

Constructional sources of implicit agents in sentence comprehension

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Abstract

Much research about on-line sentence comprehension focuses on the contributions of individual lexical items, with specific interest in verbs. One aspect of sentence meaning that has been claimed to be rooted in verb representation is event structure. There is a growing body of evidence supporting the claim that the verb is not the sole contributor of event structure, but that the syntactic construction of a sentence is also a contributor. In this paper, we repeat a study designed to support a verb-based view using novel verbs derived from nouns. The pattern of sentence comprehension is the same for both known verbs and novel verbs, suggesting that the syntactic construction of the sentence also contributes to event structure.

Keywords: Construction Grammar; event structure; novel denominal verbs.

1. Event structure

One primary function of sentences is to describe events and situations (Jackendoff 2002). Within a sentence, the event structure is the “who does what to whom” aspect of meaning. The event structure of a sentence is composed of the participants (or arguments) of the event and how they relate, e.g., an agent acting on a patient. Two different accounts for the source of event structure, i.e., what types of representations contribute to

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the composition of a sentence's event structure, have been proposed. The "lexical" account is that the sentence's event structure is built entirely from the event structures of its words, with verbs as the major contributor (e.g., Pustejovsky 1991; Levin and Rappaport Hovav 2005). The "constructional" account is that the grammatical construction itself contributes event structure independently of any of the particular words that make up the sentence (e.g., Goldberg 1995; Croft 2001; Fillmore, Kay, Michaelis, and Sag forthcoming).

In this paper, we focus on the contributions of verbs and constructions in the event structure of sentences. To put our work in perspective, we start with a review of theories and data for the lexical and constructional views of event structure. Then, we present data from a study using novel verbs to examine the influence of constructions on event structure.

Before describing lexical and constructional approaches, we should make a few things clear. Both "lexical" and "constructional" approaches are heterogeneous, i.e., there are many lexical and constructional approaches. However, there is enough commonality to afford this classification. This paper compares the two classes of approaches by focusing on some of the basic principles that underlie all lexical and constructional theories. For lexical accounts: that meaning is entirely composed from lexical meanings and the rules to combine them. For constructional accounts: whether words and constructions share the burden. For completeness, some of the within class differences will be discussed, but it is not a goal of the paper to argue for a particular framework within either class.

We also want to make clear that these frameworks have goals beyond accounting for event structure. Many of these theories seek to specify our knowledge of language in entirety (e.g., Sign-based Construction Grammar Fillmore et al. forthcoming), and so they address aspects of meaning from the highest-levels (e.g., presupposition and implicature) on down. We focus on event structure because it has been a particular point of contention between the approaches (e.g., Goldberg 2006) and, as in the current studies, has been the subject of psycholinguistic experimentation (e.g., Kaschak and Glenberg 2000; Maunder and Koenig 2000).

1.1. *Lexical approaches to event structure*

We start with a discussion of lexical views of event structure. Again, there are many lexical frameworks (such as HPSG (Pollard and Sag 1994), LFG (Kaplan and Bresnan 1982), CCG (Steedman 2000)). What they all share is a commitment to lexical-based compositionality of meaning. The meaning of utterances is built up entirely from words and morphemes. To describe the lexical position, we mainly focus on work along

the lines of Rappaport-Hovav and Levin (1998) and Jackendoff (1990), which have been called “Projectionist” accounts of event structure.

Linguistic analyses suggest that a verb’s meaning is decomposable, and that the components predict the verb’s syntactic behavior (Jackendoff 1990). Furthermore, verbs can be classified by the semantic components and syntactic behavior they share (Levin 1993). For example, in general, verbs that share the semantic component *become* (which specifies a change of state for one of the participants) can appear in the “middle construction”. The middle construction is composed of a simple intransitive sentence, with a patient as subject plus an adverb.

- (1) *The bread sliced easily.*
- (2) *The ice melted quickly.*

These event structures can be read as: The patient (e.g., *bread* and *ice*) comes to be in the state specified by the verb. All of the verbs of this class share this event structure; they differ in what state they specify.

These verbs can also appear in the passive, where the agent is conceptually evoked, but it is optional in the syntax (see Langacker 1991 for detailed discussion). The general form of the sentence structure is shown in (5). The adverb is also optional, but is shown here to match the middle construction.

- (3) *The bread was sliced easily (by the knife).*
- (4) *The ice was melted quickly (by the heat).*
- (5) The X was Y-ed Z-ly (by W)

This event structure can be interpreted as: The agent acts causing the patient, to come to be in the state specified by the verb. In (3) and (4), the events to which the verbs refer have a different structure than the events in (1) and (2).

Theories that assume the entire event structure comes from the verb must further assume that verbs have multiple event structures. According to at least one account, these event structures are not stored separately from the rest of the semantic representation, but rather are an intrinsic piece of the semantic representation (Jackendoff 2002). On this view, a verb with two event structures has two semantic representations. Two semantic representations means that the verbs are polysemous, and according to the psycholinguistic experimentation on this topic, polysemous words have separate storage in the lexicon, such that different senses of the same word are actually different lexical items (Klein and Murphy 2001, however this is a controversial issue in theoretical linguistics see Cruse 1986; Raven and Leacock 2000; Sweester 1990 among many others). Lexical accounts often posit a different stored item for each

syntactic form in which a verb appears (Pinker 1989; Stevenson and Merlo 1997). We are unaware of any independent experimental evidence supporting separate storage of verbs that participate in multiple event structures, and there is some experimental evidence against it (McKoon and MacFarland 2002).¹

1.2. *Constructional approaches to event structure*

Construction Grammar (CxG) takes a different approach to the composition of meaning (Goldberg 1995; Croft 2001; Fillmore et al. forthcoming). In CxG, every stored piece of language is a pairing of form and meaning, from individual morphemes to full clauses. Phrase- and clause-sized pieces of meaning unify with word meaning in a parallel constraint satisfaction process (e.g., Fillmore et al. forthcoming).

