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Meanings, propositions, and verbs

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The event template for a verb is a lexical representation of the type of event that the verb can denote. Manner of motion verbs have a simple template: An entity is engaged in a manner of motion activity (e.g., *walk*). Change of location verbs have a different template: An entity changes from one location to another (e.g., *arrive*). We propose, and support empirically, that these templates determine the propositional structures of sentences in which the verbs are used.

Since the 1970s, psycholinguists have believed that the ideas expressed by sentences can be represented as propositions, where a proposition is an "idea unit" composed of a relation and its arguments. In this article, we suggest that lexical information about verbs might determine the propositional structures of sentences.

Propositional structures are made up of individual propositions and the connections among them (e.g., Kintsch, 1974). For the sentence *Romulus, the legendary founder of Rome, took the women of the Sabine by force*, there are four propositions: (*took*, *Romulus*, *women*, *by force*), (*founded*, *Romulus*, *Rome*), (*legendary*, *Romulus*), and (*Sabine*, *women*), where the relations are *took*, *founded*, *legendary*, and *Sabine*. One proposition is directly connected to another if and only if they share an argument. For example, (*took*, *Romulus*, *women*, *by force*), (*founded*, *Romulus*, *Rome*), and (*legendary*, *Romulus*) are directly connected to each other because they share the argument *Romulus*.

Research programs based on propositional analyses of the type just described have been remarkably successful and long-lived (e.g., Anderson, Budiu, & Reder, 2001; Ericsson & Kintsch, 1995). The earliest studies supported propositions as important units of meaning (Kintsch, 1974; Kintsch & Keenan, 1973; Kintsch, Kozminsky, Streby, McKoon, & Keenan, 1975), and later studies used propositional analyses to frame investigations of sentence comprehension and memory. For instance, Adlai Stevenson's presidential campaign speeches were often said by political commentators to be more difficult than Eisenhower's, although they did not use less common words, longer sentences, or more complex syntactic structures. Instead, Kintsch and Vipond (1979) showed that Stevenson's speeches were more complex in their propositional structures. Moving from the 1970s and 1980s into current research, propositional analyses provide core representational constructs for influential processing models, including models of the processes that combine pieces of information to form discourse structures, models of problem solving, and models of how knowledge is stored in memory (e.g., Anderson & Lebiere, 1998; Kintsch, 1988).

In this article, we address how propositional representations are derived from sentences. We focus on sentences that denote movement, such as, for example, *the refugees drifted into the camp*. The question is whether the representation should have one proposition or two. If one proposition, the activity and the change of location would be combined into a single proposition. For the "refugee" example, the proposition would be

1 = (*drift*, *refugees*, *into camp*).

If two propositions, the combination of the activity and the change of location would be represented as

1 = (*drift*, *refugees*)
2 = (*into camp*, 1),

where the second proposition references the first.

To address the question of whether sentences like *the refugees drifted into the camp* should be represented by one or two propositions, we invoke a theoretical framework in which sentence structures are related to propositional meanings via event templates. Event templates are lexical semantic decompositions of verbal meaning, and they lay out the event structures that verbs may denote (e.g., Dowty, 1979, 1991; Pinker, 1989; Pustejovsky, 1991; Rappaport Hovav & Levin, 1998; Tenny, 1994; Van Valin & LaPolla, 1997). Semantic analyses by lexical semanticists (e.g., Dowty, 1991) suggest that there are four possible event templates:

x(ACT), where an entity (x) engages in some activity (e.g., *walk*, *hit*).

x(STATE), where an entity exists in some state (e.g., *live*, *survive*).

x(BECOME IN STATE), where an entity comes to be in some new state (e.g., *bloom*, *arrive*).

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y CAUSE x(BECOME IN STATE), where an external cause (y) results in an entity coming to be in some new state (e.g., *break*, *bend*).

In our framework, every verb has one and only one of these four templates (unless it has two or more unrelated meanings—e.g., the two meanings of *bolt*). The single template determines all of the sentence structures in which a verb can occur, as outlined below. Verbs that have the same template differ in other parts of their meanings (Grimshaw, 1993). For example, *bloom* and *arrive* are both change of state verbs [x(BECOME IN STATE)]; but for *bloom*, the change is from not blooming to blooming, and for *arrive*, the change is from one location to another.

