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Syntactic Entrainment: The Repetition of Syntactic Structures in Event Descriptions

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Abstract

Syntactic structures can convey certain (subtle) emergent properties of events. For example, the double-object dative ("the doctor is giving a patient pills") can convey the successful transfer of possession, whereas its syntactic alternative, the prepositional dative ("the doctor is giving pills to a patient"), conveys just a transfer to a location. Four experiments explore how syntactic structures may become associated with particular semantic content – such as these emergent properties of events. Experiment 1 provides evidence that speakers form associations between syntactic structures and particular event depictions. Experiment 2 shows that these associations also hold for different depictions of the same events. Experiments 3 and 4 implicate representations of the semantic features of events in these associations. Taken together, these results reveal an effect we term *syntactic entrainment* that is well positioned to reflect the recalibration of the strength of the mappings or associations that allow syntactic structures to convey emergent properties of events.

Keywords: Linguistic communication, language production, sentence production, syntactic production.

Syntactic Entrainment: The Repetition of Syntactic Structures in Event Descriptions

Language conveys information about the real world through conventions governing how meanings map onto sounds. The fact that the sounds of the word "donkey" describe the animal that it does is arbitrary; the phonology of the word "donkey" expresses that meaning because English speakers learn the conventions that map those sounds onto that meaning. Though the conventionality of language is notably apparent through the relationships between words' sounds and meanings, conventionality is also relevant at other linguistic levels. In particular, the rules that guide how we combine words into sentences – namely, syntax – also exhibit their own conventions, permitting us to express and interpret the aspects of meaning that syntax conveys. In the current study, we report a newly-discovered effect that can be seen as reflecting the learning or recalibration of one particular type of syntactic convention.

Syntactic Conventions

The syntactic structure of a sentence can convey at least two types of information. First and most prominently, syntactic structure conveys relational information about roles in events – who did what to whom. Such relational information is expressed by conventions that map event roles onto grammatical functions. For example, in English active sentences, the *agent* of an event (the thing doing the action) is mapped onto the grammatical subject, whereas the *patient* (the thing the action is done to) is mapped onto the grammatical object. (Note that although we characterize these in terms of traditional thematic roles, we make no theoretical commitment to any particular theory of event-role representation.) Thus, in the sentence "the donkey chased the man," the donkey is the pursuer, but in "the man chased the donkey," the man is the pursuer. When learning any language, speakers must acquire the conventions that map event

roles onto grammatical functions, so that they can convey who did what to whom in the events they describe, and understand the same in the events they hear described.

However, another type of information that may be conveyed by syntactic structure relates not to event roles, but to event content. That is, at least according to some linguistic approaches (Goldberg, 1995; Green, 1974; Pinker, 1989), in addition to conveying the elements of events (via words) and event roles (via grammatical functions), sentences may also convey what we term here *emergent properties* of events. Consider the well-known *dative* alternation. The *prepositional dative* sentence, "the man sent the check to the woman" can also be worded as the double-object dative, "the man sent the woman the check." Interestingly, for inanimate recipients, the prepositional dative is acceptable – "the man sent the check to the address" – but the double-object dative is not – "*the man sent the address the check." The most common explanation for this contrast (Goldberg, 1995; Pinker, 1989) is that these two structures are not fully interchangeable. In particular, whereas the prepositional dative expresses a change whereby a *theme* (e.g., "the check") moves to a new *location* (e.g., "the address"), the double-object dative expresses an additional change whereby *possession* of the theme is also successfully transferred. Thus, the double-object dative structure imposes the additional requirement that the end-point of the transfer be able to take possession of the theme as its *recipient*; in contrast, the prepositional dative structure can have a location as an end-point of the transfer (e.g., "the address") because that endpoint need not take possession (Gropen, Pinker, Hollander, Goldberg, & Wilson, 1989). Thus, because an address is an acceptable location, the prepositional dative ("the man sent the check to the address") is acceptable, but because an address cannot take possession of a theme (i.e., it cannot be a recipient), the double-object dative ("*the man sent the address the check") is unacceptable.

If indeed syntactic alternatives convey emergent properties of events, the conventions for how these emergent properties are mapped onto corresponding syntactic structures must be learned. For example, when describing transfer events, language users must learn to use the double-object structure if they want to express (or imply) that possession of the theme was successfully transferred. We address this question in the current study by developing a novel paradigm to test whether adult language users can learn to associate specific event content with particular syntactic structures. In analogy to a related literature (see Chang, Dell, & Bock, 2006), we suggest that such an effect could reflect the way that language users learn how event content (viz., emergent event properties) maps onto particular syntactic structures in natural language.

Syntactic Priming and Learning the Conventions that Express Event Roles

As noted, one type of information that is conveyed by syntactic structure is event-role information – who did what to whom. The communication of event-role information via syntactic structure is underpinned by mappings or associations between, at one end, representations of event roles – agents, themes, and goals – and, at the other end, representations of the corresponding elements of syntactic structures. One account of how these mappings are learned and recalibrated across the lifespan emerges from an explanation of the well-known *syntactic priming* effect. Syntactic priming refers to language users' tendency to repeat the syntactic structures that they have recently experienced. Syntactic priming has been shown to occur in the spoken (e.g., Bock, 1986), written (e.g., Pickering & Branigan,1998), and signed modalities (e.g., Hall, Ferreira, & Mayberry, 2015); in both comprehension (e.g., Thothathiri & Snedeker, 2008) and production (e.g., Bock, 1986), and between the two (Bock, Dell, Chang, & Onishi, 2007; Branigan, Pickering, & Cleland, 2000; Ferreira, Kleinman, Kraljic, & Siu, 2012; Potter & Lombardi, 1998). People even repeat syntactic structures between different languages

(Hartsuiker, Pickering, & Veltkamp, 2004). Syntactic priming has been shown to persist after numerous intervening trials (Bock & Griffin, 2000), and for periods of up to a week (Kaschak, Kutta, & Schatschneider, 2010). Crucially, syntactic priming may be observed for any subsequent utterance that permits the repeated structure, regardless of differences in the phonological (Bock & Loebell, 1989), lexical (Bock, 1986, 1989) or semantic (Bock, 1986; Bock & Loebell, 1989) content between the new sentence and the sentence whose syntax is repeated. Furthermore, syntactic priming does not appear to depend on explicit memory, and indeed, it has been demonstrated in patients who have anterograde amnesia – although these patients have significantly compromised memory for the content of sentences, they nonetheless show robust syntactic priming (Ferreira, Bock, Wilson, & Cohen, 2008).

Chang and colleagues (2006) present a connectionist model that explains syntactic priming as reflecting the process of learning mappings between event roles and syntactic structures. For example, after hearing the sentence, "the man was chased by the donkey," speakers are subsequently more likely to produce passive structures because they have strengthened the mapping of the patient event role onto the grammatical subject syntactic position, and the agent event role onto the by-object syntactic position.

More specifically, the model initially learns the grammar of the language it is presented with by trying to predict upcoming words in sentences. When its predictions are incorrect, the model updates its parameters to increase the accuracy of its predictions in the future. Thus, functionally, the system learns to order the words describing event roles into grammatically interpretable sequences that are similar to those that it encounters in its input language. Crucially, in this model, the sequencing system only has access to the roles played by particular

constituents of the sentence. As a consequence, the actual content of those event roles is not relevant to the prediction or learning of grammatical knowledge in the model.

In this model, the syntactic learning mechanism continues to operate even after a mature language system has been acquired. In both the initial acquisition process and in the mature system, the learning mechanism continuously recalibrates the model's language representations (predicted and produced) to be more like its input. Functionally, this leads the model to repeat recently encountered syntactic structures, which allows it to account for the range of syntactic priming effects that have been reported in the literature. Furthermore, according to a number of theories, the continued recalibration of the mappings between event roles and grammatical sequences in the model can serve a functional role. Specifically, learning to use the same distribution of linguistic forms as one's linguistic community (and one's conversational partners in particular) may lead to enhanced communicative efficiency (Fine & Jaeger, 2013; Jaeger & Snider, 2013; Pickering & Garrod, 2004). For example, when language users relocate to new linguistic communities, they may be relatively less efficient at understanding (and being understood by) speakers of the local dialect because their speech exhibits different distributions of grammatical forms. However, over time, if the new speakers recalibrate their linguistic knowledge to align with the community, they will expect (and produce) a similar distribution of grammatical forms as their new interlocutors produce (and expect), thus facilitating more efficient communication.

In the present study, we aim to discover whether an analogous effect exists for another type of information that is conveyed by syntactic structure. Specifically, we assess whether the mapping of the contents of events onto syntactic structures may be similarly learned and

recalibrated, potentially underlying how emergent properties (e.g., successful transfer of possession) are expressed by syntactic structures (e.g., the double object).

Learning the Conventions that Express Emergent Properties

As noted, according to multiple approaches (e.g., Goldberg, 1995; Green, 1974; Pinker, 1989), in addition to conveying event role information, syntactic structures can also convey more holistic aspects of events, termed here emergent properties. Under the hypothesis that the expression of such emergent properties of events through the use of particular syntactic structures is a conventionalized aspect of language, the mappings that underlie them must be learned.

Above, we described accounts that view syntactic priming as a recalibration of the mappings between event roles and syntactic structures. Crucially, syntactic priming effects are independent of the specific semantic content of sentences. That is, syntactic priming reflects a process whereby speakers learn how sets of *abstract* event roles map onto particular syntactic structures, irrespective of the semantic content of those event roles. Conversely, to explain how syntactic structures come to conventionally express emergent properties of events, speakers must be able to learn how particular aspects of event content map onto particular syntactic structures. The experiments reported below provide evidence to address how this learning may occur.

To provide a concrete sense of the empirical effect that is at stake, we next outline the experimental task that we used. In these experiments, subjects were told they were going to play a language game. The general procedure (with minor differences between experiments) consisted of four interactive rounds between the subject and experimenter, each containing a prime block followed by a target block. In the prime block, experimental subjects heard experimenters describe twelve events, depicted as partially colored line drawings. Each of the twelve events

could be described with two opposing syntactic structures (structural alternatives), for example, either a double-object dative or a prepositional dative. Within each block of prime trials, subjects heard an equal number of opposing structures (e.g., subjects heard two double-object dative and two prepositional dative structures in each prime block). Next, in the target block, subjects described those same twelve events back to an experimenter. For example, in the prime block, a subject might hear a double-object dative like "the doctor is giving a patient pills," used to describe a particular picture. Then at some point during the target block – only after all of the sentences in the prime block have been presented – the subject was given the same picture to describe back to the experimenter. If listeners map event content onto a particular syntactic structure after hearing that event described with that structure, then they should be more likely to reuse that same structure (as compared to the structural alternative) to describe the same picture later on. Because this design assesses priming only after an entire prime block is completed, an average of 12 (comprehended or produced) picture descriptions intervened between when a subject heard a picture described and when they described it back, and up to five of those descriptions could be the other syntactic alternation of the description they heard.