Support for CxG often comes from analyzing somewhat idiomatic constructions, e.g., the “What’s X doing Y?” construction, whose meaning is not entirely decomposable to the meaning of its constituent words (Kay and Fillmore 1999). In the late summer of 2008, one could have asked (6)

(6) *What’s Manny Ramirez doing in a Dodger’s Uniform?*

This speaker was not asking about the activity being performed, (the most likely answer being “playing baseball”), but instead commenting on the unexpected nature of the current state of affairs, as Ramirez had spent the previous seven and a half seasons with the Red Sox. CxG takes as its justification these “more than the sum of their parts” constructions, but then takes the principles behind their composition and transfers them

1. There are further distinctions among approaches to verb meaning that can be made. For example, the Projectionist approach, can be contrasted with the Frame Semantics approach (e.g., Fillmore 1985, Nemoto 2005). The projectionist approach is particularly interested in how a verb’s meaning predicts its syntactic behavior. Thus creating “semantic” classes of verbs is largely driven by their syntactic realization. This is somewhat problematic because, for example, it doesn’t allow *carve* and *slash* to be grouped with *slice*, as they have different distributional properties, but intuitively similar meanings. This focus on syntactic patterning creates large classes, resulting in a rather rough semantic representation, with abstract thematic roles, e.g., agents, patients, and themes.

In contrast, Frame Semantics defines frames with much more specific thematic roles called *frame elements*. For example, in the *Communication* frame, there are roles for the communicator, addressee, and message. Often, when predicting the syntactic realization of these frame elements, it is useful to see how they become construed as members of the more abstract syntactic categories of agent, recipient and theme respectively (c.f., Nemoto, 2005, and below).

In this paper, we are agnostic between these approaches. When we use the term “event structure”, this should not be interpreted as a preference for syntax-based semantic classification over the Frame Semantic, or any other similar approach.

to the more “regular” constructions. This allows for a single system to account for all of grammar. If one started with the regular constructions, as generative grammar does (e.g., Chomsky 1965), then there is no account for the irregular.

The arguments for constructional accounts of event structure stem from the same sort of non-decomposable-meaning evidence. The basic claim is that the construction can add arguments to a sentence that are not directly licensed by the verb. The role of the construction and its ability to contribute arguments can be seen in examples (7) and (8) (from Goldberg 1995).

- (7) *John sneezed the foam off the coffee.* (*Sneeze* assumes the meaning of the *Caused-Motion* construction)
 (8) *Bob baked his mother a pie.* (*Bake* assumes the change of possession aspect of the *Ditransitive* construction’s meaning)²

Sentence 7 is a novel use of the verb *sneeze*. The first time that this use of the verb is encountered, there must be some information that allows it to be understood. In some cases, of course, language can be connected to specific events in the environment. However, in the absence of this direct grounding, some constructional source of event structure must be available to allow readers to comprehend novel uses of verbs.

One advantage of this approach is that it can ease some burdens that would be put onto verbal polysemy. We need not posit there is a sense of *bake* that means: bake with the intention to give the product to somebody else. This is not to say that construction based event structure gets rid of the need for verbal polysemy altogether. In fact, one area where different CxG approaches have differed is in how much of the event structure burden is given to fine-grained verb meaning differences and how much is attributed to the construction (e.g., Boas 2008; Croft 2003; Iwata 2005; Nemoto 2005). What all CxG approaches have in common is the ability for constructions to contribute event structure to an utterance in addition to the arguments contributed by the verb, and that is what is critical for the current experiments, but as this is an active place in CxG research it is worth briefly discussing the issues here.

Goldberg (1995) was the first to discuss constructional event structure, and the ability for the construction to add arguments, previously thought to be the job solely of lexical predicates. In that original work, verb meaning was de-emphasized, polysemy all but eliminated, and the construction’s status was elevated greatly. However, in more recent work, it has

2. Here, the transfer of possession is intentional; his mother doesn’t have to receive the pie. See further discussion below.

become clearer that the interaction of the two is more nuanced. One stream of this work explores how constructions themselves range in specificity of meaning (e.g., Boas 2008). For example, with the ditransitive, there appear to be subtypes that are verb-class specific (Croft 2003, building on Goldberg's 1995 notion of "constructional polysemy", also see Kay 2005 for another analysis). At its most abstract, the ditransitive's meaning is that of transfer of possession. As already seen in (8), there is a sub-variety that only specifies the intent to transfer possession. Verbs like *cost*, and *deny*, are used in a sub-type that prevents the transfer of possession (see Croft 2003 for the other verb-class-specific variants).

(9) *The lousy interview cost Fred the job.*

Other work has shown that one needs to pay attention to subtle verb meaning differences and verbal polysemy to account for the complete patterning of the locative alternation. Nemoto (2005; see also Iwata 2004) discusses the different meanings of the constructions making up the locative alternation, and then focuses on individual verb sense meanings to predict which verb can unify with which construction. Importantly, this approach better accounts for the pattern than Goldberg's (1995) original analysis, which aimed to eliminate verbal polysemy as an explanation.

The big picture painted by papers on CxG is that there are constructions at different levels of specificity and each level has its own implications for unifying with verbs (e.g., Boas 2008; Croft, 2003; Fried and Östman 2004; Langacker 2000). For the most part, CxG is a usage-based theory (c.f., Fillmore et al. forthcoming). Usage-based theories view constructions as schemas generalized across utterances, taking language development data as an inspiration (e.g. Tomasello 2000). These generalizations are potentially stored at many different levels of granularity simultaneously (e.g., from verb-sense-specific constructions, to verb-specific, to verb class-specific to verb general). With this in mind, we can return to the motivation for the current experiments.

The experiments in this paper contrast the middle and passive constructions. As we discussed, the class of verbs that appear in the middle construction is associated with the meaning that a patient comes to be in some state specified by the verb. Because a construction's meaning is a generalization over its exemplar utterances, the middle construction itself evokes the same *change-of-state* meaning.³ When this class of verbs' ap-

3. If this characterization of this class of verbs is incorrect however, then correspondingly, this would be an incorrect characterization of the construction. For example, the Frame Semantic approach to verb meaning (e.g., Fillmore 1985) might classify these verbs in a different way, and thus this alternate classification may be more applicable to the construction.

pears in the passive, these utterances are associated with the same event structure, but with the additional element of an agent acting on the patient causing it to change state. Thus, the passive construction itself evokes a conceptualization of the event with an agent while the middle does not. To use Langacker's (1991) terms, the agent is part of the *profiled* relationship expressed in the passive, but is not by the middle.

Now to finish motivating the current studies, we review a few psycholinguistic experiments on event structure.

1.3. *Experimental investigations of event structure*

We focus this discussion on research by Mauener and Koenig (2000) because it is framed as support for a lexical account of event structure, but their data do not rule out a constructional account. The goal of our study is to determine whether their results reflect lexical or constructional event structure.⁴ The goal of Mauener and Koenig's investigation was to contrast the differences between linguistically evoking an agent as part of the profiled relation of an event (what they called, "linguistically encoding" the agent) and just having "world knowledge" of the agent. In the first experiment, subjects judged both (10) and (11) as nonsensical. To match the sentences, an auxiliary verb was included in the middle construction, and an adverb was included in the passive.