The experiment in this article used two sets of verbs, one a subset of activity verbs and the other a subset of change of state verbs. The activity verbs were verbs that denote the manner in which a motion activity is carried out—for example, *walk*, *stroll*, and *slither*. The template is x(MOVE), where MOVE instantiates the activity in x(ACT). The verbs in the change of state subset denoted a change of location—for example, *arrive*, *depart*, and *appear*. The template is x(BECOME IN LOC), where x comes to be in some new location, LOC.

Table 1 shows how the templates for manner of motion (MOM) verbs and change of location (COL) verbs link to sentences in which the verbs occur and to propositional representations. For the first two sentences, the surface syntax is the same—a subject and a verb—but according to the verbs' templates, the propositions that they express are different. For *escape*, the template contains a location, and we take this to mean that the proposition for *the hostages escaped* includes an implicit location (LOC). The template for *drift* contains no location, so none is in the proposition.

For the third and fourth sentences, the surface syntax is again the same: a subject, a verb, and a directional prepositional phrase. The *escape* sentence makes explicit the location (LOC) that was implicit in the template, resulting in the single proposition (*escaped*, *hostages*, *cell*). In contrast, for the *drift* sentence, the MOM template (x MOVE) does not contain a location, and so the *into camp* location is an "add-on." The MOM activity is combined with the change of location to yield two connected propositions: 1 = (*drifted*, *refugees*) and 2 = (*into camp*, 1).

The important claim is that event templates are psychologically real in that they determine the propositional structures of sentences. For a MOM verb to express movement of an entity from one location to another, the change of location must be added onto the verb's basic x(MOVE) template, resulting in two propositions. For a COL verb, no add-on is necessary, so there is only one proposition. The x(BECOME IN LOC) template already includes movement to a new location.

Classifying Verbs

In the experiment below, we compared sentences with MOM and COL verbs. The two types of verbs are highly similar in that both can be used to express movement. It is necessary, therefore, to provide a mechanism for deciding whether a particular verb should be classified as MOM or COL. The mechanism we use, borrowed from lexical semantics research, is to compare the surface sentence structures in which the two types of verbs occur.

For the sentences of interest in this article, surface structures are derived from event templates according to two rules: (1) An entity that causes an event is linked to subject position in a sentence, and (2) an entity that is affected by an event is linked to direct object position (e.g., Dowty, 1979; Pinker, 1989; Rappaport Hovav & Levin, 1998; Van Valin & LaPolla, 1997). For MOM verbs, the x in x(MOVE) causes the activity and so it is linked to subject position. In *the refugees drifted*, the refugees cause the drifting activity and so *refugees* is in subject position. For COL verbs, the x in x(BECOME IN LOC) is affected in that it changes location. It would appear in direct object position in a sentence except that it must move to subject position to meet the constraint that every sentence must have a subject (e.g., Rappaport Hovav & Levin, 1998). In *the hostages escaped*, the hostages are affected by the escaping event, and *hostages* moves from object to subject position.

According to the view just outlined, the MOM template provides no affected entity and so, when a MOM verb is used in a sentence, the direct object position is open. It can be filled in several ways. A resultative phrase specifies a change of state that results from a verbal event. For example, in *the children swam their hearts out*, the resultative phrase is "their hearts out," where the change of state is that their hearts became (metaphorically) "out." In another type of resultative, the change of state is expressed by a reflexive, as in *you're going to run yourself out of life*, where the change of state is (metaphorically) "out of life." In both cases, the change of state fills the direct object position as an add-on to the x(MOVE) template. It might be represented something like x(MOVE) CAUSE y(BECOME IN STATE) (Carrier & Randall, 1992; Goldberg, 1994; Simpson, 1983).

MOM verbs also occur with a construction known as "X's way," as in *that adorably ugly extraterrestrial has waddled his way into the hearts of millions of moviegoers.*

Table 1
Propositions Derived From Sentences via Event Templates

Template	Sentences	Propositions
Sentences Without Prepositional Phrases		
MOM (manner of motion) verbs x(MOVE)	*The refugees drifted.*	(*drifted*, *refugees*)
COL (change of location) verbs x(BECOME IN LOC)	*The hostage escaped.*	(*escaped*, *hostage*, LOC)
Sentences With Prepositional Phrases		
MOM verbs x(MOVE)	*The refugees drifted into camp.*	1 = (*drifted*, *refugees*) 2 = (*into camp*, 1)
COL verbs x(BECOME IN LOC)	*The hostage escaped from the cell.*	(*escaped*, *hostage*, *cell*)

This construction has been interpreted as denoting a movement activity that continues over time, eventually resulting in the specified change of location (e.g., Jackendoff, 1990). The X's way phrase, like resultative phrases, takes the direct object position unfilled by the MOM template (e.g., Goldberg, 1994; Levin & Rappaport Hovav, 1995).

