence that immediately preceded that event. That is, an event description that included a post-verbal prepositional phrase did not count as a use of the primed VP frame when uttered after a prime that included a post-verbal noun phrase. Other than coding for subject-internal prepositional phrases, syntactic coding within phrases was coarse: e.g., "the alien" and "the alien in the car" were coded as having different structures (NP and [NP_PP], respectively), but "his car" and "his blue car" were coded as having the same structure (i.e., NP).

The reliability of trends observed in the data was tested using multilevel mixed logit modeling with crossed random intercepts for Subjects and Items (after Baayen, Davidson, & Bates, 2008). Random slopes for fixed variables that varied within subjects and/or items (e.g., Condition, Trial Block) were included in Subject and Item effects structures when those slopes were not perfectly correlated with the random intercept for this factor. This analysis offers a more sophisticated treatment of random factors (Subject, Item) than the tradition of analyzing subject and item means separately. Logit modeling is also a better treatment of the data because coding values are binomial (absent vs. present) at the trial level.

Results

Message Planning: Priming of informational content

Our analysis of the informational content of target event descriptions reveals that event structure priming affects the information that speakers choose to talk about during Message Planning. Table 2 provides information about the proportion of event descriptions in each condition that included information about the Manner and/or Path of target motion events. In the absence of a priming sentence, i.e., in the Control condition, participants included information about Manners of motion in *all* of their event descriptions, but included Path information in only 70% of descriptions. Across priming conditions, participants consistently provided information about the Manners of motion depicted in target events. However, Path mention increased in conditions in which target events were preceded by prime sentences that included information about both the manner and the path of an unrelated motion event, both when the path evoked in the prime was similar to that depicted in the target event (Verb + Event Type condition) and when it was different (Event-Type Only condition). For example, when describing the event in Fig. 1, participants were more likely to mention that the alien was entering the cave if they had just heard a sentence describing a path of motion, regardless of whether it was the same kind of path (entering) or a different kind of path (circling). This increase in Path mention was not observed in the No-Overlap condition, in which prime sentences did not describe motion events.

We tested the reliability of these observations using multilevel logistic modeling as described above in 'Data coding and analysis'. Binary values at the trial level for mention of Manners and Paths in event descriptions (mentioned, not mentioned) were modeled separately using the between-subjects variable Condition (Control, Verb + Event Type, Event-Type Only, No-Overlap) as a first-level fixed factor.[5] Modeling confirmed a main effect of Condition for Path mention ($p < .001$ vs. a model with no fixed effects), but not for Manner mention ($p = .24$ vs. a model with no fixed effects). Pairwise comparisons of individual priming conditions to the Control condition (Table 3) revealed that Path mention increased significantly compared to Control only in the motion event prime conditions, Verb + Event Type ($p < .001$ vs. Control) and Event-Type Only ($p < .05$ vs. Control) ($p = .13$ for Path mention in No-Overlap vs. Control).

When an accumulated priming effect is observed over a series of target items, it is possible that speakers begin to repeat primed elements not because of local influences on production but because of either cumulative effects of the repetition of prime types or strategies developed during the course of the task. To rule out these possibilities, we examined Path mention in blocks of four target items for event descriptions from the two conditions that showed event structure priming. Binary values for Path mention were modeled separately for the Verb + Event Type and Event-Type Only conditions, with Trial Block (First4, Mid4, Last4) as a first-level fixed factor. For the Verb + Event Type condition, Trial Block was also added as a random slope to the Subject effects structure. Modeling showed no significant effect of Trial Block in either condition. This finding confirms that in both conditions the increase in mention of event Paths was due to local priming effects.

Thus we do observe priming of the informational content of motion event descriptions. When primed with a sentence that described the path of a motion event, participants were more likely to mention the path of motion of a depicted motion event, even if the prime sentence described a motion event different from the depicted event (Event-Type Only). Such a finding suggests that activation of event structure influences the Message Planning stage of production, including the selection of motion (path/manner) information.

From Message Planning to Linguistic Formulation: Priming how event components are mapped to language

Given the finding that priming with sentences that evoke events of the same type as those presented in target videos affects the information that speakers choose to mention about target events, the next step is to assess whether priming of event type also influences the way in which that information is mapped onto linguistic elements. We assess the mapping of event components to language by asking whether priming leads to the encoding of Path and Manner information in primed locations: Path in main verbs ('Priming of Path verb production') and Manner in subject modifiers ('Priming of Manner location').

Priming of Path verb production. Analysis of Path verb production reveals that priming led to an increased use of Path verbs in event descriptions that included information about Paths of motion only when primes provided lexical as well as conceptual overlap with target events, i.e., in the Verb + Event Type condition, but not in the Event-Type

[5] For all analyses of data in Experiment 1, models that included Trial Order as a fixed factor did not significantly improve the fit.

Table 2
Mean proportion of mention of Manner and Path in event descriptions, Experiment 1.

Event component	Control condition (no prime)	Priming condition		
		Verb + Event Type	Event-Type Only	No-Overlap
Manner	1.00 (±0.00)	0.96 (±0.04)	0.98 (±0.02)	0.98 (±0.02)
Path	0.70 (±0.14)	0.94 (±0.04)**	0.83 (±0.05)*	0.80 (±0.07)

Values represent participant means (±95% confidence intervals). Significance tests for an effect of condition on production of each event component were performed using multilevel logistic modeling with crossed random intercepts for Subjects and Items: significantly different from Control at $^{*}p < .05$, $^{**}p < .001$.

Table 3
Fixed effects from best-fitting multilevel linear models of Path mention, Experiment 1.

Effect	Estimate	*SE*	*z*-Value
Intercept	**1.50**	**0.67**	**2.23***
Condition: Control vs. Verb + Event Type	**2.64**	**0.55**	**4.39****
Condition: Control vs. Event-Type Only	**1.12**	**0.60**	**2.04***
Condition: Control vs. No-Overlap	0.83	0.54	1.53

Formula in R: DepVar ~ Condition + (1|Subject) + (1|Item).
* $p < .05$.
** $p < .001$.

Only or No-Overlap conditions. In the Control condition, participants used Path verbs in 45 (±12)% of their motion event descriptions that included information about the Path of motion. When primes provided a Path verb that could be used to describe the target event (Verb + Event Type condition), participants used a Path verb in their target event descriptions 66 (±10)% of the time, as in the event description "The alien entered the cave." Otherwise, they tended to use a verb that encoded the Manner of the target motion event, e.g., "The alien drove into the cave." When verbs in prime sentences encoded Paths that were different from those depicted in target events (Event-Type Only condition) or that did not encode Paths at all (No-Overlap condition), use of Path verbs in event descriptions was lower than in the Control condition (Event-Type Only: 34 (±7)%, No-Overlap: 27 (±8)%).

The reliability of these observations was tested using multilevel logistic modeling as described above. Assessment of Path verb use was based on all event descriptions in which Path was mentioned. Binary values at the trial level for production of a Path verb (mentioned, not mentioned) were modeled with Condition (Control, Verb + Event Type, Event-Type Only, No-Overlap) as a first-level fixed factor. Modeling confirmed a main effect of Condition for Path verb use ($p < .001$ vs. a model with no fixed effects). Pairwise comparisons of individual priming conditions to the Control condition (Table 4) revealed that Path verb use was significantly higher in the Verb + Event Type condition than in the Control condition ($p < .001$) and significantly lower in the No-Overlap condition than in the Control condition ($p < .05$) ($p = .22$ for Event-Type Only vs. Control).

When participants in the Verb + Event Type condition produced a Path verb, 71% of the time they were repeating the same verb that had been in the immediately preceding prime sentence. In comparison, participants in the Event-Type only and No-Overlap conditions *never* repeated primed verbs. Moreover, priming of Path verb use in the Verb + Event Type condition began within the first block of four target items. Binary values for Path verb use were modeled for the Verb + Event Type condition, with Trial Block (First4, Mid4, Last4) included as a first-level fixed factor and as a random slope in the Subject effects structure. Modeling showed no significant effect of Trial Block, confirming that the increase in use of Path verbs was due to local priming effects rather than to a build-up of priming over the course of the experiment.