(10) *The clocks had sold quickly, but no one sold them.*

(11) *The clocks were sold quickly, but no one sold them.*

Neither (10) nor (11) explicitly mention that there is an agent of the selling, but one's knowledge of selling events includes an agent leading to both being judged non-sensical. Mauener and Koenig hypothesize that (11)'s matrix clause evokes a conceptualization where the agent is present while (10)'s does not. Importantly, in this off-line judgment, it is one's world knowledge that is the cause of the nonsense judgment. A second on-line task reveals their hypothesized difference in the evoked conceptualization or profiled relationship rooted in the same world knowledge.

In their framework, the event structure of passive verbs evokes an agent (which can remain implicit, i.e., not syntactically realized); while the middle forms of the verbs do not. They argue that (12) is grammatical while (13) is not because the infinitive clause they share needs an agent to be comprehended, and only (12) evokes the agent who is raising some money for charity.

4. See Koenig, Mauener, and Bienvenue (2003) for work in the same theoretical framework that is uncontroversial evidence of verb based event structure.

- (12) *The antique clocks were sold easily to raise some money for charity.*
 (13) **The antique clocks had sold easily to raise some money for charity.*

Maurer and Koenig asked subjects to read the entire first clause and judge its sensibility. After the judgment, the rest of the sentence was presented one word at a time. After each word subjects pressed one button if the sentence continued to make sense, and another if it did not. If the sentence was judged as nonsense then the trial was ended and the main clause of a new sentence was presented. They predicted that subjects would judge a sentence as nonsense within the first four words of the infinitive clause if no agent was evoked in the main clause. In the examples above, the critical region is *to raise some money* because it is this action that needs the agent. The critical region of each sentence had the form of *to*, a verb, a modifier, and a noun. Subjects judged significantly more sentences to be nonsensical at the verb and the noun in the critical region when they had middle first clauses than when they were passive.

Maurer and Koenig (2000) suggested that the differences between the two sentence types are rooted in differences in verb representation. These data do not rule out a constructional account. There is evidence that the verb contributes the same event structure each time it is processed (McKoon and MacFarland 2002). If the same verb-based event structure is processed every time the verb is, and Maurer and Koenig find differences in the evoking of an agent across different uses of the same verb, then something besides the verb must be accounting for that difference. We think the most likely source of this difference is the varying construction based event structures.⁵

In this paper, we aim to demonstrate that the results of Maurer and Koenig reflect constructional event structure. To do so, we adapt a method used by Kaschak and Glenberg (2000) to provide experimental evidence for constructional event structure.⁶ Kaschak and Glenberg had subjects interpret sentences with novel denominal verbs in different constructions. A denominal verb is a verb derived from a noun. For example, the website *google.com* becomes the verb *to google*, meaning to look up something on the web using the website. The logic of their experiment was that any difference in interpretation of the novel denominal verbs was completely due to the constructional event structure, because a verb does not already have an event structure when it is used for the first time.

5. Of course, it is still possible that constructions can provide event structure independently of the verb and verbs can have multiple event structure representations.

6. For a review of experimental evidence for Construction Grammar see Goldberg and Bencini (2005).

To achieve this goal, Kaschak and Glenberg came up with novel uses of objects, so that people could not just infer that the object was being used for its typical purpose. For example, crutches are typically used to help people with leg injuries, but Kaschak and Glenberg created the denominal verb in sentences like these

- (14) *Lyn crutched Tom her apple to prove her point.*
 (15) *Lyn crutched the apple to prove her point to Tom.*

Consistent with a constructional approach, the majority of subjects given (14) interpreted it consistently with the hypothesis that the dative construction carries a meaning of transfer of possession. They assumed that *Lyn transferred the apple to Tom using the crutch*. This interpretation was significantly less frequent for (15), because this syntactic frame is not strongly associated with a transfer of possession meaning.

We bring together Mauner and Koenig's (2000) paradigm with Kaschak and Glenberg's (2000) insights to study the role of constructions in the interpretation of novel denominal verbs in an on-line comprehension task. We replicate Mauner and Koenig's (2000) technique with sentences containing novel denominal verbs. This task is considered a measure of on-line comprehension because the judgments are made while the representation of the sentence is being constructed, and the judgments are speeded taking under 700 ms on average throughout the purpose clause, as opposed to Kaschak and Glenberg's task, in which participants gave an untimed interpretation after reading the whole sentence.

To adapt Mauner and Koenig's study, we generated novel denominal verbs that involve a change of state (Levin 1993). We selected nouns that specify products that require a change of state to produce. For example, *sauce* is made from a fruit or vegetable (e.g., a tomato). So, the denominal verb *to sauce*, would refer to the process of turning the item into a sauce. To facilitate the interpretation of these novel verbs in the study, we introduced each novel verb in a passage that highlighted the change of state. The passages all ended with a novel denominal verb in the middle construction. Subjects were then asked of the meaning of the sentence with the novel denominal verb. This test was used to ensure that subjects understood the intended meaning. Only one answer was plausible. For example,

Anthony and Joey work at an Italian restaurant. They were having a discussion about how to make the best marinara sauce. Anthony says "I need the ripest and freshest tomatoes. They taste the best and they are the best to work with". He then points to a bushel of tomatoes and says, "Those tomatoes sauce easily".

What does the underlined sentence mean?

- A) Sauce is easily made from those tomatoes.
- B) Tomatoes grow all over the world.

In the second phase of the study, subjects interpreted a series of sentences using Mauner and Koenig's method. In addition to the sentences with novel denominal verbs, we also included the original stimuli from Mauner and Koenig (2000) to replicate their effects. If constructions provide event structure independently from the verb then sentences with novel denominal verbs (e.g., (16) and (17)) will show the same pattern of sensicality judgments exhibited by Mauner and Koenig's original stimuli.

- (16) **The ripe tomatoes had sauced well to complement the pasta at the gala dinner.*
- (17) *The ripe tomatoes were sauced well to complement the pasta at the gala dinner.*

One potential limitation of this design is that we introduce the novel denominal verb once before the critical test sentence. Thus, we do not know whether a novel verb gets an event structure that becomes part of its lexical meaning after this initial presentation. To distinguish between the possibilities that the differing constructional event structure of the matrix clause causes the difference in interpretation during the purpose clause, or whether the difference in the purpose clause is based in a lexical representation of the novel verb instantiated during the training phase, we present a second version of this study in which participants read the test sentences without the introductory passages. We included the passages in the first version of the study to prevent subjects from rejecting the main clause of the sentence as nonsensical. If sentences with novel verbs get their event structure from constructional semantics, then we expect the same pattern of results for both versions of the study, except that more sentences with denominal verbs may be rejected as nonsensical when the main clause is presented when there is no introductory passage than when there is an introductory passage.