It follows from the analyses just described that resultative constructions are not allowed for COL verbs. For one reason, the underlying direct object position is already filled by the entity changing location. Also, resultative phrases are ruled out because COL verbs already describe a change of state and it is generally considered that an event cannot denote more than one change of state (e.g., Tenny, 1994). A sentence with a resultative phrase such as *they escaped the cell into happiness* is unacceptable because it describes a change of location, "out of the cell," plus a change of state, "into happiness." X's way sentences (e.g., *he escaped his way to freedom*) are not allowed with COL verbs because the direct object position required for "way" is already filled and because X's way denotes the manner in which a motion occurs and COL verbs do not denote the manner by which a location is reached.

The resultative and X's way constructions serve as diagnostics to determine whether a verb is classified as MOM or COL: The former but not the latter can occur with resultative and X's way phrases. These data converge with the results of psycholinguistic experiments (McElree, Traxler, Pickering, Seely, & Jackendoff, 2001; McKoon & Macfarland, 2000, 2002). COL verbs denote an entity, a change of location, and a location, whereas MOM verbs denote an entity and an activity. If the COL template is more complex, whether because it denotes a change of location rather than an activity or because it denotes both an entity and a location, then it should take longer to process. McKoon and Macfarland (2000, 2002) obtained this effect. In lexical decision and sentence comprehension, processing times were slower for verbs with more complex templates than for verbs with less complex templates.

The Present Experiment

The hypothesis was that verbs' event templates determine the propositional structures of sentences in which the verbs are used. For *the refugees drifted into camp*, there are two propositions. The template for *drift* provides the first proposition—(*drift*, *refugees*)—and a second is added to express *into camp*. For *the hostage escaped from the cell*, there is only one proposition. The template for *escape* provides a location and so *from the cell* does not require a second proposition.

For the experiment, we employed a paradigm used in early demonstrations of the psychological reality of propositions—priming in item recognition. Ratcliff and McKoon (1978; see also McKoon & Ratcliff, 1980, 1992) had subjects study a long list of sentences. Then, after a 20-min delay, they were presented with single-word test items. For each word, they were asked to decide whether it had appeared in a studied sentence. Response times were shorter when a word from a sentence was immediately preceded in the test list by another word from the same proposition in its sentence than when it was preceded by a word from a different proposition. For example, *the mausoleum that enshrined the tsar overlooked the square* has the propositions (*enshrined*, *mausoleum*, *tsar*) and (*overlooked*, *mausoleum*, *square*). Response times for *square* were shorter when *square* was immediately preceded in the test list by *mausoleum* than when it was immediately preceded by *tsar*.

In the experiment described here, priming was used to compare the propositional representations of MOM and COL sentences. Table 2 shows the design of the experiment. Every sentence explicitly expressed a location. For a sentence with a COL verb, the verb's template binds the entity and the location together into a single proposition. For a sentence with a MOM verb, the entity and the location are in different propositions. The prediction was that priming between the entity and the location would be greater for COL than for MOM sentences.

METHOD

Materials

There was one set of sentences for each of two groups of subjects. Two different sets were used to add generality to the findings. For each set, there were 13 pairs of COL

Table 2
Experimental Conditions

		Primed		Unprimed	
Verbs	Sentences and Their Propositions	Prime	Target	Prime	Target
	Manner of Motion (MOM) Verbs				
x(MOVE)	*The refugees drifted into the camp.* 1 = (*drifted*, *refugees*) 2 = (*into camp*, 1)	*refugees*	*camp*	*hostage*	*camp*
	Change of Location (COL) Verbs				
x(BECOME IN LOC)	*The hostage escaped from the cell.* (*escaped*, *hostage*, *cell*)	*hostage*	*cell*	*refugees*	*cell*