We give this hypothetical effect the descriptive label *syntactic entrainment*, as a specific form of entrainment in general (note that this is distinct from a *conceptual pact*; see, e.g., Brennan & Clark, 1996). Generally, linguistic entrainment refers to conversational partners' tendency to re-use aspects of each other's referring expressions. For example, if one participant in a conversation refers to an abstract shape (a Tangram) as "a skater," their conversational partner is more likely to refer to that same item as "a skater" as well (Clark & Wilkes-Gibbs, 1986). This re-use of referring expressions (e.g., "skater") to refer to particular referents in a dialogue has been termed *lexical entrainment*. Analogously, if speakers re-use the syntactic

structures their interlocutors used to refer to particular events, this would constitute syntactic entrainment.

It is important to note that if subjects do tend to show syntactic entrainment in this task context, it cannot be the same effect as syntactic priming. In each block of prime trials, subjects hear two pictures described using one structural alternative (e.g., the double-object) and two different pictures described using the opposite structural alternative (e.g., the prepositional dative). This means that at the point where subjects are asked to describe a given picture back to the experimenter, they will have heard an equal number of opposing structural alternatives (e.g., when describing the picture of a doctor giving pills to a patient, a dative event, back to the experimenter, subjects will have heard a total of four dative structures in the round, two double-objects and two prepositional datives). If subjects thus tend to produce the structure they heard used to describe that particular picture rather than the alternative structure, this repetition must have been contingent on the specific content of the event or picture and not the abstract event roles implicated in syntactic priming.

Mechanisms Underlying Syntactic Entrainment and Learning to Express Emergent Event Properties

If indeed speakers repeat the syntactic structures that were used to describe particular events – that is, if speakers show syntactic entrainment – what mechanism might underlie the effect? Current theories of sentence-level production to date do not include mechanisms for the expression of emergent properties. But in analogue to accounts such as Chang et al. (2006), we speculate that upon hearing a particular event described with a particular syntactic structure, language users strengthen the mappings or associations between representations of the meaning of the event and representations of the syntactic structure. For example, upon hearing a

particular event described with, “the doctor is giving a patient pills,” speakers will strengthen associations between all aspects of that event that they inferred from comprehending the utterance, including doctors, patients, and holistic event-semantic features like *successful transfer of possession*, and the representation of the double-object syntactic structure. This predicts that when subsequently describing the same event, the just-strengthened associations between the features of the event (e.g., patients, doctors, and successful transfer of possession) and the double-object structure should increase the likelihood that speakers will use the double-object structure when describing that event. Furthermore, this account predicts that the degree of syntactic entrainment that is observed should be independent of superficial details of the pictures (as tested in Experiment 2), and complementarily, that the degree of syntactic entrainment should be sensitive to manipulations of event content (in particular, the homogeneity manipulation we test in Experiments 3 and 4).

The general account outlined here assumes that speakers will strengthen the mappings or associations between all aspects of the content of an event (e.g., doctors, patients, successful transfer of possession) and syntactic structure (the double object). Even so, the idea is that in everyday language use, language users will across a lifetime of experience hear many events described with double-object structures. These events will involve different referents, but most or all will involve successful transfer of possession (because, as assumed here, that is the convention in English). This implies that language users will consistently strengthen the association between the double-object structure and the successful transfer of possession feature, whereas associations between the double-object structure and non-conventionalized aspects of the meaning of double-object structures (e.g., doctors, patients) will wash out. Thus, given sufficient experience, a mechanism that strengthens associations between representations of

event content and representations of syntactic structure should arrive at a set of mappings between emergent event properties and syntactic structures that matches that of the linguistic community. Hypothetically, such a mechanism could underlie both the learning of conventions by new learners (by both children and new members of the linguistic community), as well as the continued recalibration of these conventions by mature language users, which would serve to maintain and reinforce the conventions among the linguistic community.

Of course, it is in principle possible that in the task context used here, subjects will form associations between much shallower representations. That is, speakers can repeat an utterance verbatim (i.e., "parrot" an utterance), and can even form paired associations between stimuli (e.g., a particular picture of a doctor giving a patient pills) and sentence-length responses (e.g., "a doctor is giving a patient pills"). Such a simple paired-associates account would imply that event-semantic meaning per se is minimally involved in any observed entrainment effect. The experiments here address this possibility two ways. First, Experiment 2 tests whether speakers show a smaller degree of entrainment when describing different versions of the pictures they originally heard described; if speakers form paired associations between picture stimuli and sentence-length responses, changing the pictures speakers describe back should diminish the size of the observed effect. Second, Experiments 3 and 4 directly test for the involvement of categories of event-semantic information in the effect (e.g., whether an event involves giving vs. throwing); if the observed effects are due to simple paired associations between stimulus pictures and sentence responses, event-semantic-category information should be irrelevant.

All experiments tested three different alternations: The dative alternation, consisting of the prepositional dative (e.g., the man is giving a prescription to the doctor) and double object dative (e.g., the man is giving the doctor a prescription) alternatives; the locative alternation,

consisting of *with*-variant (e.g., *a man is smearing his face with shaving cream*) and *on*-variant (e.g., *a man is smearing shaving cream onto his face*) alternatives; and the transitive alternation, consisting of the active (e.g., *a whale is swallowing a man*) and passive (e.g., *a man is being swallowed by a whale*) alternatives. We make no a priori predictions about possible differences among these alternations. To analyze effects collapsed across structures, for each verb class, we classify the syntactic form that is *preferred* (double-object dative, on-variant locative, and active transitive) versus *dispreferred* (prepositional object dative, with-variant locative, and passive transitive) on the basis of general observed preferences in English. Whether speakers produce preferred or dispreferred structures is the primary dependent variable in these experiments.

Experiment 1

Method

Subjects. Twenty-seven undergraduates from the UC San Diego community participated in the study in exchange for course credit. All subjects reported being native English speakers.

Materials and design. Fifty-one line drawn pictures of action scenes were used in the study. These pictures were partially colored to highlight task-relevant aspects of the scenes, and were printed and laminated individually as 4 1/2" x 3 2/3" cards. Four experimental decks of these cards were printed. The actions depicted on the cards were equally divided into three verb/event classes: dative events, locative events, and transitive events. Three of the pictures (one of each verb class) were used in the practice round, while the remaining forty-eight pictures appeared in 4 rounds of 12 pictures each. Each round contained equal numbers of dative, locative, and transitive events.

Two experimental lists were constructed to serve as scripts for the confederate to read when "describing" her cards to the participant. Each list contained 48 prime sentences, with 16

from each verb class (dative, locative, transitive). The event depicted on each card could be described using two alternative syntactic structures. For each verb class, the confederate described half of the pictures using one syntactic alternative and half using the other syntactic alternative, both within each round and across the experiment (e.g., half of transitive events were described with passive sentences and half with active sentences). The lists were counterbalanced such that each picture was described equally often with each alternative across subjects. Materials for all experiments are reported in Appendix A.

Participants were seated across from the confederate at a large table separated by a 24-inch high divider that allowed them to see each other's faces but not their respective workspaces. Printed arrays of 12 rectangles of the same dimensions as the cards were placed in front of the participant and confederate to serve as placeholders for the cards. The sessions were audio recorded using a digital recorder.

Procedure. The cover task was that participants were playing a collaborative picture-matching game. Participants alternated blockwise between two roles in the game, the *director* and the *matcher*. The task of the director was to describe their set of 12 cards in the order they were placed on the table, and the task of the matcher was to rearrange their cards into the order as described by the director (adapted from Clark & Wilkes-Gibbs, 1986). Each round consisted of two blocks, such that the subject and confederate served as both director and matcher for each set of cards. At the beginning of the experiment, the experimenter ostensibly randomly selected the confederate to be the first director. During the first block of each round, the confederate described 12 cards by reading the scripted sentences (maintaining the cover that they were spontaneous picture descriptions), which served as the prime stimuli. In the subsequent target block, the subject described the same set of 12 pictures back to the confederate in a different

order. This composed one round of the experiment. The experiment consisted of four such rounds, each with a different set of 12 cards.

Scoring and analysis. Audio recordings of the sessions were transcribed by trained research assistants. Each sentence was then coded for its syntactic structure. Only targets that conformed to the intended syntactic alternation were included in the final analysis. Dative targets were coded as either double-object or prepositional dative; locative targets were coded as either with-variant or on-variant; and transitive targets were coded as either active or passive. Target sentences that did not fall into these categories were marked as unscorable. Sentences were counted only if the main verb could have been used in either form of the syntactic alternation. As noted aboveo be able to collapse across verb class, we construct our dependent variable by classifying for each verb class the syntactic form that is *preferred* (double-object dative, on-variant locative, and active transitive) versus *dispreferred* (prepositional object dative, with-variant locative, and passive transitive) on the basis of general observed preferences for each structure in English. (Note that preferred vs. dispreferred status per se is not theoretically important.)

Three subjects were excluded from the analysis due to recording errors, and two additional subjects were excluded because they produced scorable responses on fewer than half of trials (a criterion that was established a priori for all experiments). We used R (R Core Team, 2014) and *lme4 version 3.3.1* (Bates, Maechler, Bolker, & Walker, 2014) to perform a mixed effects logistic regression of the effect of the confederate's prime syntactic structure on the subject's target syntactic structure. Prime type (preferred or dispreferred structure), verb class (dative, locative, and transitive), and their interaction (prime type x verb class) were entered into the model as fixed effects. We initially included the maximal random effects structure in our

model (Barr, Levy, Scheepers, & Tily, 2013), however the full model failed to converge using this strategy, and so we removed correlations between random effects from the model. As random effects, we included intercepts for subjects and items, as well as by-subjects and by-items random slopes for the effect of prime type, the effect of verb class, and the interaction between prime type and verb class. Models were run using the bobyqa optimizer to aid convergence. All reported *p*-values were obtained using likelihood ratio tests. Interaction effects were tested by comparing the full model against the model with the interaction term removed. Fixed main effects were tested by comparing the full model against the model with the relevant fixed main effect removed. Variables were contrast-coded using sum coding, with factor levels coded as -0.5 and +0.5. Model output for all experiments is shown in Appendix B.

Results and Discussion

Subjects produced scorable responses on 66.5% of trials overall (766 out of 1152 trials), including on 71.9% of dative trials (276 out of 384), 51.8% of locative trials (199 out of 384), and 75.8% of transitive trials (291 out of 384). The low percentage of scorable responses for locative trials was primarily due to the fact that subjects often used verbs that conveyed a similar meaning as the intended verbs but did not allow both syntactic alternatives.

The results of Experiment 1 are shown in Figure 1. Subjects overall were 12.5% more likely to produce the preferred syntactic structure (corresponding to the double-object dative, on-variant locative, and active transitive as discussed above) when primed with the preferred structure (67.7%) than when primed with the dispreferred structure (55.2%), and including prime type in the model significantly improved the model fit ($\chi^2(1) = 20.03$, $p < .0001$). The main effect of verb class on subjects' responses was not significant ($\chi^2(2) = 3.93$, $p = .14$). Note that this non-significant main effect is theoretically uninteresting, as it would only indicate that some

verb classes are more or less biased toward one of their syntactic alternatives compared to the other verb classes.