Before presenting the experiment, we summarize our logic and claims. Mauner and Koenig (2000) found that verbs in passive sentences were less likely to evoke an agent than were verbs in middle constructions. Mauner and Koenig claim that this difference is rooted in the verb's representation (i.e., the verb has multiple event structure representations). Kaschak and Glenberg (2000) showed, through the interpretation of novel verbs, that a construction has the ability to contribute arguments to the event structure of a sentence. Novel verbs do not have a pre-existing

event structure, so the construction must be the source of any observed differences between the interpretations of the same novel verbs across different grammatical structures. We extend this construction-based explanation to Mauner and Koenig's paradigm by replicating their study with novel verbs. We are not advocating any particular view of construction grammar or any particular view of event structure or the representation of semantic roles. What our experiments support is the claim that constructions can contribute arguments to a sentence and therefore that lexically-based theories of the composition of meaning are incomplete.

2. Methods

2.1. Participants

Forty English-speaking undergraduates from the University of Texas participated in this experiment for partial course credit. Thirty-seven participated in the replication.

2.2. Materials

The materials included a packet of short passages that made the intended meaning of the novel denominal verbs apparent (see Appendix A). During the main task, 14 sets of sentence pairs (similar to the pair shown in 16 and 17) were included (see Appendix B). Every sentence contained a novel denominal verb in the matrix clause, followed by a purpose clause, matching the structure of the sentences from Mauner and Koenig. Each sentence in the pair differed in the construction of the matrix clause; one was in the middle construction, the other the passive. This difference was marked by differing auxiliary verbs. The purpose clause was identical for both sentences in the pair. Separate lists were made with one of each pair in each list, counterbalanced across participants. Also, the 14 pairs from Mauner and Koenig (2000) Experiment 2 were used (see Appendix B).

These 28 experimental items were intermixed with 42 filler sentences. Twelve of the filler sentences were designed to be nonsensical. Following Mauner and Koenig, the filler sentences shared features with the critical trials to ensure that subjects could not develop a special strategy to respond to experimental trials. To prevent participants from making judgments based on the auxiliary verb alone, some of the fillers were passive sentences that contained the auxiliary *have*. Other fillers contained *was/were*, but did not introduce an implicit agent. Sentences with infinitive clauses in various sentence positions were also used as fillers.

The replication had slightly different materials. First, the packet of short passages was not used. Second, a few of the adverbs for the items with the novel denominal verbs were changed. The adverbs *carefully* and *expertly* that were used in a few items in the first version of the study require an agent, so those were changed for the replication (see Appendix B). Because this change did not significantly influence the results, we do not discuss it further.

2.3. Procedure

Participants were tested individually, seated in front of a computer. Before using the computer they read 14 short passages, one for each novel denominal verb. They were asked a multiple choice question about the meaning of the novel denominal verb; there was only one plausible answer to ensure that subjects understood the intended meaning. The passages were included to ensure that subjects would be able to make rapid semantic judgments in the main phase of the experiment. The replication did not have this phase.

The main phase used the program *SuperLab* on a Dell PC. The sentences were presented as in Mauner and Koenig (2000) Experiment 2, and as described in the introduction. Participants read the entire first clause and judged its sensicality as sensical or nonsensical. The rest of the sentence had dashes in place of words. After the judgment, the rest of the sentence was presented one word replacing the dashes at a time. After each word, participants pressed the “1” button if the sentence continued to make sense, and the “2” button if it did not. The filler sentences were displayed in the same way. The entire first clause was presented at once because some verbs need the adverb to have the proper reading in the middle construction. Many sentences could have been prematurely called nonsensical at the main verb if the entire sentence was presented one word at a time.

Participants were instructed to read the sentences quickly, but at a natural rate, and to make their sensicality judgments as quickly as possible without sacrificing their accuracy. They were given examples of sentences that did not make sense. Then, they had 8 practice trials before the main phase. This procedure differed from Mauner and Koenig’s only in that participants continued to judge sentences until their completion even if they judged them nonsensical. During scoring, the important measure was when they first judged a sentence as nonsense, later judgments were ignored to keep analysis consistent with Mauner and Koenig (2000). Despite this departure from Mauner and Koenig’s procedure, we were still able to replicate their findings.

3. Results

3.1. Scoring procedure

We adopted the scoring procedure from Mauner and Koenig (2000) Experiment 2. At each word position in the sentence, we calculated the percentage of sentences that were judged as nonsense, for the *first time*. If we used the cumulative percentage, i.e., the percentage of sentences that had been judged as nonsense up until and including that sentence region, then there would be an “end of sentence” bias. To evaluate changes in judgments across the main clause and the critical region of the purpose clause, we transformed data into adjusted percentages that reflected the number of remaining possibilities of responding “nonsense” at the main clause, and at each word position in the critical region. We adopted this procedure to minimize the problem of using either the raw number or cumulative percentages for which the value at any given word position would be correlated with the value at preceding word positions. For each participant, percentages of remaining nonsense responses were calculated at each word position by dividing the number of “nonsense” responses obtained at a given position by the remaining number of opportunities to respond “nonsense” at that position. The remaining number of opportunities to respond “nonsense” at each position was determined by subtracting the total number of “nonsense” responses of all previous word positions from 7, because 7 was the total number of opportunities to respond “nonsense” in each sentence condition.⁷ A similar procedure was followed to adjust percentages for the analysis by items across participants.

3.2. Analysis

Figures 1a and 1b show the adjusted proportion of sentences judged as nonsensical for the familiar and novel verbs respectively. Adjusted percentages of “nonsense” responses for each of Mauner and Koenig’s stimuli with familiar verbs and for the novel verbs were submitted to a 2 (List) \times 2 (Construction) \times 5 (Region/Word position) ANOVAs. All data were analyzed by subject and by item. The analysis of the familiar verbs yielded significant main effects of construction, $F(1, 38) = 48.1$, $p < .001$ by participants, $F(1, 13) = 54.234$, $p < .001$ by items, and of region/word position, $F(4, 35) = 7.01$, $p < .001$ by participants, $F(4, 10) = 11.711$, $p = .001$ by items. There was also a significant interaction of

7. There were 14 sentences taken from Mauner and Koenig (2000) and 14 that included the novel denominal verbs, so that is 7 of each in each construction.