Priming of Manner location. Analysis of the location in which Manner information was first mentioned in event descriptions reveals that, as for Path verb production, priming led to an increase of Manners in subject position only in the Verb + Event Type condition, in which primes overlapped lexically as well as conceptually with target events. Fig. 2 shows the proportion of utterances including information about Manners of motion in which participants first mentioned the Manner in the three coded locations: subject, verb, and post-verb. In the Control condition, participants mentioned the Manner of target events most often in the verb and less often in the subject and in post-verbal positions. In the Verb + Event Type and Event-Type Only conditions, speakers were primed with sentences in which information about the manner of an unrelated motion event appeared in the subject of the sentence. Under these priming conditions, only participants in the Verb + Event Type condition were more likely (vs. the Control condition) to produce descriptions of target motion events in which Manner was encoded in the subject. Participants in the Event-Type Only condition, as well as those in the No-Overlap condition in which prime sentences did not describe motion events (and, hence, did not include Manner information at all), showed the same distribution

Table 4
Fixed effects from best-fitting multilevel linear models of Path verb use in event descriptions that include Path information, Experiment 1.

Effect	Estimate	*SE*	*z*-Value
Intercept	−0.55	0.65	−0.85
Condition: Control vs. Verb + Event Type	**1.73**	**0.49**	**3.49****
Condition: Control vs. Event-Type Only	−0.60	0.49	−1.23
Condition: Control vs. No-Overlap	**−1.06**	**0.50**	**−2.13***

Formula in R: DepVar ~ Condition + (1|Subject) + (1|Event).
* $p < .05$.
** $p < .001$.

of Manner encoding for target events as participants in the Control condition.

Multilevel logistic modeling was performed as described above on binary values at the trial-level for production of Manner in subjects, verbs, and post-verbal positions, out of all event descriptions that included Manner information, using Condition (Control, Verb + Event Type, Event-Type Only, No-Overlap) as a first-level fixed factor. Modeling revealed a main effect of Condition (Table 5) for production of Manners in subjects ($p < .001$ vs. a model with no fixed factors) and verbs ($p < .01$), but not for post-verbal positions ($p = .07$). Production of subject Manners in the Verb + Event Type condition was significantly higher than in the Control condition ($p < .001$). In addition, production of Manners in verbs ($p < .001$) was significantly lower in the Verb + Event Type condition vs. Control. No differences from Control were found for the proportion of Manners produced in subjects or verbs in the Event-Type Only and No-Overlap conditions.

Priming of Manner location in the Verb + Event Type condition began within the first block of four target items. Binary values for Manner encoding in subjects and verbs were modeled separately for the Verb + Event Type condition, with Trial Block (First4, Mid4, Last4) included as a first-level fixed factor and as a random slope in the Subject effects structure. Modeling showed no significant effect of Trial Block for either Manner location.

Priming of first Manner location was stronger when verbs were repeated by participants in this condition (92% of Manners were encoded in subjects vs. 22% in the Control condition), but Manner location was still primed even when verbs were not repeated (41% Manners in subjects). That is, although participants in the Verb + Event Type condition were likely to repeat the primed Manner-in-subject encoding whether or not they also repeated the primed Path verb, the probability that they would encode Manners in subjects increased when they also used primed verbs. These trends were confirmed by modeling binary values for Manner encoding in subjects just for participants in the Verb + Event Type condition, with Primed Verb Use (Repeated, Not repeated) included as a first-level fixed factor and as a random slope in the Subject effects structure. Modeling confirmed that participants in the Verb + Event Type condition were significantly more likely to encode Manners in subjects when they had repeated primed verbs than when they had not ($p < .001$). Binary values for Manner encoding in subjects were also modeled separately for participants in the Verb + Event Type condition who did produce primed verbs and for those who did not, with Condition (Control, Verb + Event Type) as a first-level fixed factor. Condition was also included as a random slope in the Item effect structure for modeling of event descriptions that did not include primed verbs. Both groups of participants in the Verb + Event Type condition were significantly more likely to encode Manners in subjects than participants in the Control condition: $p < .001$ for primed verb repeaters, and $p < .01$ for primed verb non-repeaters.

Thus we observe that event structure priming influences not only the information that speakers choose to mention about motion events, but also the way they map that information onto linguistic elements. We observed priming of the mapping of Path and Manner information to particular structural positions only in the Verb + Event Type condition, in which primes both overlapped with targets in event type and provided a verb that could be used to describe the target. However, this priming was successful even when the verbs provided in prime sentences were *not* repeated in descriptions of target events, suggesting that successful priming of event component mapping cannot be reduced to an effect of lexical priming. Taken together with the results from the previous section, these findings indicate that priming influences not only the way that a message is selected, but also the way the message itself is structured in the output.

Linguistic Formulation: Priming of syntactic frame

So far, we have shown that priming speakers with a particular event structure affects the way they select information to mention when describing a target motion event ('Message Planning: Priming of informational content'), and that providing lexical (verb) overlap with a target event also leads them to distribute that information to particular linguistic elements: Path to verbs ('Priming of Path verb production') and Manner to subjects ('Priming of Manner location'). The final question to ask is what the downstream effects of all this priming are on the syntactic structure of the event descriptions that speakers provide. Our analyses of the syntactic structures used in participants' utterances revealed reliable priming of syntactic structure only in the Verb + Event Type condition, in which the event structure of prime sentences overlapped with that of target events and primes also provided a lexical boost. Fig. 3 plots the average proportion of primed syntactic frames used in participants' motion event descriptions in each condition. Use of primed frames was determined on an item-by-item basis, since priming frames differed slightly across items. In the absence of a prime sentence,

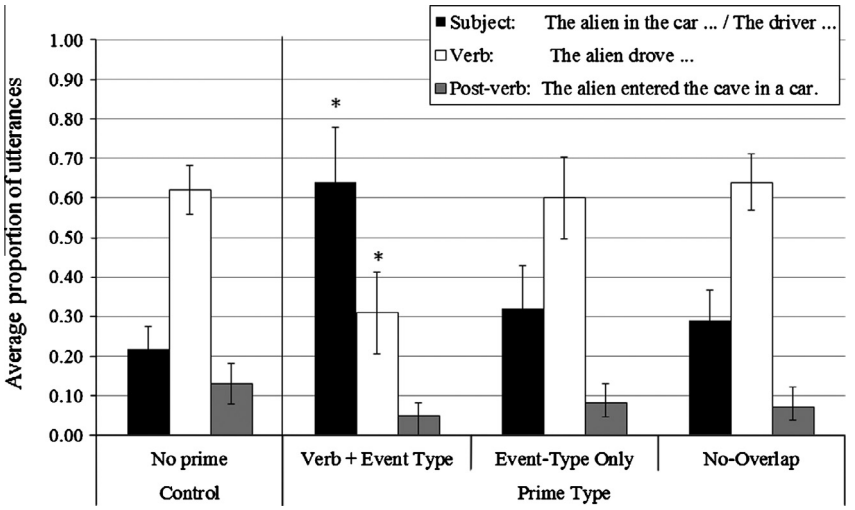

Fig. 2. Location of first Manner mention for utterances produced in Experiment 1. Manner locations are described in the text (ex. 9). Proportion of mention is calculated based on all event descriptions in which Manner was mentioned. Error bars represent 95% confidence intervals. *Use of this frame is significantly different from its use in the Control condition at $p < .001$.

Table 5
Fixed effects from best-fitting multilevel linear models of location of first Manner mention, Experiment 1.

Effect	Estimate	*SE*	*z*-Value
Manner in subject			
Intercept	**−1.80**	**0.58**	**−3.10***
Condition: Control vs. Verb + Event Type	**2.68**	**0.51**	**5.26****
Condition: Control vs. Event-Type Only	0.70	0.51	1.38
Condition: Control vs. No-Overlap	0.46	0.51	0.91
Manner in verb			
Intercept	0.68	0.64	1.05
Condition: Control vs. Verb + Event Type	**−1.85**	**0.55**	**−3.34****
Condition: Control vs. Event-Type Only	−0.06	0.52	−0.12
Condition: Control vs. No-Overlap	0.27	0.51	0.55

Formula in R for both models: DepVar ~ Condition + (1|Subject) + (1 + Condition|Event). For Manners in Post-verbal positions, the model including Condition did not provide a better fit than an empty model with no fixed effects.
* $p < .01$.
** $p < .001$.

speakers most often produced simple NP subjects and VPs that consisted of verbs and post-verbal prepositional phrases (V_PP), giving rise to sentences like "The alien drove into the cave." In the Verb + Event Type condition, the use of complex [NP_PP] grammatical subjects and primed VP frames increased compared to their use in the Control condition. However, in the Event-Type Only and No-Overlap conditions there were no increases in the use of primed VP frames, and although use of complex subject frames increased in both of these conditions compared to Control, this trend did not reach significance for either experimental condition.