There were also numerical differences in the prime effect for the different verb classes, although these differences (i.e., the interaction between prime type and verb class) did not reach statistical significance ($\chi^2(2) = 2.03$, $p = .36$). For dative targets, subjects were 10.2% more likely to produce a prepositional dative structure when primed with a prepositional dative (57.0%) than when primed with a double-object (46.8%). For locative targets, subjects were 17.3% more likely to produce an on-variant structure when primed with an on-variant (79.6%) than when primed with a with-variant structure (62.3%). For transitive targets, subjects were 10.1% more likely to produce an active structure when primed with an active structure (66.6%) than when primed with a passive (56.5%). Given the non-significant interaction and the fact that it is not relevant to our theoretical questions, we collapsed across the verb class factor in the analyses in subsequent experiments.

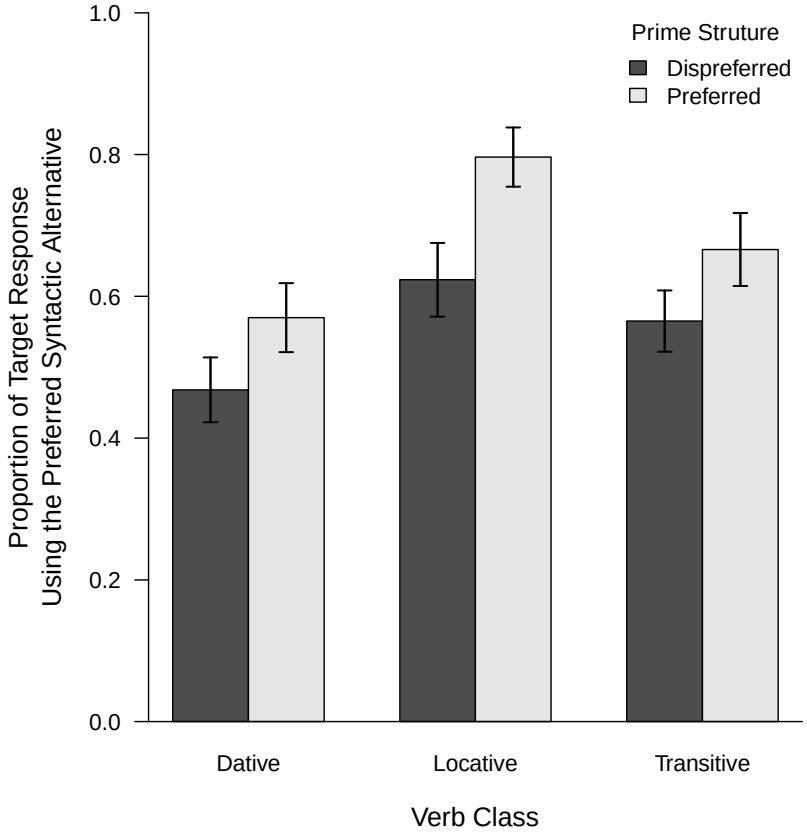

Figure 1. Proportion of preferred structure responses as a function of whether subjects heard events described with preferred or dispreferred structures and verb class in Experiment 1. Error bars represent standard errors.

These results indicate that conversational partners demonstrate syntactic entrainment: When speakers hear events described using particular syntactic structures, they are more likely to use that structure subsequently when describing the same events. As suggested above, such an effect could reflect how we establish associations or mappings underlying the conventions within the linguistic community regarding the expression of emergent properties and how such expression is constrained by event-semantic properties.

Thus far, given the nature of the materials used in Experiment 1, it may be that speakers exhibited entrainment by forming simple paired associations between the picture stimuli and sentence-length responses. To assess this possibility, in Experiment 2, we created two depictions of each event that varied on a number of dimensions (the perspective, the relative size of actors and objects, coloring, and other stylistic differences), such that the two pictures were visually different, but still could be described with the same sentence. If syntactic entrainment reflects a simple paired association between the picture stimulus and a sentence-length response, then when subjects describe back a different drawing of the same event, they should be more likely to generate a new description, and so should be less likely to repeat the same syntactic structure, compared to when they describe back the same drawing of the same event.

Experiment 2

In this experiment, we tested whether subjects used the same syntactic structures as their conversational partner not only to describe the same event depiction, as shown in Experiment 1, but also when describing a different depiction of that same event. If so, it would suggest that the syntactic entrainment effect reflects associations between syntactic structures and an abstract representation of the event, rather than representations of the specific picture stimuli.

Method

Subjects. Forty-eight undergraduates from the UC San Diego community participated in exchange for course credit. We doubled the number of subjects tested here (and in subsequent experiments) because each experiment introduces a second factor of theoretical interest to the experimental design. All subjects reported being native English speakers.

Materials and design. Ninety-nine line-drawn pictures similar to those used in Experiment 1 were used in this experiment. Three cards were used for the practice round, while

the remaining 96 cards were divided into two groups, Version A and Version B. Each event depicted in the Version A group had a matching event in the Version B group. The Version B images portrayed the same elements and the same relationships within the event as the Version A images, but varied the perspective, the relative size of actors and objects, and the coloring of the event participants, along with other stylistic differences. The artist who drew the drawings was given latitude in deciding how to implement these modifications, with the requirements that the Version B depiction could be described using the same sentence, and that it was clearly distinct from the Version A depiction. Figure 2 provides an example of Version A and Version B of a particular event.

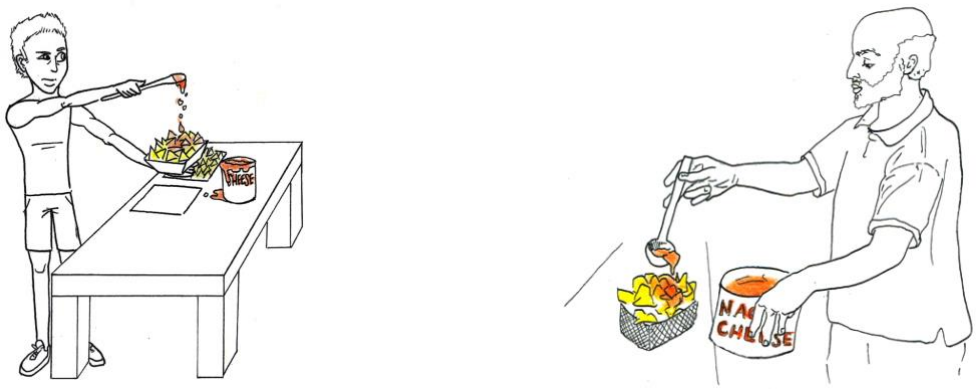

Figure 2. Version A and Version B depictions of events intended to elicit "The man is drizzling nacho cheese on his nachos"

Scoring and analysis. Experiment 2 employed a similar scoring procedure as Experiment 1. Prime type (preferred vs. dispreferred structure), and event depiction (whether subjects described the same or different event depictions as they originally heard the experimenter describe), and their interaction were entered as fixed effects into the model. We included the maximal random effects structure in our models. As random effects, we had intercepts for subjects and items, as well as by-subjects and by-items random slopes for the effect

of prime type, the effect of event depiction, and the interaction between prime type and event depiction. All other details of the analyses were identical to Experiment 1.

Results and Discussion

Subjects produced scorable responses on 74.1% of trials overall (1707 out of 2304 trials), including on 81.0% of dative trials (622 out of 768), 53.8% of locative trials (413 out of 768), and 87.5% of transitive trials (672 out of 768).

The results of Experiment 2 are shown in Figure 3. Overall, subjects were 12.0% more likely to produce the preferred syntactic structure when primed with the preferred structure (72.9%) than when primed with the dispreferred structure (60.9%), and including prime type in the model significantly improved the model fit ($\chi^2(1) = 29.4$, $p < .0001$). The main effect of event depiction was not significant ($\chi^2(1) = 2.55$, $p = .11$); note that this factor is theoretically uninteresting, as it assesses whether, regardless of which structure a picture was originally described with, subjects use the preferred syntactic structure at different rates when they see the same depiction in prime and target trials compared to when they see a different depiction in prime and target trials.

The critical effect is the interaction between prime type and event depiction. On trials where the subject described the same event depiction as the one described by the experimenter, they were 11.0% more likely to produce the preferred structure when primed with the preferred structure (74.4%) than when primed with the dispreferred structure (63.4%). On trials where the subject described a different depiction of the event than had been described by the experimenter, they were 12.9% more likely to produce the preferred structure when primed with the preferred structure (71.4%) than when primed with the dispreferred structure (58.5%). Although there was a small numerical difference (1.9%) opposite the direction of any depiction-sensitive effect, this

difference was not statistically significant, and including the interaction term (event depiction x prime type) did not improve our model fit ($\chi^2(1) = 0.0844$, $p = .77$).

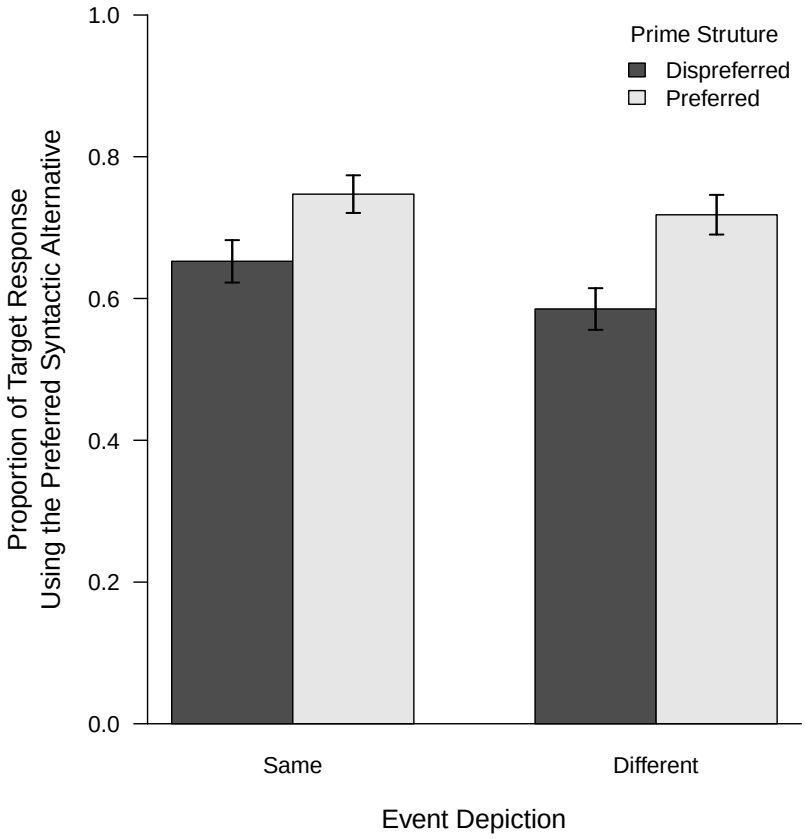

Figure 3. Proportion of preferred structure responses for target descriptions in which subjects either described the same or a different depiction of an event as they saw in the prime block in Experiment 2. Error bars represent standard errors.

In sum, after hearing descriptions of particular event depictions, subjects are subsequently more likely to reuse the same syntactic structures, both when describing the identical event depiction as well as distinct event depictions that display the same general event. That is, syntactic entrainment is observed for events regardless of how those events are depicted.

This suggests that syntactic entrainment reflects the strengthening of associations not with particular picture stimuli, but instead with a more abstract representation of the content of the event. Experiments 3 and 4 assess a specific possibility of what that abstract event representation might be.