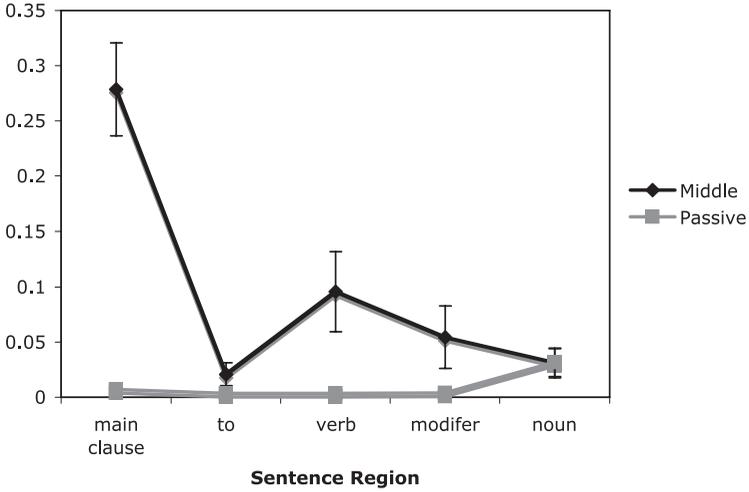


Figure 1a. Participant means and standard errors of adjusted percentages of nonsense judgments_for_familiar_verbs

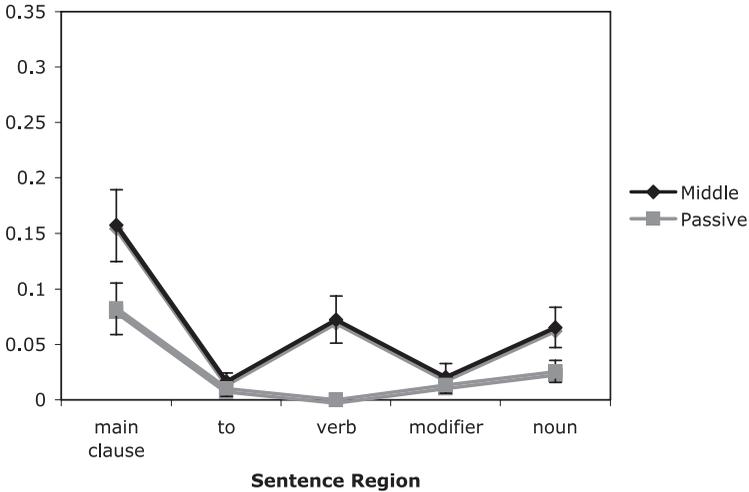


Figure 1b. Participant means and standard errors of adjusted percentages of nonsense judgments_for_novel_verbs

construction X region/word position, $F(4, 35) = 8.95$, $p < .01$, by participants, $F(4, 10) = 7.741$, $p = .004$ by items.

We then carried out planned comparisons of the specific sentence regions in the two constructions. Maurer and Koenig found significant dif-

ferences at the main clause, at the verb in the critical region, and at the noun in the critical region. As can be seen in Figure 1a, we replicated their differences at the main clause, $t(39) = 6.54$ $p < .001$, by participants, $t(13) = 6.47$ $p < .001$ by items, and at the verb, $t(39) = 2.50$ $p < .02$, by participants, $t(13) = 2.82$ $p < .015$ by items.⁸ The results are not identical to those of Mauner and Koenig in their fine details. However, they did not predict the specific word position within the clause where the difference would emerge, only that it would emerge somewhere in the region. The analysis of the novel verbs revealed a similar pattern.

There were significant main effects of construction, $F(1, 38) = 23.07$, $p < .001$ by participants, $F(1, 13) = 6.52$, $p < .025$ by items, and of region/word position, $F(4, 35) = 5.70$, $p = .001$ by participants, $F(4, 10) = 11.916$, $p = .001$ by items. Once again, the individual comparisons of word positions are what is most important, and can be seen in Figure 1b. With the novel verbs, Mauner and Koenig's pattern was replicated, with significant differences found at the main clause, $t(39) = 2.82$, $p < .01$ by participants, but not items $t(13) = 1.89$, $p = .08$, at the verb in the critical region, $t(39) = 3.40$, $p = .002$, $t(13) = 2.52$, $p = .025$ and at the noun in the critical region, $t(39) = 2.05$, $p < .05$, by participants, but not by items, $t(13) = 1.36$.

In the replication, we expected that more of the matrix clauses containing the novel verbs would be judged nonsensical than we observed for the initial study. When the matrix clause was deemed acceptable, however, we expected the same pattern of data as in the original study. This predicted pattern was observed. Overall, approximately half of the matrix clauses were rejected, (40% of the passives, 62% of the middles). There were enough missing trials that many cells in the subject analysis were empty, making the otherwise appropriate repeated measures tests unusable. However, with much more data going into each cell for the items analyses, analyses were done in the same manner as the first version. There were significant main effects of construction, $F(1, 13) = 36.026$, $p < .001$ and region/word position, $F(4, 10) = 84.302$, $p < .001$. Most importantly, and as shown in Figure 2, the pattern in the purpose clause is consistent with the results of the original study. The middle constructions were judged nonsensical more often than the passive constructions at the verb $t(13) = 2.41$, $p < .05$, and at the modifier, (Middle $M = .130$, Passive $M = .011$) $t(13) = 2.63$, $p < .05$.

Because so many of the 249 sentences (per construction) were eliminated before the purpose clause, we include some descriptive statistics of

8. All t-tests are two-tailed.

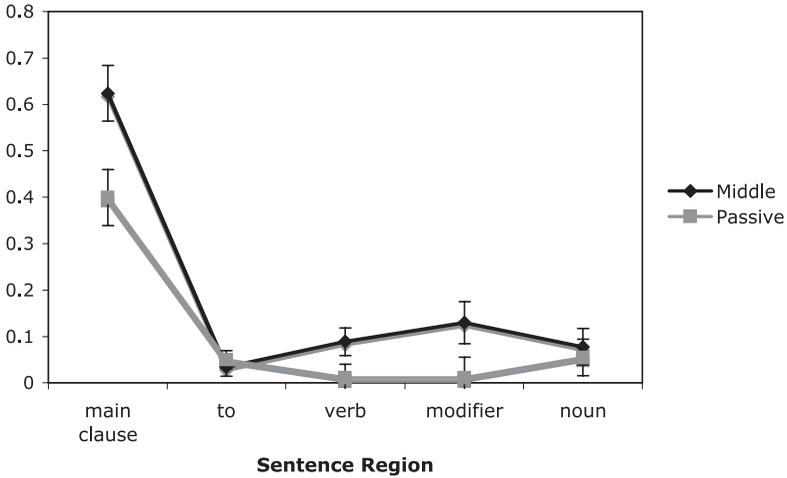


Figure 2. *Item means and standard errors of adjusted percentages of nonsense judgments for novel verbs in the replication*

the two regions where differences emerge. The remaining sentences, mean proportion rejected at that region, standard deviation proportion rejected, and a measure of effect size are shown in Table 1.