We tested the reliability of these observations using multilevel logistic modeling as above. Binary values at the trial-level for use of Primed VPs and Complex Subject NP frames were modeled separately using Condition (Control, Verb + Event Type, Event-Type Only, No-Overlap) as a first-level fixed factor. For modeling of the use of Primed VPs, Condition was also included as a random slope in the Item effect structure. Modeling revealed a main effect of Condition for both types of syntactic frame (both $p < .001$, Table 6). Pairwise comparison of primed frame use in the Control condition to that in individual priming conditions revealed that use of both Complex Subjects and Primed VPs increased significantly compared to Control in the Verb + Event Type condition (both $p < .001$ vs. Control). In the Event-Type Only and No-Overlap conditions, there were no significant differences in the use of Complex Subjects or Primed VPs compared to their use in the Control condition.

To test for possible long-term priming effects on the use of primed syntactic frames, binary values for production of Complex Subjects and Primed VPs were modeled separately for the Verb + Event Type condition. Trial Block (First4, Mid4, Last4) was used as a first-level fixed factor in each model, and was also added as a random slope to the Subject effects structures. Modeling showed no significant effect of Trial Block on use of primed syntactic frames in the Verb + Event Type condition.

Finally, use of Complex Subjects in the Verb + Event Type condition increased whether or not primed verbs were repeated in event descriptions, although priming of

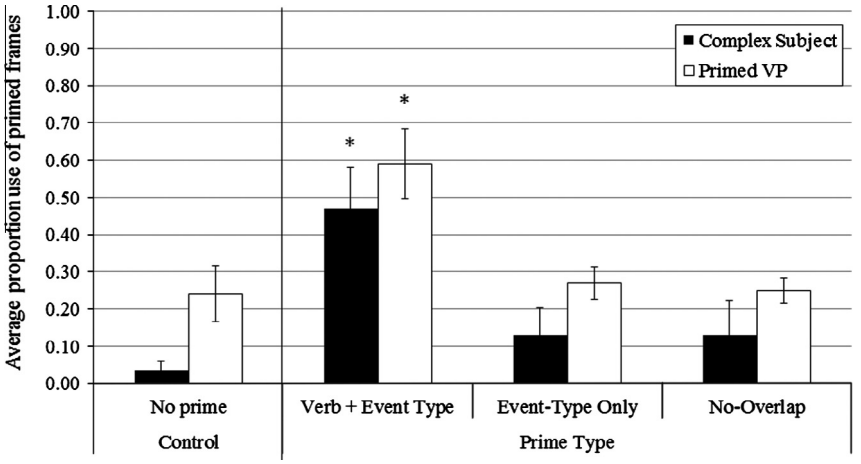

Fig. 3. Proportion of use of primed subject and VP frames across conditions in Experiment 1. Details about syntactic frames are given in the text (ex. 6). Proportion of use is calculated from all syntactic frames used in event descriptions. Error bars represent 95% confidence intervals. *Use of this frame is significantly different from its use in the Control condition at $p < .001$.

this syntactic frame was stronger when primed verbs were repeated. In contrast, use of Primed VP frames in this condition increased only when primed verbs were repeated. To test for differences in the use of primed frames for trials in which participants had and had not repeated primed verbs, binary values for use of primed subject and VP frames were also modeled just for trials in the Verb + Event Type condition, with Primed Verb Use (Repeated, Not repeated) as a first-level fixed factor. Primed Verb Use was also added as a random slope to the Subject effects structure for production of complex subjects and to the Subject and Item effects structures for production of primed VP frames. Modeling confirmed that participants in the Verb + Event Type condition were significantly more likely to produce complex subjects and primed VPs when they had repeated primed verbs than when they had not (both $p < .001$). Binary values for use of primed subject and VP frames were also modeled separately for trials in the Verb + Event Type condition on which participants did and did not produce primed verbs, with Condition (Control, Verb + Event Type) as a first-level fixed factor. Condition was also added as a random slope to the Item effect structure for the analysis of Primed VP use. Participants in the Verb + Event Type condition were significantly more likely to produce Complex Subjects than participants in the Control condition whether or not they had repeated primed verbs ($p < .001$ for both comparisons), but were only more likely to produce Primed VP frames when they *also* repeated the primed verb ($p < .001$ for Repetition of Primed Verb vs. Control, $p = .65$ for No Repetition of Primed Verb vs. Control).

Thus in this experiment syntactic structure of event descriptions aligned with that of prime sentences only when primes provided both conceptual and lexical overlap with target events. We observed priming of the use of particular VP frames only in the Verb + Event Type condition, and only in those event descriptions in which participants repeated the verbs that had been presented in prime sentences. In the same condition, however, participants produced primed complex subject frames whether or not they also repeated primed verbs.

Summary

The results of this experiment provide support for the hypothesis that processing a sentence with a particular event structure activates an abstract representation of that event structure, thereby priming it for later use, and confirm that this priming has implications for both the content and the form of a speaker's output. Prime sentences that described motion events influenced the Message Planning level of production by guiding the information (i.e., Manner, Path) that speakers chose to mention about target motion events ('Message Planning: Priming of informational content'). The finding that this content priming was not limited to event descriptions in which a particular verb was repeated – i.e., it was seen in the Event-Type Only condition – demonstrates that conceptual priming cannot be reduced to a lexical effect.

Mapping of Manner and Path information to noncanonical structural positions also showed effects of priming, but only when primes provided both lexical and conceptual overlap with targets: speakers increased their likelihood of encoding Path information in verbs ('Priming of Path verb production') and Manner information in subjects ('Priming of Manner location') only when primed with a sentence that included a verb that could also be used to describe the target event. The way that event information is mapped to language is decided during both Message Planning and Linguistic Formulation: as part of the message-planning process, speakers may choose to present a particular perspective on an event and select and order linguistic elements in a way that will communicate that perspective, or particular lexical items that speakers choose to use may place constraints on the way that the rest of a message may be structured. The fact that we see priming of event component encoding only when speakers are provided with a verb that can be used to describe the

Table 6
Fixed effects from best-fitting multilevel linear models of Primed frames use, Experiment 1.

Effect	Estimate	*SE*	*z*-Value
Complex Subject			
Intercept	**−4.38**	**0.82**	**−5.31****
Condition: Control vs. Verb + Event Type	**4.21**	**0.87**	**4.83****
Condition: Control vs. Event-Type Only	1.63	0.89	1.83
Condition: Control vs. No-Overlap	1.40	0.90	1.55
Primed VP			
Intercept	**−1.71**	**0.57**	**−2.99***
Condition: Control vs. Verb + Event Type	**2.22**	**0.48**	**4.60****
Condition: Control vs. Event-Type Only	−0.05	0.55	−0.09
Condition: Control vs. No-Overlap	0.15	0.47	0.31

Formulas in R: Complex Subject: DepVar ~ Condition + (1|Subject) + (1|Event); Primed VP: DepVar ~ Condition + (1|Subject) + (1 + Condition|Event).
* $p < .01$.
** $p < .001$.

target event—that is, in the presence of lexical priming—seems to suggest that what we are seeing is an effect at the level of Linguistic Formulation: speakers are led by the prime sentence to select a particular verb, and this choice constrains how the rest of the message may be encoded. However, this explanation is called into question by the fact that we see priming of event component encoding whether or not speakers actually repeat the primed verb. This suggests, instead, that verb priming activates semantic or conceptual information which, in turn, affects the way that information is organized at the level of Message Planning.