Experiment 3

Experiment 2 established that the syntactic entrainment effect involves associations between syntactic structures and some aspect of the event representation that is more abstract than the specific picture stimuli. The introduction described that syntactic structures in general can hypothetically express holistic aspects of events, termed here emergent properties. Experiment 3 investigates whether syntactic entrainment involves representations akin to the types of event-semantic features that in general resemble these emergent properties. Such a result would support the possibility that syntactic entrainment is well positioned to reflect a process of conventionalizing the associations between syntactic structures and emergent properties, as is observed in natural language.

To test this hypothesis, Experiment 3 adopts a general paradigm that has been used to test for the representation of meaning-based category features in production tasks. In one specific instance of this paradigm (Damian, Vigliocco, & Levelt, 2001), subjects name sets of objects and their production latencies are measured. Subjects are slower to name the objects in a set when they all belong to the same semantic category (e.g., animals) compared to when all they belong to different semantic categories. These results follow from the hypothesis that the semantic system underlying object meaning is organized according to such semantic categories. When naming blocks of semantically homogeneous objects, associations between each object name and the semantic features that are common to all of the objects are all strengthened, causing

interference (Howard, Nickels, Coltheart, & Cole-Virtue, 2006; Oppenheim, Dell, & Schwartz, 2010). In contrast, when naming blocks of objects from distinct semantic categories, the absence of common semantic features within the set reduces such interference. For example, if a subject names a set of pictures that include a dog, a cat, a pig, and a cow, then associations between a feature such as "mammal" (common to all four in the set) and each object name will be strengthened as each object is named. As each picture is named again, the fact that an association to a different name was previously strengthened slows production latencies. But if instead a subject names a set of pictures that include a dog, a chair, a sun, and a house, the reduction in the number of common semantic features correspondingly reduces such interference; that is, the "mammal" feature of dog will not have its association to names other than "dog" strengthened (because "mammal" only participates when "dog" is to be named), and so the subsequent naming of "dog" will be slowed less. (The Oppenheim et al., 2010 model additionally includes a weakening component that we do not detail here.)

Experiment 3 adopted an analogous logic, but for semantically related events described with syntactic structures. Specifically, we tested whether naming blocks of events from a common *event-semantic category* – that is, a category of events with common event-semantic features – causes interference in the syntactic entrainment effect. For example, dative events, which can be described with either prepositional dative or double-object dative structures, come from (at least) four event-semantic categories: give-type events, where something is (potentially) transferred from one entity to another; tell-type events, where information is (potentially) transferred from one entity to another; show-type events, where information is displayed from one entity to another; and throw-type events, where something is projected through the air from one entity to another. (See Appendix C for a complete list of the semantic categories used in this

study). In *homogeneous* blocks, all four dative events within the block came from the same event-semantic category (e.g., all four dative events were give-type events, though different verbs could be used, such as "give" and "hand"). Recall that in the standard entrainment procedure (in Experiments 1 and 2), two dative events are heard described with prepositional dative structures and two with double-object structures. Thus, if a feature that places an event into an event-semantic category of give-type events (as distinct from the other dative event-semantic categories) participates in the entrainment effect – that is, if the give-type event-semantic feature becomes associated with the syntactic structure used to describe the picture – then that give-type event-semantic feature will be associated twice with the prepositional dative structure and twice with the double-object structure. By hypothesis, this should reduce the entrainment effect to the extent that the effect is driven by the representation of the event-semantic feature.

In contrast, in *heterogeneous* blocks, all four dative events within the block came from different event-semantic categories – one each from the give-type, tell-type, show-type, and throw-type categories. If the features that categorize events as belonging to event-semantic categories participate in the entrainment effect, then one syntactic structure (e.g., the prepositional dative) will be associated with two of the event-semantic features and the other syntactic structure (e.g., the double-object dative) will be associated with the other two event-semantic features. If the event-semantic features that define the event-semantic categories participate in the entrainment effect, then when (e.g.) the give-type event is described, its event-semantic feature was associated with only one syntactic structure, and so any interference elicited in the homogeneous block should be reduced.

Method

Subjects. Forty-eight undergraduates from the UC San Diego community participated in the study in exchange for course credit. All subjects reported being native English speakers.

Materials and design. Sixty-seven cards – similar to those used in Experiment 1 – were used in Experiment 3. Three cards were used for the practice round. Of the remaining cards, 16 were used as filler items and 48 as experimental items. The 16 fillers were transitive events from previous experiments, which were not suitable to address the experimental questions of Experiment 3. The 48 experimental items were divided into 8 event-semantic categories of dative and locative events, consisting of 6 items (pictures) each (see Appendix C for an explanation of these categories).

As in Experiments 1 and 2, the experimenter described 12 unique pictures in each of four rounds, for a total of 48 unique pictures across the experiment. Each round consisted of four each of transitive, locative, and dative events. However, unlike Experiments 1 and 2, only locative and dative structures were critical items; transitive event depictions were used as filler items. Thus, each experimental list contained 16 dative sentences and 16 locative sentences, for a total of 32 critical items per subject. As in Experiments 1 and 2, the events depicted on the cards could be described using two alternative syntactic structures, and prime type was counterbalanced within round, such that two dative events per round were described using the prepositional dative and two using the double-object dative, and two locative events per round were described using the with-variant, and two using the on-variant.

Across subjects, a given picture was described by the experimenter equally often in a homogenous and in a heterogeneous block. However, due to counterbalancing constraints, a particular subject saw only 32 of the 48 critical items. Therefore, 16 pictures were shown to every subject (for half of the subjects, in the homogenous condition and half in the

heterogeneous condition) and the remaining 32 pictures were shown to only half of the subjects (again, for half of those subjects in the homogenous condition and half in the heterogeneous condition). (Note that Experiment 4 replicates Experiment 3 with a balanced items design.) Prime type was counterbalanced across subjects, meaning each picture was described by the experimenter half of the time using its preferred structure and half of the time using its dispreferred structure. Eight experimental lists of picture descriptions were constructed for the experimenter to read in his or her role as director, crossing which pictures were shown by homogeneity and prime type.

The manipulation of interest was whether the four events of one syntactic alternation within a round came from the same event-semantic category (homogeneous condition), or whether they came from distinct event-semantic categories (heterogeneous condition). Homogeneity was counterbalanced by verb class across rounds, such that in a given round, the locative events were homogeneous and dative events were heterogeneous, or the reverse. Thus, in two of the four rounds the locative events were from a single semantic category (homogenous condition), and the dative events were each from distinct semantic categories (heterogeneous condition); in the other two rounds dative events were from a single semantic category (homogenous condition), and locative events were each from distinct semantic categories (heterogeneous condition).

Procedure. The same procedure was used as in Experiment 1.

Scoring and analysis. The same coding procedure was used as in previous experiments. Prime type (preferred or dispreferred structure), homogeneity (homogeneous or heterogeneous block), and their interaction (prime type x homogeneity) were entered into the model as fixed effects.

We included the maximal random effects structure for subjects in our model. However, we did not include correlations between random effects for items since the homogeneity condition was unbalanced across items. As random effects, we had intercepts for subjects and items, as well as by-subjects and by-items random slopes for the effect of the prime condition, the effect of the homogeneity condition, and the interaction between prime and homogeneity conditions. Three items lacked data in at least one of the four cells. Models run including these items failed to converge, and so they were removed for the final analysis. All reported *p*-values were obtained using likelihood ratio tests by comparing the full model against the model with the fixed effect in question removed. All other analysis details were as in previous experiments.

Results and Discussion

Subjects produced scorable responses on 62.2% of trials overall (956 out of 1536 trials), including on 76.8% of dative trials (590 out of 768) and 47.7% of locative trials (366 out of 768).

Results are shown in Figure 4. In contrast to the previous experiments, although subjects were numerically (3.5%) more likely to produce the preferred syntactic structure when primed with the preferred structure (75.2%) than when primed with the dispreferred structure (71.7%), the main effect of prime type was not significant and including prime type in the model did not improve the model fit ($\chi^2(1) = 0.71$, $p = .40$). The (theoretically uninteresting) main effect of homogeneity condition was not significant ($\chi^2(1) = 2.05$, $p = .15$).

For the interaction between prime type and homogeneity, speakers showed an 6.5% greater syntactic entrainment effect in the heterogeneous condition than in the homogeneous condition. In heterogeneous blocks, subjects were 6.7% more likely to produce the preferred structure when primed with the preferred structure (79.2%) than when primed with the dispreferred structure (72.5%). In homogeneous blocks, subjects were only 0.2% more likely to

produce the preferred structure when primed with the preferred structure (71.2%) than when primed with the dispreferred structure (71.0%). However, this numerical difference in degree of syntactic entrainment between the homogeneous and heterogeneous conditions was not statistically significant, and including the interaction term (prime type x homogeneity) did not improve model fit ($\chi^2(1) = 0.15$, $p = .70$).

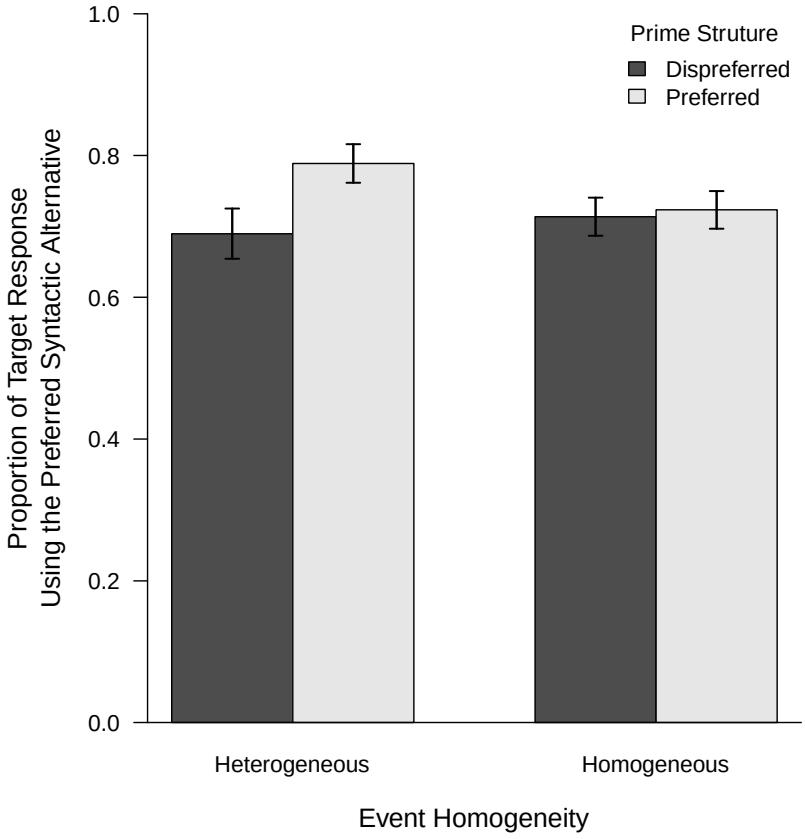

Figure 4. Proportion of preferred structure responses for target descriptions of events that were either in heterogeneous blocks (4 event semantically distinct depictions) or homogeneous blocks (4 event semantically similar depictions) in Experiment 3. Error bars represent standard errors.