Table 1. *Descriptive statistics of item analyses for verb and modifier in replication*

Sentence region	Construction	#Remaining sentences	%Rejected mean	%Rejected stn dev	Cohen's D middle vs passive
Verb	Middle	93	.088	.132	.67
Verb	Passive	149	.010	.026	
Modifier	Middle	83	.130	.169	.73
Modifier	Passive	147	.011	.041	

4. Discussion

We replicated Maurer and Koenig (2000)'s key result that there were more judgments of nonsense made during infinitive clauses following middle constructions which do not evoke a conceptualization of the event with an agent than following passive constructions that do evoke such a conceptualization. This pattern was produced with Maurer and Koenig's stimuli using familiar verbs and with the stimuli we developed that contained novel denominal verbs. The present experiment indicates that con-

structions can provide event structure independently of the verb,⁹ and suggests a different explanation for the findings of Mauner and Koenig (2000).

The same pattern of data was obtained in a replication without the initial passages, though subjects did judge more of the matrix clauses nonsensical. Because we got the same pattern of data in both versions of the study, it is unlikely that the results of the first version of the study reflect that people create a lexical event structure for a novel verb in a single presentation. This interpretation of the data is bolstered by the fact that the initial passages introduced the novel verb using a sentence with the middle construction. If the novel verb had its event structure determined by the initial presentation, then subsequent presentations of the verb in a passive construction should have led to increased judgments of nonsense, but clearly they did not.

The current study also extends work by Kaschak and Glenberg (2000) by showing that constructional event structure guides interpretation of sentences with novel verbs on-line in addition to retrospectively. That is, taking Kaschak and Glenberg's task alone, participants could have used knowledge of the construction and the affordances of the object from which the verb is derived (e.g., *crutch*), and interpreted the sentence after it was completed. On this view, people clearly have an understanding of the semantics of constructions, but this knowledge is incorporated into sentence processing only in retrospect. The present data argue against that interpretation of the previous findings.

4.1. *Open questions*

These findings raise several questions. We discuss two here. First, what, if anything, constrains how a novel verb "inherits" the event structure of a construction? Second, how could one integrate constructional event structure with models of sentence processing?

4.2. *Constraints on event structure inheritance*

Since Goldberg (1995), a major challenge for CxG has been to understand how verbs and constructions fuse/unify such that the generativity behind such examples as (7) and (8) can be explained without also generating infelicitous utterances. All CxG accounts (in some form or another) take both the constraints of verb meaning and construction meaning into

9. When we use the word "independently" we do not mean that constructions and verbs are independent to the extent that constraints imposed by the verb do not need to be satisfied, just that the construction has its own set of constraints that can license arguments.

account, and make some sort of proposal of how their meanings unify and mutually constrain each other in well-formed utterances. How does this extend to novel denominal verbs? It is possible that novel denominal verbs carry no constraints with them and just inherit the entire event structure of a construction. Kaschak and Glenberg (2000) suggest that objects have *affordances*, that is properties that determine how they can be used, and that these properties constrain the interpretation of the denominal verb. For example, if one person in an office wants to transfer the daily mail to a second person by means of a chair, the chair must have some means of conveyance like wheels. Thus, in sentence (18), the denominal verb *to chair* can be used in the ditransitive sensibly only when it is known to have a means of conveyance (such as functioning wheels).

- (18) *Rachel noticed a chair with four good/*missing wheels and then she chaired the scientist his mail.*

Similarly, we picked nouns (e.g., *sauce*) that are associated with a state change to be more congruently interpreted with the middle construction, which seems to have state-change as part of its semantics. We did not contrast that with nouns that had no obvious state changing process associated with it, but this could be an avenue for future research.

We can also take a lesson from an existing denominal verb, *brush*. Nemoto (2005) explains interesting behavior of *brush* in the locative alternation.

- (19) *Jim brushed the marinade onto the chicken.*
 (20) *Jim brushed the chicken with marinade.*
 (21) *Jim brushed the crumbs onto the floor.*
 (22) **Jim brushed the floor with crumbs.*

Following Goldberg (1995), Nemoto classifies (19) and (21) as instances of the caused-motion construction, as is (7) above. (20) and (22) are classified as instances of a “causative + adjunct” construction. Nemoto then suggests that *brush* is polysemous; one sense is akin to *smearing with a brush*, while the second is akin to *sweeping with a brush*. Nemoto uses the Frame Semantics approach to meaning (e.g., Fillmore 1985) to account for how to integrate verb and construction meanings, and suggests that *brush*'s different sense are rooted in different frames, i.e., in different relational event structures, each with own set of semantic roles.¹⁰ (19) and

10. See note 1 for a comparison of the Frame Semantics approach to verb meaning and Projectionist accounts

(20) specify that the brush makes contact with both the marinade and the chicken, evoking the *smearing* frame, while for (21) and (22), the brush only makes contact with the crumbs, evoking the *sweeping* frame. When verbs evoke the *smearing* frame, both alternates are acceptable because the direct contact suggests that both post-verbal arguments are affected by the instrument, while only one post-verbal argument can be represented as a patient in the *sweeping* frame, and the “caustive + adjunct” construction requires the direct object to be a patient.

The point of this discussion, is that when a novel denominal verb is interpreted, one’s conception of the object and the situation will evoke/activate certain frames. Then, in theory, that frame will allow for unification with the frame(s) associated with a construction in the same manner as it would for a familiar verb (e.g., *brush*). From Kaschak and Glenberg (2000), a crutch’s affordances allows it be both part of the general *causative action* frame, as in (15) and the more specific *transfer* frame, as in (14). The point of this paper, building on Kaschak and Glenberg, is that the grammatical construction is also one of the ways to evoke the frame that guides interpretation of the novel verb. The “frame activation” process, from constructions, object, and situation concepts, is still far from being spelled out and completely understood. One contribution made by these studies is to show that novel word interpretation is a good method for investigating the influence of the interaction of verbs and constructions on sentence meaning.