Finally, we found that priming of conceptual and lexical elements led to effects at the Linguistic Formulation level of production, specifically to repetition of primed syntactic structures in the Verb + Event Type condition ('Linguistic Formulation: Priming of syntactic frame'). It is unlikely that this repetition is a result of pure priming of syntactic structure, because we do not see the same pattern of priming in the No-Overlap condition. Likewise, it is unlikely to be due simply to the activation of event structure because we do not see the same pattern of priming in the Event-Type Only condition. Priming of complex subjects in the Verb + Event Type condition was successful whether or not primed lexical items were repeated in the particular utterance produced by the participant. However, repetition of VP frames was restricted to event descriptions in which primed verbs were also repeated, suggesting that this priming was strengthened by the kind of lexical boost described by Pickering and Branigan (1998). Neither the syntactic nor the semantic structure of target event descriptions was successfully primed when there was no overlap in event structure between primes and targets.

Experiment 2

As mentioned in the Introduction, English speakers have a bias to describe motion events by encoding information about manner of motion in the verb and information about path of motion in a post-verbal phrase, e.g., "The alien drove into the cave" (e.g., Talmy, 1985b). The precise nature of this bias is not fully understood, but it appears to create a preference to encode information about event components in a particular linear order, e.g., manner before path, as well as in particular linguistic elements. In Experiment 1, we primed participants to encode manner and path in dispreferred structural locations but allowed them to maintain the preferred order of mention. The results of that experiment demonstrated that, with the appropriate conceptual boost, speakers can be primed to violate the apparent bias to map particular kinds of information to particular linguistic elements: as long as the preferred order of event components was maintained, speakers could be primed to encode information about manner and path information in noncanonical linguistic elements. In Experiment 2, we disrupted the ordering bias as well. Experiment 2 followed the design of Experiment 1, with the exception that prime sentences presented speakers with a different syntactic frame and, for prime sentences that described motion events, with a different order of mention of manner and path information, with path information encoded in main verbs and manner information encoded in post-verbal phrases. Our goal was to test the potency of the priming effects observed in our earlier experiment. The extent to which speakers can be primed to produce dispreferred mappings of event components to linguistic structure will be informative about the strength of the influence that priming of event structure has on the ordering and encoding of event components during language production.

Methods

Participants

Data were collected from 30 adult native speakers of American English. Participants were students at the University of Delaware or the University of Pennsylvania and received either $8 or course credit as compensation for participation. Data were excluded from an additional two participants who were not native speakers of English, from one participant who did not produce event descriptions that could be coded using our rubric, and from one participant in the Event-Type Only condition who never mentioned the Paths of target events, a production pattern that differed more than two standard deviations both from other participants in the Event-Type Only condition and from participants in the Control condition.

Materials

The same 12 target and 19 filler videos created for Experiment 1 were used as stimuli in Experiment 2. Three new prime sentences were created to precede each target event, giving a total of 36 prime sentences across items and conditions. Prime sentences differed from those in Experiment 1 both in syntactic frame and in the structural locations in which information about manner and path appeared. Prime sentences followed the same syntactic structure across conditions. All prime sentences began with a simple phrase (determiner, noun) that identified the agent of some event, e.g., "The zebra..." This subject was followed by a verb and two post-verbal phrases.

The three different prime sentences constructed for each target event used the same syntactic frame but differed in the degree to which they overlapped in content with the target event. Differences between prime types were the same as those described for Experiment 1, giving rise to three between-subjects manipulations: Verb + Event Type, Event-Type Only, and No-Overlap (Table 7). For example, given the target event in which the alien drives his car into a cave (Fig. 1), the Verb + Event type prime sentence in this experiment was "The zebra entered the garage on a motorcycle," which both describes a motion event and includes a verb that can be used to label the target event. The Event-Type Only prime sentence "The man circled the tower in a helicopter" overlaps with the driving-alien target only in event type: both are motion events. And the No-Overlap prime sentence "The nurse baked a pie with skill" does not overlap with the target either in verb or event type. A full list of the prime sentences associated with each target event in Experiment 2 is given in Appendix B.

Motion prime sentences (Verb + Event Type and Event-Type Only) in this experiment were constructed directly from motion primes in Experiment 1 by moving the information about manner of motion that was provided in the subject modifier of each sentence in Experiment 1 into a post-verbal phrase. For example, the Experiment 1 Verb + Event Type prime sentence "The zebra on the motorcycle entered the garage" became "The zebra entered the garage on a motorcycle" in Experiment 2. Likewise, the Event-Type Only prime "The man in the helicopter circled the tower" from Experiment 1 became "The man circled the tower in a helicopter" in Experiment 2. As a result, verbs in these prime sentences always encoded information about the path of motion, the first post-verbal phrase identified a Ground object, and the second post-verbal phrase identified the instrument or vehicle that determined the agent's manner of motion. Thus, in this experiment the distribution of manner and path elements presented in motion primes resulted not only in the mapping of manner and path to noncanonical structural positions, but also violated the manner-before-path ordering of information used in canonical English motion event descriptions, with path encoded in the verb and manner encoded in a post-verbal prepositional phrase. No-Overlap prime sentences were also constructed on the basis of sentences in Experiment 1. For these sentences, the subject, verb, and first post-verbal phrase remained the same, but the subject modifier was deleted and a second post-verbal adjunct phrase was added, e.g., "for an hour," "with a smile," "with her children." For example, the Experiment 1 No-Overlap prime sentence "The nurse with the freckles baked a pie" became "The nurse baked a pie with skill" in Experiment 2.

Table 7
Types of prime sentences used in Experiment 2.

Type of overlap	Prime sentence
Target event: An alien drives a car into a cave	
Verb + Event Type	The zebra entered the garage on a motorcycle
Event-Type Only	The man circled the tower in a helicopter
No-Overlap	The nurse baked a pie with skill

All of these prime sentences were matched with the event pictured in Fig. 1. No-Overlap primes used the same syntactic frame as Verb + Event Type and Event-Type Only primes, but did not describe motion events.

As in Experiment 1, the path verbs that were chosen for motion event primes dictated the syntactic form of the first post-verbal phrase: for eight sets of prime sentences the first post-verbal phrase was an NP, as in sentence (10a), and for the remaining four sets it was a PP, as in sentence (10b).

(10) a. The zebra entered the garage on a motorcycle. NP_V_NP_PP
b. The nurse landed on the mountain in a helicopter. NP_V_PP_PP

All prime sentences assigned to a particular target event followed the same syntactic structure. In addition, the same four target events that were associated with the [N_PP]_V_PP primes in Experiment 1 were associated with NP_V_PP_PP primes in Experiment 2.

The 38 prime sentences associated with filler events in Experiment 2 were the same as those used in Experiment 1 (19 sentences with verbs that matched associated filler events, 19 sentences with nonmatching verbs).

Procedure and design

The procedure and design were identical to that described for Experiment 1. For this experiment, participants were pseudo-randomly assigned to one of three experimental conditions, distinguished by the type of prime sentence (Table 7) presented before video stimuli: Verb + Event Type, Event-Type Only, and No-Overlap.[6] As in Experiment 1, filler prime sentences with verbs that matched the associated video event were used in the Verb + Event Type condition, and filler sentences with mismatching verbs were used in the Event-Type Only and No-Overlap conditions.

Data coding and analysis

Coding for informational content, location of Manner and Path encoding, and syntactic frame use were carried out as described for Experiment 1. Utterances were coded as repetitions of a Primed frame only if the VP frame used

[6] The six experimental conditions in Experiments 1 and 2 were run during the same time period, and study participants were actually assigned pseudo-randomly to conditions across the two experiments.

in the event description matched the one used in the prime sentence that immediately preceded that event, e.g., the utterance in (11b) would be coded as a repetition of the structure primed by sentence (11a), but the utterance in (11c) would not.

(11) Prime sentence
a. The zebra entered the garage on a motorcycle. NP_V_NP_PP
Event descriptions
b. The alien entered the cave in a car. NP_V_NP_PP
c. The alien drove into the cave in a car. NP_V_PP_PP

Data analysis was carried out as described for Experiment 1, with data from the three priming conditions in Experiment 2 compared to data from the Control condition described in Experiment 1.

Results

Message Planning: Priming of informational content

Our analysis of the informational content of target event descriptions reveals, as in Experiment 1, that event structure priming affects the information that speakers select to talk about. Table 8 provides information about the proportion of event descriptions in each condition that included information about the Manner and/or Path of target motion events. Across conditions, participants consistently provided information about the Manners of motion depicted in target events. Moreover, as in Experiment 1, mention of the Paths depicted in target events increased compared to Control in the two conditions in which prime sentences provided information about the manner and the path of an unrelated motion event: i.e., in the Verb + Event Type and Event-Type Only conditions. This difference from the Control condition was not observed in the No-Overlap condition, in which prime sentences did not describe motion events.