Overall, in Experiment 3, there was a relatively large numerical moderation of the entrainment effect by homogeneity, although this effect was not statistically significant. It is possible that statistical support for this interaction effect was compromised by the unbalanced items design. Experiment 4 aimed to replicate Experiment 3 using a balanced items design. We nonetheless report Experiment 3 here both so as to avoid "file drawering" it, but also because a balanced items design required changing other aspects of the overall procedure. Given the closer parallel of the design and procedure, Experiments 1 and 2 are numerically more comparable to the observed outcomes of Experiment 3 than those of Experiment 4.

Experiment 4

Experiment 3 tested the hypothesis that the entrainment effect is modulated by event homogeneity, thereby implicating the strengthening of associations between event-semantic categories and syntactic structures. Experiment 3 showed a numerical but not statistically significant interaction between event homogeneity and the entrainment effect, perhaps due to the unbalanced items design. Experiment 4 was designed to keep the event homogeneity manipulation but also show every picture an equal number of times across subjects. Doing so (while counterbalancing the items across other factors) required other changes to the procedure – most importantly, a reduction in block size from 12 to 6 pictures per block (this and other changes are noted below) – that changed the overall magnitude of the syntactic entrainment effect. Regardless of the absolute magnitude of the entrainment effect, if the event-semantic features that determined homogeneity participate in the entrainment effect, then a larger entrainment effect should be observed for heterogeneous compared to homogeneous blocks.

Method

Subjects. Forty-eight undergraduates from the UC San Diego community participated in the study in exchange for course credit. All subjects reported being native English speakers.

Materials and design. Forty-eight cards – a subset of the cards used in Experiment 3 – were used in Experiment 4. Sixteen transitive events were used as filler items (as in Experiment 3) and 32 as experimental items. The 32 experimental items were divided into 8 event-semantic categories of dative and locative events, consisting of 4 items each. Over the course of the experiment, each subject was presented with descriptions of events from every event-semantic category. The total number of experimental items, as well as the number of items in each block, was smaller in Experiment 4, to meet the counterbalancing needs with a reasonable number of distinct cards necessary to create the stimulus set.

Four experimental lists of picture descriptions were constructed for the experimenter to read in their role as director. Each list contained 32 experimental sentences, including 16 dative sentences and 16 locative sentences. As in the previous experiments, the events depicted on the cards could be described using two alternative syntactic structures. Within each block, subjects heard six pictures described: two locative and two dative event descriptions, which were balanced with respect to the syntactic structure used, and two transitive event descriptions as filler items. Thus, in one round, subjects heard one dative event described using the prepositional dative and one using the double-object dative, and one locative event described using the with-variant, and one using the on-variant (and two transitive filler items). As in Experiment 3, the manipulation of interest was whether the two events of the syntactic alternation (dative or locative) within a block came from the same event-semantic category (homogeneous condition) or from distinct event-semantic categories (heterogeneous condition).

Procedure. The procedure was similar to Experiment 3, except that participants described the pictures in the same order that the director described them. This change was made to ensure that the prime and target events for a given picture always had all other pictures between them, either in the prime block (in which the experimenter described the pictures) or in the target block (in which the participants described the pictures).

Scoring and analysis. The same coding and analysis procedure was used as in the prior experiments. We tested the main effect of the prime sentences' syntactic structure on subjects' target utterances (preferred or dispreferred), the main effect of the homogeneity of each event type (datives and locatives) within a block (homogeneous or heterogeneous), and the interaction of the prime type and homogeneity.

We included the maximal random effects structure in our model (Barr et al., 2013). As random effects, we had intercepts for subjects and items, as well as by-subjects and by-items random slopes for the effect of prime type, the effect of the homogeneity condition, and the interaction between prime type and homogeneity conditions. All reported *p*-values were obtained using likelihood ratio tests by comparing the full model against the model with the fixed effect in question removed.

Results and Discussion

Subjects produced scorable responses on 90.4% of trials overall (1388 out of 1536 trials), including on 95.1% of dative trials (730 out of 768) and 85.7% of locative trials (658 out of 768).

The results of Experiment 4 are shown in Figure 5. Overall, subjects were 20.1% more likely to produce the preferred syntactic structure when primed with the preferred structure (59.9%) than when primed with the alternative (39.8%), and including prime type in the model improved the model fit ($\chi^2(1) = 25.47$, $p < .001$). The theoretically uninteresting main effect of

homogeneity did not improve model fit ($\chi^2(1) = 0.66$, $p = .41$). Most critically, there was prime type by homogeneity interaction: When an experimental block did not contain two pictures depicting the same event type (i.e., heterogeneous condition), subjects were 23.5% more likely to produce the preferred structure when primed with the preferred structure (60.9%) than when primed with the dispreferred structure (37.4%). In comparison, when an experimental block contained the two pictures depicting the same event type (i.e., in the homogeneous condition), subjects were 16.7% more likely to produce the preferred structure when primed with the preferred structure (58.8%) than when primed with the dispreferred structure (42.1%). Thus, the entrainment effect was 6.8% larger in the heterogeneous than in the homogeneous conditions; including the interaction term significantly improved our model fit ($\chi^2(1) = 6.18$, $p = .01$).

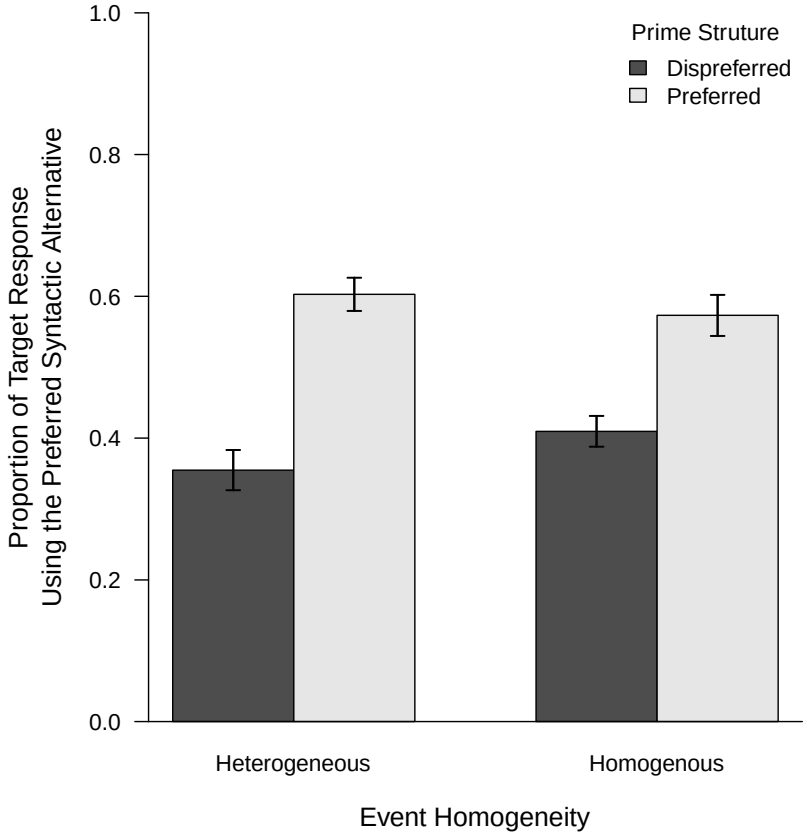

Figure 5. Proportion of preferred structure responses for target descriptions of events that were either in heterogeneous blocks (two events from different event-semantic categories) or homogeneous blocks (two events from the same event-semantic category) in Experiment 4. Error bars represent standard errors.

In Experiment 4, there was a statistically significant moderation of the entrainment effect by homogeneity. These results, which are consistent with the numerical patterns observed in Experiment 3, support the hypothesis that syntactic entrainment at least in part reflects the recalibration of the strength of associations between event-semantic features and syntactic structures.

One clear difference between the results of Experiment 3 and Experiment 4 is the overall size of the entrainment effect. In Experiment 3, speakers were overall 3.5 % more likely to use preferred syntactic structures when primed with sentences with preferred structure (6.7% in the heterogeneous condition and 0.2% in the homogeneous condition, a 6.5% difference). In comparison, in Experiment 4, speakers were overall 20.1% more likely to use preferred syntactic structures when primed with sentences with preferred syntactic structures (23.5% in the heterogeneous condition and 16.7% in the homogeneous condition, an 6.8% difference). The larger overall effect in Experiment 4 is likely due to the difference in the number of pictures used per experimental block. In Experiment 3, each block contained 12 distinct pictures (4 dative, 4 locative, and 4 transitive [filler] pictures). In Experiment 4, each block contained only 6 (2 dative, 2 locative, and 2 transitive [filler] pictures) – a change necessitated by the requirement that the items design be balanced. Thus, speakers in Experiment 4 had fewer intervening sentences between prime sentences and the target sentences, in turn implying less general interference from those intervening sentences. This is congruent with the observation that Experiment 4 yielded many more scorable responses than Experiment 3, and that the across-participant variability is smaller.

General Discussion

The four experiments reported above contribute three primary observations. First, all experiments (to varying degrees) demonstrate a basic syntactic entrainment effect: Speakers tend to describe particular scenes with the same syntactic structures that had been used to describe those scenes earlier in the experimental task. Second, syntactic entrainment was independent of whether the scenes that subjects heard described and then themselves described back were identical or were different, showing that the effect is unrelated to the stimuli used to

elicit the effect. Third, syntactic entrainment was smaller when the set of events that could be described with a particular alternation belonged to a common event-semantic category than when they belonged to distinct event-semantic categories, showing that such event-semantic categories are implicated in the representational basis of the effect.

To our knowledge, this is the first demonstration of speakers reusing syntactic structures when describing particular events. Syntactic entrainment was observed despite the fact that (in most of the experiments here) prime and target descriptions were separated by an average of 12 intervening sentences (comprehended or produced), some of which had the opposite syntactic structure.

The latter two primary observations noted above suggest that the pattern of effects observed across these experiments is unlikely to reflect simple paired associations formed between stimulus pictures and sentence-length responses. Simple paired associations between picture stimuli and sentence-length responses on the one hand should be sensitive to the similarity or dissimilarity of the picture stimuli. On the other hand, simple paired associations between picture stimuli and sentence-length responses should be insensitive to the homogeneity of event-semantic category information, because event-semantic categories are unrelated to the picture stimuli and the spoken descriptions.

Taken together, this pattern of effects is consistent with the possibility that syntactic entrainment reflects a process by which speakers develop associations between the event content expressed by sentences – and in particular, event-semantic features – and the syntactic structures used in those sentences. Specifically, we suggest that syntactic entrainment reflects a process whereby upon hearing a description (e.g., “the doctor is giving the patient pills”), language users strengthen associations between the syntactic structure of the heard description (e.g., a double

object structure) and the meaning – especially the event-semantic meaning – that is inferred from that description (e.g., an event with a doctor, a patient, pills, and successful transfer of possession). Upon subsequently describing that same meaning back (e.g., a doctor transferring pills to a patient), language users are – as a result of the strengthened association to the syntactic structure – more likely to use that syntactic structure (e.g., the double-object structure).