4.3. CxG and constraint-based models of sentence processing

Our findings suggest that constructional semantics influences sentence comprehension. Because many current models of sentence comprehension make no claims about the existence or use of constructional semantics, we now discuss how one could start to incorporate it. To make this discussion concrete, we discuss constraint-based models of sentence comprehension (e.g., MacDonald, Pearlmutter, and Seidenberg 1994; McRae, Spivey-Knowlton and Tanenhaus 1998), though other models are also consistent with aspects of this discussion (e.g., McKoon and Ratcliff 2003). Constraint-based models are a good candidate to extend to findings like ours, because they already have much of the necessary machinery to implement a CxG framework. In CxG, constructions are conceptualized as a pairing of form (i.e., syntax) and meaning (i.e., semantics) each with equal stature, in direct opposition to “syntactocentric” models (see Jackendoff 2002 for extensive discussion). Constraint based models process syntax and semantics in parallel in direct opposition to two stage models that consider syntax to be informationally

encapsulated, (so that there is an initial stage where syntax alone guides parsing, and is deaf to semantic and pragmatic constraints (as in Ferreira and Clifton 1986).

Constraint-based models of sentence processing have been applied primarily to experiments of on-line syntactic ambiguity resolution (e.g., McRae et al. 1998), and the constraints are implemented to reflect the behavioral data. Ambiguous syntactic contexts, by definition, lend themselves to multiple potential parses. Examining under what conditions different parses, are made sheds light on how different sources of information interact and are used to guide initial and final interpretations. Sentence (23) shows an example of the main verb vs. verb of a reduced relative clause ambiguity, while (24) shows the direct object vs. subject of an sentential complement ambiguity.

(23) *The cop arrested by the FBI agent was convicted.*

(24) *Bill accepted the gift would be late.*

A constraint based model like the one in McRae et al, would parse these sentences one word at a time. At any given point, different parses are activated to different degrees. *Arrested* could either be parsed as the main verb of the clause, or the verb of a relative clause modifying *cop* (i.e., one parse could be more strongly activated). The *gift* could either be parsed as the direct object of the verb or the subject of the sentential complement. In both these cases the wrong parse would be more highly activated because *arrest* has a preference to assign *cop* to the agent role (which would happen if *arrest* were the main verb in the sentence). In contrast, *accept* is frequently followed by a direct object.¹¹ Later in the sentence, when it becomes clear that the wrong parse was more highly activated, a reanalysis must occur. This reanalysis is behaviorally marked by a slowed reading time in experimental participants. However, the correct parses would be more highly activated to begin with in (25) and (26), because *arrest* prefers to assign the *criminal* to the patient role, which it would do as the verb of a reduced relative, and *realize* is more frequently followed by a sentential complement. Thus, no slow down in reading time would be predicted.

(25) *The criminal arrested by the FBI agent was convicted.*

(26) *Bill realized the gift would be late.*

11. This preference of course depends on verb sense. "Mental accept" has a sentential complement preference, but out of context, the "physical accept" will be assumed as a default.

The constraints needed for these model parses are a verb's thematic role assignment and syntactic preferences. These constraints are the ones most commonly incorporated into the models, and their effects on ambiguity resolution are widely studied. If one were to extend these models to event structure and constructional semantics, then one would want to ground the implementation of these constraints with sentence processing data. In theory, data from investigating on-line event structure ambiguity resolution in analogous ways to syntactic ambiguity resolution would equally reveal how different sources of information interact to guide its instantiation.

Consider examples (7) and (8) from above. Both *sneeze* and *bake* have certain event structure preferences, which presumably are not that of the caused-motion and ditransitive's event structures, respectively. The on-line processor would activate their event structure preferences at the verb, but then as the parse continues, it would eventually become clear that this parse was wrong, and the constructional event structure would become more strongly activated through a reanalysis. This reanalysis would reveal itself in studies by a slowed reading time. Then, studies could focus on what prevents the need for this reanalysis. For example, Hare, McRae and Elman (2003) show that sentences like (24) do not lead to a slowed reading time when the context primes the "mental accept" sense, which preferentially selects for the sentential complement. Analogous studies could be done where the frame associated with a construction could be primed through discourse context, or perhaps just repeated use of the construction (see Chang, Bock and Goldberg 2003).

The point of comparing event structure parsing to syntactic ambiguity resolution was to illustrate how many open questions and potential avenues of research there are on on-line processing investigating constructs developed in a CxG framework. There is an entire literature on on-line syntactic processing from which to take lessons. After the empirical groundwork is laid, research can begin to explore how to incorporate construction-meaning constraints into constraint-based models.

4.4. Conclusion

The composition of meaning in language is one of the central questions of linguistics and the cognitive sciences more broadly. Understanding the units of language that contribute to this composition is of central concern. Using event structure as a test-bed, our results suggest that grammatical constructions play a role in the composition of meaning that is denied by lexical frameworks. However, further theoretical and experimental work must be done to determine the most efficient and

psychologically accurate way to include information about constructional semantics and the semantics of event structure within the grammar and processing system.

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Appendix A: Passages explaining the meaning of the novel verbs

Passage 1.

Jon and Tom work for a window manufacturer. They were having a discussion about the most efficient ways to construct glass windows. Jon says “It all starts with the sand.” Then he points at a picture on the front of a booklet from their sand supplier and says “That sand glasses easily.”

What does the underlined sentence mean?

- A) Glass is formed easily from that sand.
- B) Sand is easily found on beaches.

Passage 2.

Bill and Jaime are bakers. They were having a discussion about how to make the most delicious whole-grain bread. Jaime says “It is really important to have some high quality wheat. It makes the whole process smoother.” He then refers to the farmers that supply the bakery with wheat and says, “That wheat breads easily”.

What does the underlined sentence mean?

- A) Wheat is good for you.
- B) Bread is easily made from that wheat.

Passage 3.

Beth and Lizzie are construction workers. They were having a discussion on the best methods for forming concrete. Lizzie says “I need to have some good gravel. It’ll make the concrete come out sturdier” Lizzie then points at a truck bed full of gravel and says “That gravel concretes easily”.

What does the underlined sentence mean?

- A) Falling on gravel will hurt.
- B) Concrete is easily formed from that gravel.

Passage 4.

Jeff and Lisa work for a manufacturer of jelly. They were having a discussion on how to make the sweetest jelly. Lisa says “For me, it’s all about the fruit. I need delicious strawberries that are also nice to work

with.” She then points to a case of strawberries and says, “Those strawberries jelly easily”.

What does the underlined sentence mean?