The reliability of these observations was tested using multilevel logistic modeling as described above. Binary values at the trial level for mention of Manners and Paths in event descriptions (mentioned, not mentioned) were modeled separately using Condition (Control, Verb + Event Type, Event-Type Only, No-Overlap) as a first-level fixed factor. Modeling revealed a main effect of Condition for Path mention ($p < .05$ vs. a model with no fixed factors), but not for Manner mention. Pairwise comparisons of individual priming conditions to the Control condition (Table 9) revealed that Path mention increased significantly compared to Control in both of the motion event priming conditions (Verb + Event Type and Event-Type Only, both $p < .01$ vs. Control), but not in the No-Overlap condition ($p = .10$ vs. Control).

To examine the possibility that Path mention increased over the course of the experiment in the Verb + Event Type and Event-Type Only conditions, binary values for Path mention were modeled separately for the two conditions, with Trial Block (First4, Mid4, Last4) as a first-level fixed factor. Modeling showed no significant effect of Trial Block in either condition.

Thus, as in Experiment 1, we observe priming of the informational content of motion event descriptions. When primed with a sentence that described the path of a motion event, participants were more likely to mention the path of an unrelated motion event. Again, this finding suggests that activation of event structure influences the way that speakers select information to communicate during the Message Planning stage of language production.

From Message Planning to Linguistic Formulation: Priming of Path verb production and Manner location

Unlike Experiment 1, participants in this study did not exhibit any evidence of priming on the way that event components were mapped to linguistic elements. In motion prime conditions (Verb + Event Type and Event-Type Only), participants were presented with sentences in which Path information was encoded in main verbs and Manner information in post-verbal prepositional phrases. However, neither of these patterns increased in descriptions of target events compared to the Control condition.

Participants in the Control condition used Path verbs in 45 (±12)% of their event descriptions that included Path information, and use of Path verbs did not increase in the priming conditions (Verb + Event Type: 41 (±20)%; Event-Type Only: 29 (±11)%; No-Overlap: 36 (±18)%). When participants in the Verb + Event Type condition produced a Path verb, 65% of the time they were repeating the same verb that had been in the immediately preceding prime sentence.

Fig. 4 shows the proportion of utterances in which participants first mentioned the Manners of motion events in the three coded locations: subject, verb, and post-verb. Unlike Experiment 1, participants in this experiment did not exhibit any effects of motion event priming on the location in which they first mentioned the Manners of target motion events. That is, even when they had been primed with sentences in which information about the manner of an unrelated motion event appeared in a post-verbal position, participants did not deviate from their baseline preference to mention the Manner of target events most often in the verb.

Multilevel logistic modeling was performed as described above on binary values at the trial-level for production of Path verbs and production of Manner in subjects, verbs, and post-verbal positions using Condition (Control, Verb + Event Type, Event-Type Only, No-Overlap) as a first-level fixed factor. Condition was also included as a random slope in Item effect structures for modeling of Manner in subjects and in post-verbal positions. Modeling revealed no effect of Condition on either Path verb production or encoding of Manner in subjects or verbs. For Manner encoding in post-verbal positions, the model including Condition did provide a significantly better fit for the data than a model with no fixed factors ($p < .05$), but this finding was driven by a difference between the Control and No-Overlap conditions (Table 10): production of Manners in post-verbal positions was lower in the No-Overlap condition than in the Control condition at a nearly significant level ($p = .051$).

Table 8
Mean proportion of mention of Manner and Path in event descriptions, Experiment 2.

Event component	Control condition (no prime)	Priming condition		
		Verb + Event Type	Event-Type Only	No-Overlap
Manner	1.00 (±0.00)	0.97 (±0.03)	0.96 (±0.04)	0.98 (±0.05)
Path	0.70 (±0.14)	0.91 (±0.09)*	0.91 (±0.08)*	0.84 (±0.15)

Values represent participant means (± 95% confidence intervals). Data for the Control condition are repeated here from Table 1. Significance tests for an effect of condition on production of each event component were performed using multilevel logistic modeling with crossed random intercepts for Subjects and Items: *significantly different from Control at $p < .01$.

Table 9
Fixed effects from best-fitting multilevel linear models of Path mention, Experiment 2.

Effect	Estimate	*SE*	*z*-Value
Intercept	**1.65**	**0.84**	**1.96***
Condition: Control vs. Verb + Event Type	**2.68**	**1.00**	**2.68****
Condition: Control vs. Event-Type Only	**2.54**	**0.99**	**2.58****
Condition: Control vs. No-Overlap	1.57	0.95	1.66

Formula in R: DepVar ~ Condition + (1|Subject) + (1|Event).
* $p < .05$.
** $p < .01$.

Unlike in Experiment 1, then, we did not observe priming of the mapping of motion event information onto particular linguistic elements. Even when given the opportunity to take advantage of lexical priming (in the Verb + Event Type condition), participants in this experiment did not increase the frequency with which they encoded Path information in verbs and Manner information in post-verbal positions. Given that what is different about these stimuli compared to those used in Experiment 1 is the order in which motion event information is mentioned in prime sentences, it seems that disruption of the English manner-before-path bias interferes with the tendency we observed in Experiment 1 for speakers to produce a primed mapping of event components to particular linguistic elements. That is, we saw in Experiment 1 that English speakers were willing to encode information about the path of a motion event in a verb as long as they had already given information about the manner of motion (there, in a subject modifier). In this experiment, however, we see that English speakers are less willing to produce path verbs when they have not yet provided information about manner.

Linguistic Formulation: Priming of syntactic frame

In this experiment, our analyses of the syntactic structures used in participants' utterances revealed reliable alignment of syntactic frames between primes and event descriptions, as in Experiment 1, only when prime sentences overlapped in both verb and event structure with target events: i.e., in the Verb + Event Type condition, but not in the Event-Type Only or No-Overlap conditions. Fig. 5 shows the average proportion of Primed syntactic frames used in participants' motion event descriptions in each condition. As in Experiment 1, use of Primed VP frames was determined on an item-by-item basis, since primed VPs differed slightly across items. As can be seen in Fig. 5, in the absence of a prime sentence, speakers used frames that consisted of verbs followed by two post-verbal phrases (either V_NP_PP or V_PP_PP, depending on the stimulus item) in approximately 12% of their utterances, giving rise to event descriptions like "An alien is driving a car into a cave." In the priming conditions, participants increased their use of the Primed frames only in the Verb + Event Type condition. There was no increase in the use of Primed frames in either the Event-Type Only or the No-Overlap condition compared to their use in the Control condition.

We tested the reliability of these observations using multilevel logistic modeling as described above. Binary values at the trial-level for use of the Primed VP frames were modeled using Condition (Control, Verb + Event Type, Event-Type Only, No-Overlap) as a first-level fixed factor. Condition was also included as a random slope in the Item effects structure. Modeling revealed a main effect of Condition ($p < .01$): use of Primed frames was significantly higher in the Verb + Event Type condition than use of the same frames in the Control condition ($p < .05$, Table 11).

To rule out the possibility that use of primed VP frames increased over the course of the experiment, binary values for production of primed VPs in the Verb + Event Type condition were modeled with Trial Block (First4, Mid4, Last4) as a first-level fixed factor. Modeling showed no significant effect of Trial Block, confirming that priming of VP frame use in this condition began within the first four trials of the experiment.