The suggestion that syntactic entrainment could reflect the recalibration of the strength of associations between more general types of events and syntactic structures, as indicated by the results of Experiments 3 and 4, enables the possibility that speakers can learn to express holistic aspects of events, such as successful transfer of possession (in the case of the double-object dative structure), or the fact that an action results in a container or surface being completely (rather than partially) filled with objects or covered with a substance (in the case of the *with*-variant locative structure) – meaning features we have here termed emergent properties. The fact that syntactic structures take the scope of an entire clause or sentence positions them well to convey information that relates to the event as a whole.

Of course, the direct evidence here for the possibility that syntactic entrainment reflects the learning and recalibration of the specific emergent event meanings that are expressed by particular syntactic structures (both for individual speakers and for the linguistic community in general) is limited, coming from the demonstration from Experiments 3 and 4 that event-semantic features are implicated in the effect. If indeed syntactic entrainment reflects the process by which syntactic structures become associated with the emergent properties actually expressed by natural languages, then (as outlined in the introduction) additional processing interactions must work to refine the associations between meaning and structure down to the emergent properties that languages actually exhibit (e.g., speakers must hear many double-object structures

that describe events involving successful transfer of possession). This is not an unreasonable possibility. If indeed emergent properties are conventionally expressed by specific syntactic alternatives, they will often be part of the meanings expressed by those alternatives, making them available to the association-strengthening mechanism hypothesized here.

It is worthwhile to note that the types of event-semantic features tested in Experiments 3 and 4 in fact restrict syntactic generalization. For example, the event semantic categories that involve continuous causation of accompanied motion (e.g., *pull*) and causation of ballistic motion (e.g., *throw*) at least in principle could be equally compatible with the transfer of possession meaning (though see Pinker, 1989, for a different view). However, only throw-type events permit the double-object structure ("Max threw the box to Naomi" and "Max threw Naomi the box"); pull-type events forbid double-objects ("Max pulled the box to Naomi," but *"Max pulled Naomi the box"). If the account presented here is correct, syntactic restrictions of this type come from language users' experience with events from that class. In particular, if the double-object conveys the meaning of successful transfer of possession, then when an event indeed involves successful transfer of possession, the verb used to describe that event is more likely to be used with the double-object. This implies that verbs that describe events that are more compatible with transfer of possession will be heard described with double-object structures more than verbs that describe events that are less compatible with transfer of possession.

Indeed, it is reasonable to suppose that in actual language use, throw-type events are more likely to involve transfer of possession than pull-type events, which could explain the observed pattern of syntactic restrictions. For example, throw-type events often involve sports, in which the aim of the action is often to transfer possession of a ball to a teammate, as in "the

pitcher tossed the catcher the ball," whereas pull-type events may be more likely to involve movement of heavy objects, such as furniture, to different locations where they would remain, as in, "The mover pulled the large sofa to the living room." Thus, according to the current account, we would expect the pull-type events to be less likely to be described using a double-object dative, which may lead to the learning of a restriction on the usage of the double-object with such events – which is what we observe in English. (One might speculate that if we lived in a very high gravity environment – where we would be more likely to transfer possession through the continuous causation of motion than through ballistic motion – verbs like "push" and "pull" might permit the double-object construction, whereas verbs like "throw" and "kick" might restrict the construction. Speculations such as these raise issues analogous to notions such "thinking for speaking" [Slobin, 1996], whereby message features that are grammatically encoded become habitually available for the purpose of speaking, whereas message features that are not are less so.)

Overall, in the current study, we demonstrate the novel effect of syntactic entrainment, whereby language users tend to repeat syntactic structures when describing event content heard described with those syntactic structures. The effect demonstrated here is different from the syntactic priming effect, where language users repeat syntactic structures when describing a set of event roles that were previously described with those syntactic structures. However, just as syntactic priming has been interpreted as reflecting the acquisition of knowledge of how event roles map onto syntactic structures, syntactic entrainment can be viewed as reflecting a mechanism that learns and recalibrates associations between aspects of event content – in particular, event-semantic features – and representations of syntactic structures. Due to the enduring nature of the change, which was observable after (on average) 12 intervening trials, and

the fact that it was present after only a single exposure to an event-structure pairing, we suggest that this process may reflect a basic function of language. Specifically, syntactic entrainment may reflect a first step in the process by which syntactic structures come to express emergent event properties, and then how they recalibrate across a language user's linguistic experience.

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Appendix A

Materials for all experiments. Order of stimuli corresponds to one order read to subjects. See text for other orders presented in some experiments.

Experiment 1

Alternation	List 1	List 2
Transitive	A clown is pulling a dog in a wagon	A dog in a wagon is being pulled by a clown
Locative	A man is smearing shaving cream on his face	A man is smearing his face with shaving cream
Dative	A woman is giving her prescription to a pharmacist	A woman is giving a pharmacist her prescription
Transitive	A man is being swallowed by a whale	A whale is swallowing a man
Locative	A man is packing a cooler with beers	A man is packing beers in a cooler
Dative	A stewardess is serving a man coffee	A stewardess is serving coffee to a man
Transitive	Lightning is striking a church	A church is being struck by lightning
Locative	A woman is rubbing lotion on a baby	A woman is rubbing a baby with lotion
Dative	A worker is giving lunch to a woman	A worker is giving a woman lunch

Transitive	A building is being destroyed by a wrecking ball	A wrecking ball is destroying a building
Locative	An elephant is spraying a clown with water	An elephant is spraying water on a clown
Dative	A nurse is handing a girl crutches	A nurse is handing crutches to a girl
Transitive	A tornado is destroying a barn	A barn is being destroyed by a tornado
Locative	A creepy guy is sticking needles in a voodoo doll	A creepy guy is sticking a voodoo doll with needles
Dative	A woman is tossing a beachball to a patient	A woman is tossing a patient a beachball
Transitive	A horse is being pulled by a girl	A girl is pulling a horse
Locative	A girl is smearing her toast with jam	A girl is smearing jam on her toast
Dative	A man is handing a woman a bowl of dogfood	A man is handing a bowl of dogfood to a woman
Transitive	A beachball is hitting a car	A car is being hit by a beachball
Locative	A man is splattering paint on a canvas	A man is splattering a canvas with paint
Dative	A girl is handing a paintbrush to a man	A girl is handing a man a paintbrush
Transitive	A little girl is being scared by the jack in the box	The jack in the box is scaring a little girl
Locative	Santa Claus is stuffing stockings with fruit	Santa Claus is stuffing fruit into stockings
Dative	A man is giving a little girl a gift	A man is giving a gift to a little girl
Transitive	A wine bottle is cutting a girl	A girl is being cut by a wine bottle
Locative	Men are loading toxic material on a truck	Men are loading a truck with toxic material
Dative	A woman is showing a dress to a man	A woman is showing a man a dress

Transitive	An angel is being poked by the devil	The devil is poking an angel
Locative	A man is stuffing his mouth with marshmallows	A man is stuffing marshmallows in his mouth
Dative	A waitress is offering the people drinks	A waitress is offering drinks to the people
Transitive	A bee is stinging a man	A man is being stung by a bee
Locative	Soldiers are draping a flag over a coffin	Soldiers are draping a coffin with a flag
Dative	A girl is throwing a leash to the dog	A girl is throwing the dog a leash
Transitive	A fly is being swatted by a flyswatter	A flyswatter is swatting a fly
Locative	A chef is brushing a turkey with butter	A chef is brushing butter on a turkey
Dative	A man is handing a clown a hat	A man is handing a hat to a clown
Transitive	A brown horse is chasing a white horse	A white horse is being chased by a brown horse
Locative	A woman is spritzing water on her plant	A woman is spritzing her plant with water
Dative	A librarian is handing a book to the boy	A librarian is handing the boy a book
Transitive	A woman is being kidnapped by a man	A man is kidnapping a woman
Locative	A man is spraying his plants with insecticide	A man is spraying insecticide on his plants
Dative	A doctor is giving a patient pills	A doctor is giving pills to a patient
Transitive	A car is popping a balloon	A balloon is being popped by a car
Locative	A girl is smearing paint on her face	A girl is smearing her face with paint
Dative	An old woman is giving a birthday cake to an old man	An old woman is giving an old man a birthday cake

Transitive	A golfer is being struck by lightning	Lightning is striking a golfer
Locative	A man is stuffing his drawers with clothes	A man is stuffing clothes into his drawers
Dative	A waitress is handing a man a menu	A waitress is handing a menu to a man

Experiment 2

Alternation	List 1	List 2
Transitive	The barn is being destroyed by the tornado	The tornado is destroying the barn
Locative	The elephant is spraying the clown with water	The elephant is spraying water on the clown
Dative	The man is drizzling nacho cheese on his nachos	The man is drizzling his nachos with cheese
Transitive	The woman is showing the man a dress	The woman is showing a dress to the man
Locative	The beachball is hitting the car	The car is getting hit by the beachball
Dative	The one guy is throwing the frisbee to the other guy	The one guy is throwing the other guy the frisbee
Transitive	The old woman is giving a cake to the old man	The old woman is giving the old man the cake
Locative	The clown is pulling the dog in the wagon	The dog in the wagon is being pulled by the clown
Dative	The man is smearing his face with shaving cream	The man is smearing shaving cream on his face
Transitive	The man is giving the woman a bowl of dogfood	The man is giving a bowl of dogfood to the woman

Locative	The farmer is scattering seeds in his field	The farmer is scattering his field with seeds
Dative	The little girl is being scared by the jack-in-the-box	The jack-in-the-box is scaring the little girl
Transitive	The mother is dabbing alcohol on her daughter's cut	The mother is dabbing her daughter's cut with alcohol
Locative	Lightning is striking the church	The church is being struck by lightning
Dative	The nurse is tossing the beachball to the patient	The nurse is tossing the patient the beachball
Transitive	The fly is being swatted by the fly-swatter	The fly-swatter is swatting the fly
Locative	The father is reading his daughter a book	The father is reading a book to his daughter
Dative	The woman is rubbing the baby with lotion	The woman is rubbing lotion on the baby
Transitive	Abraham Lincoln is reading the boy a book	Abraham Lincoln is reading a book to the boy
Locative	The baker is dusting the cake with powdered sugar	The baker is dusting powdered sugar on the cake
Dative	The woman is spritzing water on her plant	The woman is spritzing her plant with water
Transitive	The man is being swallowed by the whale	The whale is swallowing the man
Locative	The woman is showing the blueprints to the construction worker	The woman is showing the construction worker the blueprints
Dative	The brown horse is chasing the white horse	The white horse is being chased by the black horse
Transitive	The men are loading toxic waste onto the truck	The men are loading the truck with toxic waste
Locative	The mother is giving a glass of water to her child	The mother is giving her child a glass of water
Dative	The building is being destroyed by the wrecking ball	The wrecking-ball is destroying the building
Transitive	The woman is tossing the dog the leash	The woman is tossing the leash to the dog