- A) Jelly is easily made from those strawberries.
- B) Making jelly can be messy.

Passage 5.

Kevin and Carrie work for a Winery. They were having a discussion on how to make a wine with the spiciest finish. Kevin says “Well you have start with the best growing conditions and the best grapes, grapes that will make the whole job more manageable.” Kevin then points to the west half of the orchard and says “Those grapes wine easily”.

What does the underlined sentence mean?

- A) Wine is easily made from those grapes.
- B) Red wine goes great with steak.

Passage 6.

Dennis and Julia work for a tabloid. They were having a discussion on how to use the computer program photo-shop to print whatever they wanted in their magazine. Julia says “You need to start with a picture that is not too much of a close up so people won’t question that the face and the body came from the same person.” Julia then points to a picture with two people at the beach. She says, “That picture photo-shops easily”.

What does the underlined sentence mean?

- A) Photo-shop is a great product.
- B) That picture is easily altered using photo-shop.

Passage 7.

Anthony and Joey work at a Italian restaurant. They were having a discussion about how to make the best marinara sauce. Anthony says “I need the ripest and freshest tomatoes. They taste the best and they are the best to work with.” He then points to a bushel of tomatoes and says, “Those tomatoes sauce easily”.

What does the underlined sentence mean?

- A) Sauce is easily made from those tomatoes.
- B) Tomatoes grow all over the world.

Passage 8.

Alison and Nicole are lumberjacks. They were having a discussion about how they would like to build their own cabins in the woods one day. Nicole said “I would need the best strongest logs from the biggest

trees in the forest. It would make building the cabin that much nicer.” Nicole then pointed to a pile of logs and said “Those logs cabin easily”.

What does the underlined sentence mean?

- A) A cabin can be built easily from those logs.
- B) Cabins are better than tents.

Passage 9.

Eduardo and Arlene are knitting. They are having a discussion about how to knit sweaters with the least amount of hassle. Arlene says “You got to start with the right wool. The wrong wool will take forever to knit.” Arlene then points to some wool she bought yesterday and says, “That wool sweaters easily”.

What does the underlined sentence mean?

- A) Sweaters keep you warm.
- B) It will be easy to knit a sweater from that wool.

Passage 10.

Nigel and Kevin work for a distillery. They are having a discussion on how to distill the smoothest vodka. Nigel says, “It’s all about the potatoes. If you want to make smooth vodka, you have to get potatoes that will work with you.” Nigel then points to a bucket of potatoes and says “Those potatoes vodka easily”.

What does the underlined sentence mean?

- C) Vodka is easily distilled from those potatoes.
- D) Vodka mixes well with club soda and lime.

Passage 11.

Walter and Paula work for a tree farm. They are having a discussion on how to grow the healthiest trees. Walter said “you need the right kind of seeds, seeds from healthy trees will grow into healthy trees that will need less maintenance.” Walter then points at a bag of seeds and says “Those seeds tree easily”.

What does the underlined sentence mean?

- A) Those seeds will easily grow into trees.
- B) Trees are an important part of the eco-system.

Passage 12.

Albert and Hans are scientists in a lab. They were having a discussion on the best ways to synthesize molecules. Hans says “You need to right atom synthesize molecules. Some atoms combine well and some need a lot of work.” Hans then points to a column on the periodic table and says “Those atoms molecule easily”.

What does the underlined sentence mean?

- A) All matter consists of atoms.
- B) Those atoms are easily synthesized into molecules.

Passage 13.

Tim and Saul work in a paper factory. They were having a discussion on how to make their jobs easier. Saul says, “If you want the paper production to go smoothly, you need to start with the right wood.” Saul then points to some wood and says, “That wood papers easily”.

What does the underlined sentence mean?

- A) Paper is useful.
- B) That wood will easily be made into paper.

Passage 14.

Krystal and Theodore work in a cafe. They were having a discussion on how to brew coffee more efficiently. Krystal says, “if you don’t have the right beans, brewing coffee will be a big hassle.” Krystal then points to a bag of beans and says “Those beans coffee easily”.

What does the underlined sentence mean?

- A) Coffee is easily brewed from those beans.
- B) Coffee keeps you awake.

Appendix B: Critical sentences used in on-line phase

Novel verb sentences

The replacement adverbs used in the replication are shown in “()”

1. The beach’s sand had/was glassed easily to form three chalices for the king’s banquet.
1. The rough gravel had/was concreted carefully (gradually) to ensure more safety on the way home.
2. The fresh strawberries had/were jellied quickly to feed winy children who hated old jam.
3. The merlot grapes had/were wined carefully (slowly) to convince some critics who can be picky.
4. The fruit seeds had/were treed slowly to grow delicious peaches for the whole summer.
5. The hydrogen atoms had/were moleculed carefully (slowly) to conduct some studies for a thesis.
6. The Russian potatoes had/were vodkaed secretly to spike the punch at the frat party.

7. The ripe tomatoes had/were sauced expertly (well) to compliment the pasta at the gala dinner.
8. The oak's wood had/was papered quickly to supply some colleges with class materials.
9. The maple logs had/were cabined carefully (quickly) to shelter the family of poor immigrants.
10. The tangled wool had/was sweated slowly to ensure warm winters for three cousins.
11. The prom pictures had/were photo-shopped quickly to erase all images of her ex.
12. The Columbian beans had/were coffeed expertly (quickly) to enliven tired reporters on tv tonight.
13. The tall wheat had/was breaded quickly to provide some people with fresh baked goods.

Familiar verb sentences (derived from Maurer and Koenig 2000)

1. The car's engine had/was started abruptly to test the adjustments made by the mechanic.
2. The cake's icing had/was spread evenly to prepare the surface for the decorations.
3. The antique vase had/was sold immediately to raise some money for charity.
4. The horses' mane had/was braided tightly to attract the attention of the judges.
5. The new carpeting had/was installed rapidly to lessen the noise in the hospital lobby.
6. The last chapter had/was read quickly to complete the story before bedtime.
7. The pirate's loot had/was divided evenly to forestall a mutiny by the crew.
8. The leather belt had/was buckled securely to keep the pants without a button supported.
9. The baby's shoes had/were laced tightly to prevent its attempt to remove them.
10. The tangled hair had/was cut evenly to make future grooming a lot easier.
11. The shotgun had loaded quietly to avoid the possibility of frightening off the deer.
12. The baseball card had/was traded quickly to obtain three cards that completed a set.
13. The wall's holes had/were filled in easily to disguise the disrepair of the building.

14. The baby's rattle had/was shaken repeatedly to distract the baby from the dog's ears.

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