Unlike Experiment 1, use of primed VP frames in the Verb + Event Type condition was not dependent on the repetition of the verbs used in prime sentences: the likelihood of producing primed VP frames in this condition did not differ based on whether participants had repeated primed Path verbs. These trends were confirmed by modeling binary values for use of primed VP frames separately for trials in the Verb + Event Type condition on which participants did and did not produce primed verbs, with Condition (Control, Verb + Event Type) as a first-level fixed factor. For each analysis, Condition was also included as a random slope in the Item effects structure. Condition was not found to have a significant effect on production of

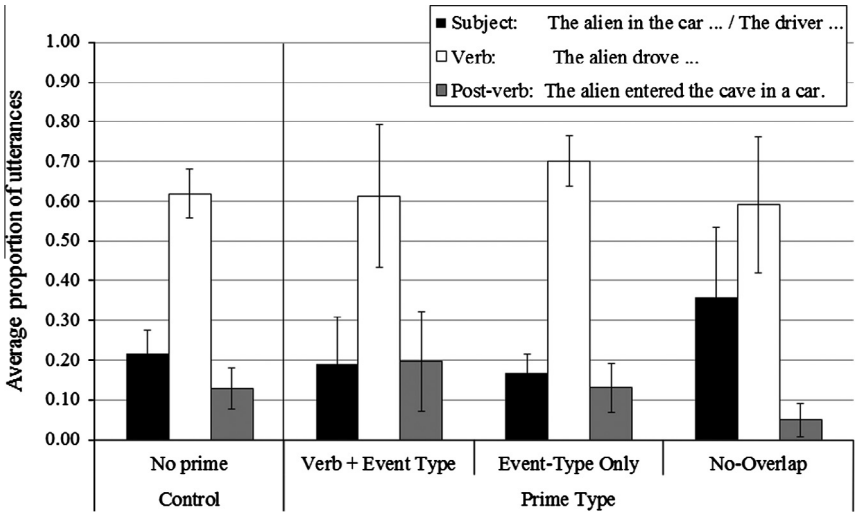

Fig. 4. Location of first Manner mention for utterances produced in Experiment 2. Manner locations are described in the text (ex. 9). Proportion of mention is calculated based on all event descriptions in which Manner was mentioned. Error bars represent 95% confidence intervals. Data for the Control condition described in Experiment 1 are repeated here from Fig. 2.

Table 10
Fixed effects from best-fitting multilevel linear model of post-verbal Manner mention, Experiment 2.

Effect	Estimate	*SE*	*z*-Value
Post-verb manner			
Intercept	**−3.30**	**0.83**	**−3.99****
Condition: Control vs. Verb + Event Type	1.25	1.01	1.23
Condition: Control vs. Event-Type Only	0.21	0.93	0.23
Condition: Control vs. No-Overlap	**−2.14**	**1.10**	**−1.95***

Formula in R: DepVar ~ Condition + (1|Subject) + (1 + Condition|Event).
* $p = .05$.
** $p < .001$.

primed VP frames for either set of comparisons, suggesting that the effect of Condition reported in Table 11 did not depend on the production of primed verbs in the Verb + Event Type condition. To test for differences in the use of primed frames for trials in which participants had and had not repeated primed verbs, binary values for use of primed VP frames were modeled for all trials in the Verb + Event Type condition, with Primed Verb Use (repeated, not repeated) as a first-level fixed factor. There were no significant differences in the production of primed VP frames in the Verb + Event Type condition for trials on which participants had repeated primed verbs vs. those on which they had not, revealing that repetition of primed verbs had no effect on the assembly of syntactic constituents. The fact that use of primed VP frames does not depend on the repetition of primed verbs suggests that these findings are not indicative of a lexical boost to syntactic priming.

Note, moreover, that because participants in the Verb + Event Type condition were not mapping event components to primed locations, even though they were producing primed syntactic frames, their event descriptions did not look like the prime sentences. That is, participants in this condition who produced the primed syntactic frame were *not* producing sentences like (12a), in which Path information is encoded in the verb and Manner information after the verb. Instead, these participants repeated the syntactic frame they were primed with, but mapped event components to that frame in their preferred order of mention, producing sentences like (12b), in which Manner is encoded in the verb and Path in a post-verbal modifier.

(12) a. The alien entered the cave in a car.
b. The alien drove a car into the cave.

Thus in this experiment, as in Experiment 1, we observe priming of VP structure when prime sentences provide both lexical and conceptual overlap with target events. Unlike Experiment 1, however, the success of priming of VP frames in this experiment was independent of the repetition of the actual verbs presented in prime sentences, providing further evidence for a conceptual boost to syntactic priming rather than a strictly lexical one.

Summary

The results of this experiment lend further support to the hypothesis that abstract event structure may be primed by input sentences, and that this priming has implications for the way that speakers choose information to communicate during Message Planning. As in Experiment 1, speakers who had been primed with sentences that included information about the path of a motion event were more likely to include information about this event component in their own descriptions of an unrelated motion event ('Message Planning: Priming of informational content'). Unlike Experiment 1, however, this priming led to downstream effects on syntactic structure at the level of Linguistic Formulation only when prime sentences provided a verb that could be used to describe target events ('Linguistic Formulation: Priming of syntactic frame').

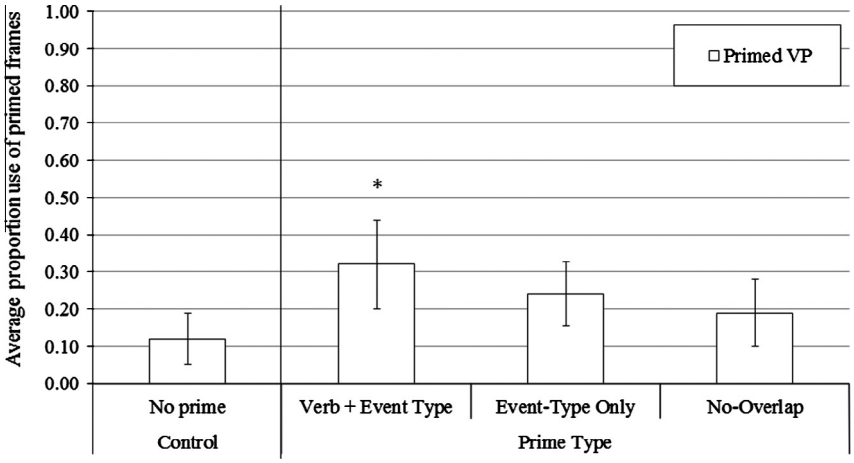

Fig. 5. Proportion of use of primed VP frames across conditions in Experiment 2. Details about syntactic frames are given in the text (ex. 10). Proportion of use is calculated from all syntactic frames used in event descriptions. Error bars represent 95% confidence intervals. Data for the Control condition described in Experiment 1 are repeated here from Fig. 2. *Use of this frame is significantly different from its use in the Control condition at $p < .05$.

Table 11
Fixed effects from best-fitting multilevel linear model of Primed VP frame use, Experiment 2.

Effect	Estimate	*SE*	*z*-Value
Intercept	**−3.02**	**0.75**	**−4.00****
Condition: Control vs. Verb + Event Type	**2.02**	**0.82**	**2.48***
Condition: Control vs. Event-Type Only	1.46	0.85	1.72
Condition: Control vs. No-Overlap	−0.03	1.02	−0.03

Formula in R: DepVar ~ Condition + (1|Subject) + (1 + Condition|Event).
* $p < .05$.
** $p < .001$.

Speakers in the Verb + Event Type condition were more likely to use the primed VP structure in descriptions of target events whether or not they actually repeated the primed verbs, suggesting that what led to this priming was activation not of the verbs themselves, but rather of the conceptual information associated with those lexical items. Finally, as in Experiment 1, in this experiment we again saw no priming of either syntactic or semantic structure when there was no overlap in event structure between primes and targets.

This experiment also sheds light on the way that language-specific encoding biases come into play during the process of language production. In Experiment 1, participants in the Verb + Event Type condition were influenced by the conceptual information encoded in the (path) verbs provided in prime sentences to encode information about the Paths of target motion events in verbs and the Manners of those events in non-verb elements. In this experiment, however, speakers did not produce manner and path information in primed structural positions, even in the presence of this conceptual boost ('From Message Planning to Linguistic Formulation: Priming of Path verb production and Manner location'). The difference between the two sets of stimuli is that in the prime sentences used in Experiment 1, manner and path information were presented in the same order that they would come in a canonical English motion event description–manner before path, but in the prime sentences used in Experiment 2, manner and path information were presented in the opposite order—path before manner. The lack of an effect of conceptual priming on event component mapping in this experiment suggests that the nature of the motion event component encoding bias in English does, indeed, impose preferences on the linear order in which motion event information is communicated, and demonstrates that the conceptual boost provided by verb overlap between primes and targets is not sufficient to overcome this linearization bias.