Locative	The missile is destroying the plane	The plane is being destroyed by the missile
Dative	The artist is splattering his canvas with paint	The artist is splattering paint on the canvas
Transitive	The clown is giving a hat to the man	The clown is giving the man a hat
Locative	The man is packing beers into a cooler	The man is packing the cooler with beers
Dative	The broken bottle is cutting the woman	The woman is being cut by the bottle
Transitive	The man is spraying his plants with insecticide	The man is spraying insecticide on his plants
Locative	The beachball is getting popped by the car	The car is popping the beachball
Dative	The little boy is throwing the man the baseball	The little boy is throwing the baseball to the man
Transitive	The priest is reading the bible to the class	The priest is reading the class the bible
Locative	The bee is stinging the man	The man is getting stung by the bee
Dative	The man is cramming his drawers with clothes	The man is cramming clothes into his drawers
Transitive	The doctor is showing the boy the x-ray	The doctor is showing the x-ray to the boy
Locative	The girl is sprinkling salt into the soup	The girl is sprinkling the soup with salt
Dative	The golfer is being struck by lightning	Lightning is striking the golfer
Transitive	The woman is reading the children a book	The woman is reading a book to the children
Locative	The chef is brushing the turkey with butter	The chef is brushing butter onto the turkey
Dative	The devil is poking the angel	The angel is being poked by the devil
Transitive	The lawyer is showing a gun to the judge	The lawyer is showing the judge a gun

Locative	The horse is being pulled by the girl	The girl is pulling the horse
Dative	The man is stocking canned goods in his bomb shelter	The man is stocking his bomb shelter with canned goods

Experiment 3 (Note: In the interest of brevity, for Experiment 3 and 4 we are including only one set of syntactic alternatives. In the actual experiment each list had an alternate version in which the opposite syntactic alternative was used for each prime sentence. Since certain Locative sentences allow multiple prepositions (e.g., "in," "on," "into," "onto"), when an unlisted prime sentence is prepositionally ambiguous the actual preposition used is listed after the sentence. Furthermore, in the interest of clarity, stimuli items are ordered by condition. The actual order in which each prime sentence was presented to subjects is listed in the table below.)

Alternation-Condition	Stimuli Order	List 1	List 2
Dative-homogenous	5	A girl is handing a man a paintbrush	A father is reading a book to his little girl
Dative-homogenous	3	A man is giving a little girl a gift	A girl is reading a book to a little boy
Dative-homogenous	6	A man is handing a bowl of dogfood to a woman	A mother is reading her child a book
Dative-homogenous	10	A man is handing his hat to a clown	A priest is reading the class the bible
Locative-heterogenous	8	Santa Claus is stuffing fruit into stockings	The mother is dabbing her daughter's cut with alcohol (on)

Locative-heterogenous	11	A man is smearing his face with shaving cream (on)	A man is stuffing his mouth with marshmallows (into)
Locative-heterogenous	2	The dad is spraying water on his kids	Uh...God is sprinkling rain onto the people
Locative-heterogenous	12	A man is drizzling his nachos with cheese (on)	the woman is spritzing water on her plants
Filler	9	A dog in a wagon is being pulled by a clown	A dog in a wagon is being pulled by a clown
Filler	7	A wrecking ball is destroying a building	A wrecking ball is destroying a building
Filler	4	A whale is swallowing a man	A whale is swallowing a man
Filler	1	An angel is being poked by the devil	An angel is being poked by the devil
Locative-homogenous	6	A clown is cramming his shoes into a box	A chef is brushing butter on a turkey
Locative-homogenous	8	A man is packing beers in a cooler	A girl is smearing paint on her face
Locative-homogenous	12	A man is stuffing his mouth with marshmallows (into)	A man is smearing his face with shaving cream (on)
Locative-homogenous	3	Men are loading a truck with toxic waste (into)	A woman is rubbing a baby with lotion (on)
Dative-heterogenous	5	A nurse is handing a girl crutches	Abraham Lincoln is reading a book to a boy
Dative-heterogenous	4	A mother is reading a book to her child	A man is handing a bowl of dogfood to a woman

Dative-heterogenous	10	The Golden Retriever is showing his cards to the other dogs	Some guy is throwing his friend a frisbee
Dative-heterogenous	2	A little boy is throwing the man a baseball	A woman is showing a construction worker the blueprints
Filler	1	A fly is being swatted by a flyswatter	A fly is being swatted by a flyswatter
Filler	9	A bee is stinging a man	A bee is stinging a man
Filler	7	Lightning is striking a church	Lightning is striking a church
Filler	11	A girl is being cut by a wine bottle	A girl is being cut by a wine bottle
Dative-homogenous	2	A guy is showing his id to a bouncer	The quarterback is throwing the football to his receiver
Dative-homogenous	3	A nurse is showing an x-ray to the boy	A boy is throwing a baseball to a man
Dative-homogenous	9	A woman is showing a man a dress	A girl is throwing the dog a leash
Dative-homogenous	10	A woman is showing a construction worker the blueprints	A little boy is throwing the man a baseball
Locative-heterogenous	1	A woman is rubbing lotion on a baby	Men are loading a truck with toxic waste (onto)
Locative-heterogenous	11	Some guy is cramming his drawers with clothes (into)	The girl is smearing jelly on her toast
Locative-heterogenous	7	The man is scattering rose petals on the bed	The artist is splattering his canvas with paint (onto)

Locative-heterogenous	5	The bus is splashing the people with mud (on)	The farmer is scattering seeds in his field
Filler	8	The car is popping the beach ball	The car is popping the beach ball
Filler	6	The jack-in-the-box is startling the little girl	The jack-in-the-box is startling the little girl
Filler	4	The man is kidnapping the woman	The man is kidnapping the woman
Filler	12	The beachball is hitting the car	The beachball is hitting the car
Locative-homogenous	3	This guy is spraying insecticide on the plants	A baker is dusting a cake with powdered sugar (on)
Locative-homogenous	6	The elephant is spraying water onto the clown	A girl is sprinkling her soup with salt (into)
Locative-homogenous	12	The woman is spritzing her plants with water (on)	A man is drizzling cheese on his nachos
Locative-homogenous	10	the artist is splattering his canvas with paint (onto)	The man is scattering rose petals on the bed
Dative-heterogenous	11	A priest is reading the class the bible	A man is handing his hat to a clown
Dative-heterogenous	1	An old woman is giving a cake to an old man	A woman is reading some kids a book
Dative-heterogenous	8	A girl is throwing the dog a leash	A woman is showing a man a dress
Dative-heterogenous	4	The lawyer is showing a gun to the judge	A woman is tossing a beachball to a patient

Filler	2	The golfer is being struck by lightning	The golfer is being struck by lightning
Filler	5	The plane is being destroyed by a missile	The plane is being destroyed by a missile
Filler	9	The tree is destroying the house	The tree is destroying the house
Filler	7	The girl is pulling the horse	The girl is pulling the horse

Experiment 3 (continued)

Alternation-Condition	Stimuli Order	List 3	List 4
Dative-homogenous	5	A man is handing a bowl of dogfood to a woman	A mother is reading her child a book
Dative-homogenous	3	A man is handing his hat to a clown	A priest is reading the class the bible
Dative-homogenous	6	A nurse is handing a girl crutches	A woman is reading a book to some kids
Dative-homogenous	10	An old woman is giving an old man a cake	Abraham Lincoln is reading a book to a boy
Locative-heterogenous	8	A clown is cramming his shoes into a box	A girl is smearing paint on her face
Locative-heterogenous	11	A man is smearing his face with shaving cream (on)	A man is stuffing his mouth with marshmallows (into)

Locative-heterogenous	2	This guy is spraying insecticide on the plants	A girl is sprinkling her soup with salt (into)
Locative-heterogenous	12	A man is drizzling his nachos with cheese (on)	The artist is splattering paint on his canvas
Filler	9	A dog in a wagon is being pulled by a clown	A dog in a wagon is being pulled by a clown
Filler	7	A wrecking ball is destroying a building	A wrecking ball is destroying a building
Filler	4	A whale is swallowing a man	A whale is swallowing a man
Filler	1	An angel is being poked by the devil	An angel is being poked by the devil
Locative-homogenous	6	A man is stuffing his mouth with marshmallows (into)	A man is smearing his face with shaving cream (on)
Locative-homogenous	8	men are loading a truck with toxic waste (onto)	A woman is rubbing a baby with lotion (on)
Locative-homogenous	12	Santa Claus is stuffing fruit into stockings	The girl is smearing jelly on her toast
Locative-homogenous	3	Some guy is cramming clothes into his drawers	The mother is dabbing alcohol on her daughter's cut
Dative-heterogenous	5	A girl is handing a man a paintbrush	A girl is reading a book to a little boy
Dative-heterogenous	4	A mother is reading her child a book	A man is handing a bowl of dogfood to a woman
Dative-heterogenous	10	A guy is showing his id to a bouncer	A boy is throwing a man a baseball

Dative-heterogenous	2	A girl is throwing a leash to the dog	A woman is showing a man a dress
Filler	1	A fly is being swatted by a flyswatter	A fly is being swatted by a flyswatter
Filler	9	A bee is stinging a man	A bee is stinging a man
Filler	7	Lightning is striking a church	Lightning is striking a church
Filler	11	A girl is being cut by a wine bottle	A girl is being cut by a wine bottle
Dative-homogenous	2	A woman is showing a man a dress	A girl is throwing the dog a leash
Dative-homogenous	3	A woman is showing a construction worker the blueprints	A little boy is throwing the man a baseball
Dative-homogenous	9	Golden Retriever is showing his cards to the other dogs	A woman is tossing a beachball to a patient
Dative-homogenous	10	The lawyer is showing a gun to the judge, I think	Some guy is throwing a frisbee to his friend
Locative-heterogenous	1	A woman is rubbing lotion on a baby	Men are loading a truck with toxic waste (onto)
Locative-heterogenous	11	A man is packing beers in a cooler	A chef is brushing butter on a turkey
Locative-heterogenous	7	The man is scattering the bed with rose petals (on)	The woman is spritzing her plants with water (on)
Locative-heterogenous	5	The elephant is spraying the clown with water (onto)	A baker is dusting powdered sugar on a cake

Filler	8	The car is popping the beach ball	The car is popping the beach ball
Filler	6	The jack-in-the-box is startling the little girl	The jack-in-the-box is startling the little girl
Filler	4	The man is kidnapping the woman	The man is kidnapping the woman
Filler	12	The beachball is hitting the car	The beachball is hitting the car
Locative-homogenous	3	The woman is spritzing her plants with water (on)	A man is drizzling cheese on his nachos
Locative-homogenous	6	The artist is splattering his canvas with paint (onto)	The man is scattering rose petals on the bed
Locative-homogenous	12	The dad is spraying water on his kids	The farmer is scattering his field with seeds (in)
Locative-homogenous	10	The bus is splashing mud onto the people	God is sprinkling the people with rain (onto)
Dative-heterogenous	11	A priest is reading the class the bible	A man is handing a hat to a clown
Dative-heterogenous	1	A man is giving a little girl a gift	A father is reading a book to his little girl
Dative-heterogenous	8	A little boy is throwing a baseball to the man	A woman is showing a construction worker the blueprints
Dative-heterogenous	4	A nurse is showing an x-ray to the boy	The quarterback is throwing his receiver the football
Filler	2	The golfer is being struck by lightning	The golfer is being struck by lightning

Filler	5	The plane is being destroyed by a missile	The plane is being destroyed by a missile
Filler	9	The tree is destroying the house	The tree is destroying the house
Filler	7	The girl is pulling the horse	The girl is pulling the horse

Experiment 4. In the interest of clarity, stimuli items are ordered by condition. The actual order in which each prime sentence was presented to subjects was random for each participant.