General discussion

Summary and interpretation of findings

In this study, we have provided evidence that speakers are sensitive to the event structure of a prime sentence, and that event structure priming affects both Message Planning and the grammatical encoding phase of Linguistic Formulation during language production. More specifically, reading prime sentences that described motion events had implications for the information that speakers chose to communicate about target motion events, the way that information was mapped to linguistic elements, and the syntactic structures that speakers used to encode that information.

In both experiments, speakers were more likely to mention the path of a target motion event if they had been primed with a sentence that provided information about the path of an unrelated motion event. This effect held even when prime sentences did not provide a verb that could be re-used to describe the target event (i.e., in both the Verb + Event Type and the Event-Type Only conditions), suggesting that it was due to priming of conceptual structure rather than priming of particular lexical items. Moreover, the effect held regardless of the order in which motion event components were evoked in prime sentences (manner before path in Experiment 1; path before manner in Experiment 2), suggesting that presenting motion event components in a noncanonical order did not affect the type of information that participants gathered from prime sentences.

When prime sentences both presented verbs that could be re-used to describe target events *and* presented motion event components in the canonical manner-before-path order, as they did in the Verb + Event Type condition in Experiment 1, speakers were primed to encode information about the manners and paths of target motion events in the same locations that they were presented in prime sentences: path information in main verbs, and manner information in subjects. The fact that we do not see this same effect in the Event-Type Only condition suggests that this effect is grounded in lexical priming. However, the fact that priming of Manner location in the Verb + Event Type condition held regardless of whether speakers actually repeated the verbs presented in prime sentences suggests that it is bottom-up activation of the conceptual information associated with primed verbs that resulted in this effect rather than the activation of particular lexical items (cf. Cleland & Pickering, 2003). Priming was not seen in the Event-Type only condition, then, because the path verbs presented in those prime sentences did not provide sufficient activation to the conceptual information that was responsible for priming motion event component encoding in the Verb + Event Type condition. Further work is needed to pin down the nature of that conceptual information, as well as to identify differences between the verbs presented in the two priming conditions.

In addition, the fact that priming of motion event component encoding was not seen in Experiment 2, in which prime sentences presented speakers with information about motion event components in the noncanonical path-before-manner order, suggests that this bottom-up conceptual priming was effective in overcoming the bias that English speakers have to map motion event components to particular linguistic elements, but not their bias to present information about motion event components in a particular order. Specifically, under the proper priming conditions, speakers were willing to violate their bias to encode manner information in verbs (Experiment 1), but not their preference to present manner information before path information (Experiment 2). A recent study by Cai et al. (2012) has demonstrated that the linear order in which thematic information encoded in NPs is produced can be affected by priming. Further research is required to determine whether the resistance to order of information priming in this study is due to the nature of the bias on motion event encoding in English (e.g., the order bias is stronger than the verb bias) or to the specific verbs that were used as primes in this study and the syntactic frames with which they are frequently associated.

Finally, in both experiments, event structure priming led to an increase in the use of primed syntactic frames in descriptions of target events. Priming of syntactic structure in this study was only successful when primes provided both conceptual and lexical overlap with target events (i.e., in the Verb + Event Type condition), but in both experiments we observed priming of syntactic structure that was independent of the repetition of primed verbs in descriptions of target events (priming of complex subjects in Experiment 1, and of VP frames in Experiment 2). When there was no lexical or conceptual overlap between primes and targets, however, syntactic structure was not primed. The fact that we observed priming of syntactic structure only in the Verb + Event Type condition suggests that repetition of primed syntactic frames in these experiments was driven, at least in part, by the same bottom-up lexical–semantic priming that affects the distribution of information about manner and path in linguistic elements in Experiment 1. Syntactic frames were primed across experiments in this condition, then, because this bottom-up priming is based on the activation of particular verbs (and their associated syntactic information), a source of priming that is absent in the Event-Type Only and No-Overlap conditions. Priming of VP frames in Experiment 1 was successful only when primed verbs were also repeated, providing further support for the kind of lexical boost to priming described by Pickering and Branigan (1998). The fact that the syntactic structure of complex subject NPs was also primed in the Verb + Event Type condition suggests that lexical overlap between primes and targets may lead to attempts at syntactic alignment that go beyond the confines of the phrase that contains repeated elements (in this case, the VP). Moreover, the fact that repetition of complex subjects was not restricted to event descriptions in which primed verbs were also repeated suggests that, unlike VP structure choice, choice of subject structure was not limited to the options offered by repeated elements.

The role of conceptual structure in sentence production

These findings contribute to our growing understanding of the way that conceptual structure comes into play during language production. Previous studies have demonstrated that bottom-up priming of conceptual information from activation of lexical items that spreads upward (and outward) to related semantic concepts has downstream implications for grammatical encoding (e.g., Cleland & Pickering, 2003), as does priming of particular mappings of thematic structure to structural locations (e.g., Chang, Dell, & Bock, 2006; Chang et al., 2003). In this study we provide evidence for an additional, top-down, locus of conceptual priming, demonstrating that activation of event structure also has implications for the Message Planning stage of language production. Priming speakers with particular event structures increased the

accessibility of those event types, and influenced, in turn, the event information that speakers selected to talk about. In order to accommodate this finding, current accounts of structural priming in language production, whether predicated on activation (e.g., Pickering & Branigan, 1998) or alignment (e.g., Pickering & Garrod, 2004) in dialogue or implicit learning of mappings between levels of linguistic representation (e.g., Chang, 2002; Chang et al., 2006), must be able to account for the kind of flexibility in the structure of a message that is possible with motion events (i.e., motion information may be omitted or may be mapped to nouns, verbs, or prepositions), as well as the fact that message content and structure may themselves be influenced by conceptual information in the input. In addition, we demonstrated an effect of bottom-up lexical–conceptual priming on the way that speakers mapped conceptual information to linguistic elements, a reflection of the perspective from which speakers choose to present information about a given event, and on the way that information was encoded in syntactic structures. Priming was not the only conceptual mechanism at play in these experiments, however, and we found that conceptual priming failed when pitted against language-specific biases about the order in which information about a motion event should be presented. The unshakeable preference we observed in this study to mention manners of motion before paths of motion is undoubtedly syntactically motivated, stemming from the bias in English to encode manner information in verbs and path information in post-verbal satellites. However, the results of this study suggest that this ordering bias, like the role that animacy plays in determining Japanese subjects (Tanaka et al., 2011), is a phenomenon independent from particular structural mappings: in Experiment 1 we found that speakers were willing to encode manner information in locations other than the verb, as long as the manner before path order was preserved.

The effect of event structure activation that we observed in Experiment 1 was independent of the particular lexical items used to evoke motion events: priming of message content was successful in this experiment even when prime sentences did not provide verbs that could be re-used in target sentences, and priming of message encoding was successful even when reusable verbs were not actually repeated. Note, however, that although we have referred to the information activated by event structure priming as "conceptual," the current study does not permit us to determine whether the event structure representation being activated by motion event primes is conceptual or semantic in nature. In this study, we used a linguistic cue to evoke motion events in primes: specifically, we provided a verb that encoded information about the path of an unrelated motion event. To the extent that the path verbs used in prime sentences in our Event-Type Only condition (in which paths in primes and targets were mismatching) form a coherent natural class, it is impossible to tease apart conceptual structure from abstract semantic knowledge associated with this particular class of verbs. At this time, it is not clear how we could identify differences between these two sources of information; it is clear, however, that in this study something more abstract than the subcategorization frames associated with particular lexical items is influencing online sentence production.

The results of this study, combined with a growing body of literature demonstrating that more than just syntax affects the structure of a target sentence (e.g., Bernolet et al., 2009; Bock et al., 1992; Chang et al., 2003; Cleland & Pickering, 2003; Hare & Goldberg, 1999; Hartsuiker & Westenberg, 2000; Hartsuiker et al., 1999; Pickering & Branigan, 1998), suggest that we carefully consider the source of priming of syntactic structure in any given data set. In many priming studies, for example, what is referred to as "syntactic priming" is actually assessed by noting the order in which thematic roles appear in a target, e.g., the order in which themes and recipients occur in dative frames, rather than coding for strict repetition of the syntactic frame used in the prime sentence (cf. Pappert, Zeiske, & Pechmann, 2009). This coding of semantic structure is often sufficient because the syntactic frames under consideration are fairly simple and largely proscribed by the type of event under consideration. It is worth noting, however, that the order in which thematic roles are mapped to syntactic structure is itself among the list of non-syntactic linguistic elements that may be affected by priming. In the current study, we found that what looks like priming of syntactic structure may instead arise as the downstream result of priming of the information that speakers choose to include in an utterance. While the results of this study certainly do not argue against the possibility of pure syntactic priming, they do suggest that we tread carefully when asking questions about syntactic priming without also controlling for possible sources of conceptual priming.

Finally, the results of this study contribute to a growing body of knowledge about the way that humans perceive, process, and make decisions about events in real-time. There is evidence that event apprehension happens on the basis of very brief displays that last less than the duration of a single fixation: on the basis of such displays, people are able to identify the category (e.g., *pushing*, *chasing*) of an event as well as the event participants and asymmetrical relations between these participants (Hafri, Papafragou, & Trueswell, in press). Other studies suggest that event participants can be identified in less than a second (Griffin & Bock, 2000; Hafri, Papfragou, & Trueswell, 2011; Wilson, Papafragou, Bunger, & Trueswell, 2011). Furthermore, nonlinguistic event apprehension seems to proceed in similar ways across members of different linguistic communities (Bunger et al., 2012a; Papafragou et al., 2008). This ability to quickly apprehend and extract information from events should have implications for language production, since in order to describe an event speakers must identify relevant event components and choose a verb to label the event (although not necessarily in that order). Bock et al. (2004) suggest that the conceptual prominence of an event component affects the way it is mapped to linguistic structure. Recent findings support this hypothesis: Wilson et al. (2011) reported parallels between the speed with which event components (agents, instruments, patients, and goals) were identified in a still depiction of an event and the frequency with which these components

were mentioned in a verbal description of the event. The results of the current study suggest that manner and path may also be components that are quickly extracted from dynamic motion events, making these components available for packaging during Linguistic Formulation.

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Appendix A

Motion events depicted in target videos and prime sentences presented before events in each condition of Experiment 1. Verb + Event Type prime sentences were designed to overlap with target events in both manner (vehicle/instrument) and path of motion. Event-Type Only primes were created by shuffling the Verb + Event Type prime sentences among target events and changing path verbs to assure no lexical overlap across prime–target pairs.

Target event: An alien drives a car into a cave
Verb + Event Type prime: The zebra on the motorcycle entered the garage.
Event-Type Only prime: The man in the helicopter circled the tower.
No-Overlap prime: The nurse with the freckles baked a pie.

Target event: A man in a hot air balloon lands on top of a building
Verb + Event Type prime: The reporter in the airplane landed on the island.
Event-Type Only prime: The ballerina in the truck went into the tunnel.
No-Overlap prime: The clown with the suspenders laughed with the strongman.

Target event: A man in a sailboat lands on an island
Verb + Event Type prime: The scientist in the kayak neared the buoy.
Event-Type Only prime: The ranger on the snowmobile entered the forest.
No-Overlap prime: The woman with her children painted a picture.

Target event: A man paddles a canoe to a dock
Verb + Event Type prime: The girl on the raft reached the houseboat.
Event-Type Only prime: the girl on skates entered the store.
No-Overlap prime: The girl with the laptop stirred the coffee.

Target event: A woman on a magic carpet lands on the moon
Verb + Event Type prime: The doctor on the bicycle approached the hospital.
Event-Type Only prime: The scientist in the kayak crossed the river.
No-Overlap prime: The man with the cough smoked a cigarette.

Target event: A man drives a motorcycle into a carwash
Verb + Event Type prime: The ballerina in the truck pulled into the tunnel.
Event-Type Only prime: The woman in the airplane landed in the field.
No-Overlap prime: The guy with the bowtie cooked with his girlfriend.

Target event: A man parachutes from the sky and lands on a tree
Verb + Event Type prime: The woman in the balloon descended onto the ship.
Event-Type Only prime: The nurse in the jeep crossed under the bridge.
No-Overlap prime: The man with the mustache sang with his wife.

Target event: A man lands an airplane on a platform
Verb + Event Type prime: The nurse in the helicopter landed on the mountain.
Event-Type Only prime: The clown on the unicycle exited from the theater.
No-Overlap prime: The ballerina with the ponytail drank with her friends.

Target event: A boy roller skates into a soccer net
Verb + Event Type prime: The girl on skates approached the ice cream stand.
Event-Type Only prime: The girl on the raft descended the waterfall.
No-Overlap prime: The girl with the scarf ate the candy.

Target event: A girl rides a scooter into the mouth of a cave
Verb + Event Type prime: The man on the snowmobile entered the igloo.
Event-Type Only prime: The monkey on the sled descended the mountain.
No-Overlap prime: The monkey with a banana stole the jewels.

Target event: A duck ice skates into a fishing hut
Verb + Event Type prime: The monkey on the sled reached the tree.
Event-Type Only prime: The doctor in the sportscar passed the truck.
No-Overlap prime: The doctor with the scar read the newspaper.

Target event: A skier skis through a finish line
Verb + Event Type prime: The ranger on snowshoes crossed the glacier.
Event-Type Only prime: The zebra on the motorcycle exited the garage.
No-Overlap prime: The scientist with the company wrote the report.

Appendix B

Motion events depicted in target videos and prime sentences presented before events in each condition of Experiment 2. Verb + Event Type and Event-Type Only prime sentences were created by moving the subject-internal PPs in prime sentences used in Experiment 1 (Appendix A) to post-verbal positions.

Target event: An alien drives a car into a cave
Verb + Event Type prime: The zebra entered the garage on a motorcycle
Event-Type Only prime: The man circled the tower in a helicopter
No-Overlap prime: The nurse baked a pie with skill.

Target event: A man in a hot air balloon lands on top of a building
Verb + Event Type prime: The reporter landed on the island in an airplane.
Event-Type Only prime: The ballerina went into the tunnel in a truck.
No-Overlap prime: The clown laughed with the strongman for an hour.

Target event: A man in a sailboat lands on an island
Verb + Event Type prime: The scientist neared the buoy in a kayak.
Event-Type Only prime: The ranger entered the forest on a snowmobile.
No-Overlap prime: The woman painted a picture with her children.

Target event: A man paddles a canoe to a dock
Verb + Event Type prime: The girl reached the houseboat on a raft.
Event-Type Only prime: The girl entered the store on skates.
No-Overlap prime: The girl stirred the coffee for two seconds.

Target event: A woman on a magic carpet lands on the moon
Verb + Event Type prime: The doctor approached the hospital on a bicycle.
Event-Type Only prime: The scientist crossed the river in a kayak.
No-Overlap prime: The man smoked the cigarette with his boss.

Target event: A man drives a motorcycle into a carwash
Verb + Event Type prime: The ballerina pulled into the tunnel in a truck.
Event-Type Only prime: The woman landed in the field in an airplane.
No-Overlap prime: The guy cooked with his girlfriend for a bet.

Target event: A man parachutes from the sky and lands on a tree
Verb + Event Type prime: The woman descended onto the ship in a balloon.
Event-Type Only prime: The nurse crossed under the bridge in a jeep.
No-Overlap prime: The man sang with his wife for a party.

Target event: A man lands an airplane on a platform
Verb + Event Type prime: The nurse landed on the mountain in a helicopter.
Event-Type Only prime: The clown exited from the theater on a unicycle.
No-Overlap prime: The ballerina drank with her friends with gusto.

Target event: A boy roller skates into a soccer net
Verb + Event Type prime: The girl approached the ice cream stand on skates.
Event-Type Only prime: The girl descended the waterfall on a raft.
No-Overlap prime: The girl ate the candy with a smile.

Target event: A girl rides a scooter into the mouth of a cave
Verb + Event Type prime: The man entered the igloo on a snowmobile.
Event-Type Only prime: The monkey descended the mountain on a sled.
No-Overlap prime: The monkey stole the jewels with a grin.

Target event: A duck ice skates into a fishing hut
Verb + Event Type prime: The monkey reached the tree on a sled.
Event-Type Only prime: The doctor passed the truck in a sportscar.
No-Overlap prime: The doctor read the newspaper with a frown.

Target event: A skier skis through a finish line
Verb + Event Type prime: The ranger crossed the glacier on snowshoes.
Event-Type Only prime: The zebra exited the garage on a motorcycle.
No-Overlap prime: The scientist wrote the report with her assistant.

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