Alternation	List 1	List 2
Dative-homogeneous	A girl is handing a paintbrush to a man	A nurse is handing a girl crutches
Dative-homogeneous	A man is giving a little girl a gift	An old woman is giving a cake to an old man
Locative-heterogeneous	The artist is splattering paint on his canvas	The elephant is spraying water on the clown
Locative-heterogeneous	Santa Claus is stuffing stockings with fruit (into)	A clown is cramming a box with his shoes (into)
Filler	A dog in a wagon is being pulled by a clown	A dog in a wagon is being pulled by a clown
Filler	A wrecking ball is destroying a building	A wrecking ball is destroying a building
Dative-heterogeneous	An old woman is giving a cake to an old man	A girl is handing a paintbrush to a man

Dative-heterogeneous	A father is reading his little girl a book	A girl is reading a little boy a book
Locative-homogeneous	A man is packing a cooler with beers (in)	Men are loading a truck with toxic waste (on)
Locative-homogeneous	A clown is cramming his shoes into a box	Santa Claus is stuffing fruit into stocking
Filler	A whale is swallowing a man	A whale is swallowing a man
Filler	An angel is being poked by the devil	An angel is being poked by the devil
Dative-homogeneous	A priest is reading the class the bible	A woman is reading some kids a book
Dative-homogeneous	A girl is reading a book to a little boy	A father is reading a book to his little girl
Locative-heterogeneous	The man is scattering the bed with rose petals (on)	A baker is dusting cake with powdered sugar (on)
Locative-heterogeneous	The mother is dabbing alcohol on her daughter's cut	A chef is brushing butter on a turkey
Filler	A fly is being swatted by a flyswatter	A fly is being swatted by a flyswatter

Filler	A bee is stinging a man	A bee is stinging a man
Dative-heterogeneous	A nurse is handing a girl crutches	A man is giving a little girl a gift
Dative-heterogeneous	The lawyer is showing the gun to the judge	A guy is showing his ID to a bouncer
Locative-homogeneous	A woman is rubbing a baby with lotion (on)	The girl is smearing her toast with jelly (on)
Locative-homogeneous	A chef is brushing butter on a turkey	The mother is dabbing alcohol on her daughter's cut
Filler	A girl is being cut by a wine bottle	A girl is being cut by a wine bottle
Filler	Lightning is striking a church	Lightning is striking a church
Dative-homogeneous	A nurse is showing a boy his x-ray	A woman is showing a man a dress
Dative-homogeneous	A guy is showing his ID to a bouncer	The lawyer is showing the gun to the judge
Locative-heterogeneous	The bus is splashing mud onto the people	The woman is spritzing water on her plants
Locative-heterogeneous	Men are loading a truck with toxic waste (on)	A man is packing a cooler with beers (on)

Filler	The car is popping the beach ball	The car is popping the beach ball
Filler	The jack-in-the-box is startling the little girl	The jack-in-the-box is startling the little girl
Dative-heterogeneous	Some guy is throwing a frisbee to his friend	A woman is tossing a beachball to a patient
Dative-heterogeneous	A woman is showing a man a dress	A nurse is showing a boy his x-ray
Locative-homogeneous	The elephant is spraying water on the clown	The artist is splattering paint on his canvas
Locative-homogeneous	The woman is spritzing her plants with water (on)	The bus is splashing the people with mud (onto)
Filler	The man is kidnapping the woman	The man is kidnapping the woman
Filler	The beachball is hitting the car	The beachball is hitting the car
Dative-homogeneous	The quarterback is throwing the football to his receiver	A boy is throwing a baseball to a man
Dative-homogeneous	A woman is tossing a patient a beachball	Some guy is throwing his friend a frisbee

Locative-heterogeneous	A man is drizzling his nachos with cheese (on)	A girl is sprinkling her soup with salt (on)
Locative-heterogeneous	The girl is smearing jelly on her toast	A woman is rubbing lotion on a baby
Filler	The golfer is being struck by lightning	The golfer is being struck by lightning
Filler	The plane is being destroyed by a missile	The plane is being destroyed by a missile
Dative-heterogeneous	A woman is reading some kids a book	A priest is reading the class the bible
Dative-heterogeneous	A boy is throwing a baseball to a man	The quarterback is throwing the football to his receiver
Locative-homogeneous	A baker is dusting powdered sugar on a cake	The man is scattering rose petals on the bed
Locative-homogeneous	A girl is sprinkling her soup with salt (on)	A man is drizzling his nachos with cheese (on)
Filler	The girl is pulling the horse	The girl is pulling the horse
Filler	The tree is destroying the house	The tree is destroying the house

Appendix B

This appendix lists all the outputs of the mixed effects model used in each experiment. In all experiments, the categorical factors were converted to numerical variables and centered, to test the significance of main effects using maximum likelihood ratio tests. Throughout, when coding PrimeType, *dispreferred* was assigned -0.5, and *preferred* 0.5. As for the dependent variable, preferred structure was coded as 1 and dispreferred structure was coded as 0 in all experiments.

Experiment 1

In Experiment 1, the by-subject random slope of PrimeType, which accounted for the least amount of variance, was removed due to the convergence failure of the full model. Below is the output of the final model in Experiment 1. When coding the factor verb class, *locative* was assigned -0.5, *dative* 0.5, and *transitive* 0 in the first comparison (Locative vs. Dative). In the second comparison (Locative vs. Transitive), *locative* was assigned -0.5, *transitive* 0.5, and *dative* 0.

Fixed effects:

Term	*Estimate*	*SE*	$\|z\|$
Intercept	0.94	0.34	2.77
Prime Type	-1.18	0.28	4.25
Verb Class (Locative vs. Dative)	-1.19	0.85	1.40
Verb Class (Locative vs. Transitive)	-0.49	0.87	0.56
Prime Type x Verb Class (Locative vs. Dative)	0.69	0.71	0.97
Prime Type x Verb Class (Locative vs. Transitive)	0.41	0.70	0.59

Random effects:

Term	*Variance*	*Standard deviation*	*Correlation*
Subject intercept	0.90	0.95	
Verb Class (Locative vs. Dative)	4.10	2.03	0.91
Verb Class (Locative vs. Transitive)	5.21	2.28	-0.69, -0.55
Prime Type x Verb Class (Locative vs. Dative)	0.63	0.79	-0.49, -0.31, 0.97
Prime Type x Verb Class (Locative vs. Transitive)	1.21	1.10	0.69, 0.50, -0.99, -0.97
Item intercept	2.47	1.57	
Prime Type	0.42	0.65	-0.44

Experiment 2

Below is the output of the final model in Experiment 2. When coding the factor Event Depiction, *same* was assigned -0.5 and *different* 0.5. When coding the factor PrimeType, *dispreferred* was assigned -0.5 and *preferred* 0.5.

Fixed effects:

Term	*Estimate*	*SE*	$\|z\|$
Intercept	1.40	0.28	4.91
Prime Type	1.13	0.21	5.43
Event Depiction	-0.32	0.19	1.69
Prime Type x Event Depiction	-0.11	0.37	0.30

Random effects:

Term	*Variance*	*Standard deviation*	*Correlation*

Subject intercept	0.39	0.63	
Prime Type	0.06	0.24	-0.33
Event Depiction	0.03	0.18	0.77, -0.86
Prime Type x Event Depiction	0.21	0.46	-0.91, -0.10, -0.43
Item intercept	2.98	1.73	
Prime Type	0.44	0.67	0.89
Event Depiction	0.13	0.36	-0.33, -0.34
Prime Type x Event Depiction	0.34	0.58	-0.05, 0.06, 0.91

Experiment 3

Below is the output of the final model in Experiment 3. When coding the factor Homogeneity, *homogeneous* was assigned -0.5 and *heterogeneous* 0.5. When coding the factor PrimeType, *dispreferred* was assigned -0.5 and *preferred* 0.5.

Fixed effects:

Term	*Estimate*	*SE*	*|z|*
Intercept	1.81	0.35	5.25
Prime Type	0.30	0.29	1.03
Homogeneity	0.56	0.37	1.54
Prime Type x Homogeneity	0.28	0.54	0.52

Random effects:

Term	*Variance*	*Standard deviation*	*Correlation*
Subject intercept	2.19	1.48	
Prime Type	0.18	0.42	-0.50

Homogeneity	1.50	1.22	0.16, -0.94
Prime Type x Homogeneity	0.08	0.28	0.10, 0.81, -0.97
Item intercept	2.37	1.54	
Prime Type	0.36	0.60	0.10
Homogeneity	1.23	1.11	0.61, -0.72
Prime Type x Homogeneity	0.27	0.52	-0.74, 0.59, -0.98

Experiment 4

Below is the output of the final model in Experiment 4. When coding the factor Homogeneity, *homogeneous* was assigned -0.5 and *heterogeneous* 0.5. When coding the factor PrimeType, *dispreferred* was assigned -0.5 and *preferred* 0.5.

Fixed effects:

Term	*Estimate*	*SE*	*|z|*
Intercept	-0.09	0.24	0.70
Prime Type	1.26	0.23	5.61
Homogeneity	-0.14	0.17	-0.83
Prime Type x Homogeneity	0.81	0.32	2.52

Random effects:

Term	*Variance*	*Standard deviation*	*Correlation*
Subject intercept	0.14	0.38	
Prime Type	0.65	0.81	-0.07
Homogeneity	0.16	0.39	0.36, -0.82
Prime Type x Homogeneity	0.08	0.20	0.77, 0.57, -0.17

Item intercept	1.54	1.24	
Prime Type	0.54	0.74	-0.07
Homogeneity	0.25	0.50	0.93, 0.26
Prime Type x Homogeneity	0.76	0.87	-0.16, 0.83, 0.22

Appendix C

Event semantic classes used in Experiment 3 and 4:

Dative events (categories adapted from Gropen et al., 1989):

1. Verbs that inherently signify acts of giving (e.g., *give, hand*)
2. Verbs of instantaneous causation of ballistic motion (e.g., *throw, toss*)
3. Verbs of type of communicated message, *Tell-variety* (e.g., *read*)*
4. Verbs of type of communicated message, *Show-variety* (e.g., show)*

Locative events (categories adapted from Pinker, 1989):

1. Simultaneous forceful contact and motion of a mass against a surface (e.g., *slather, spread, smear, rub, brush, dab*)
2. Force is imparted to a mass, causing ballistic motion in a specified spatial distribution along a trajectory (e.g., *spray, spritz, splash*)
3. A mass is forced into a container against the limits of its capacity (e.g., *load, pack, cram, stuff*)
4. Mass is caused to move in a widespread or nondirected distribution (e.g., *scatter, sprinkle, dust*)

*Note that according to Pinker, 1989, both varieties of communicated message would be categorized in the same narrow conflation class. However, there is no objective standard by which to judge whether two types of events with the same syntactic restrictions ought to be

categorized in the same or different classes. In our materials these events seemed better suited to separate categories, and we therefore categorized them as such.