Note—Verbs for Subject Group 1: MOM, *swagger* (1), *walk* (1), *wander* (1), *creep* (1), *run* (1), *travel* (2), *stumble* (2), *rush* (2), *drift* (1), *stagger* (1). COL, *ascend* (1), *leave* (1), *plunge* (1), *escape* (1), *fall* (1), *arrive* (2), *descend* (2), *depart* (2), *flee* (2). Verbs for Subject Group 2: MOM, *stray* (1), *travel* (1), *canter* (1), *hurry* (1), *rush* (2), *totter* (2), *walk* (2), *saunter* (3). COL, *ensue* (1), *dawn* (1), *occur* (1), *emerge* (1), *flow* (2), *erupt* (2), *rise* (2), *transpire* (3). The numbers in parentheses for the verbs are the numbers of sentences in which the verbs appeared in the experiment.

and MOM sentences, different pairs for each set, with each sentence expressing an entity coming to be at some new location. The sentences expressed the movement to the new location either with its beginning point (e.g., *from the cell*) or with its end point (e.g., *into the camp*). The verbs used in the sentences are listed in Table 2. To maximize the numbers of pairs of sentences while at the same time matching the sentences on all of the factors listed below, some verbs were used in more than one sentence (Table 2).

The assignments of verbs to the MOM and COL classes were decided by the diagnostics that were described above, as listed by Levin (1993). For example, all of the MOM verbs used in the experiment and none of the COL verbs can occur with resultative phrases.

Table 3 shows the factors on which the sets of sentences were matched. For none of them were there significant differences between the COL and MOM verbs or sentences (Fs < 1.0).

For ratings of the "likelihood of the event expressed by the sentence occurring in real life," the experimental sentences were mixed with highly likely and highly unlikely fillers (e.g., *the college accepted the donation*, *a professor bantered the grade*). For imagery ratings, the sentences were mixed with high- and low-imagery fillers (e.g., *the kitten scratched the furniture*, *the mathematical concept was difficult*). The subjects were different for each type of rating, with 10 subjects for each. For relatedness ratings, the pairs of words from the sentences (subject–verb, verb–object, subject–object; see Table 3) were mixed with filler pairs that included highly related and unrelated pairs (e.g., *dog–cat*, *table–branch*). Different groups of subjects (at least 10 per group) rated each of the pairs.

The sentences were also matched on two typicality of usage factors. These were calculated from a 280-million-word corpus of naturally produced text that includes adult and children's fiction and nonfiction and transcriptions of television shows. The two factors were the probability that the subject of a verb was animate and the probability that a change of location for the verbal activity was explicitly expressed by a beginning point or an end point. The last two columns of Table 3 show the probabilities with which the subjects and locations of the sentences matched the corpus probabilities. For example, for *the refugees drifted into camp*, *refugees* is animate, and in the corpus the probability that *drift* has an animate subject is .53. If *drift* had had an inanimate entity as subject (e.g., *the clouds drifted across the sky*), the probability with which the subject matched the corpus would have been .47. The mean probabilities across verbs, shown in Table 3, were calculated from each verb's "match" probability.

Subjects

Subjects participated in the experiment for credit in an introductory psychology class at Ohio State University. One group of 28 was tested with the first set of sentences, and another group of 30 was tested with the second set. For each group, the pairs of sentences were combined in a Latin square design (Table 2) with the primed and unprimed conditions (one filler item was added to each set of sentences to make 14 pairs for counterbalancing purposes but was not included in data analyses).

Procedure

The experimental sentences (26 sentences for each group of subjects) and 15 filler sentences were displayed in random order on a computer monitor for 4 sec each. Subjects were instructed to study the sentences for later recall. After the sentences were presented, subjects were given one word from each of the filler sentences and were asked to recall the sentence in writing. The experimental sentences were not tested in recall, because we did not want to confound memories of responses in recall with subjects' later item recognition responses. When subjects finished recall of the filler sentences, the experimental and filler sentences were presented for a second time to improve memory for them for the later item recognition test; they were presented for 4 sec each, in a different random order. Subjects were again instructed to study them for later recall. The second pre-

Table 3
Verb and Sentence Characteristics

	Kučera–Francis Frequency				Length						Probability	
Verbs	Subj.	Verb	Loc.	Sentence (−Verb)	Words	Syll.	Real-Life Likelihood	Imagery	Relatedness	P–T Rel.	Subj.	Loc.
					Subject Group 1							
Change of location	28	38	59	87	5.9	8.9	0.5	2.3	2.7	2.7	.66	.38
Manner of motion	28	40	52	79	6.0	8.9	0.2	2.0	2.8	2.9	.72	.25
					Subject Group 2							
Change of location	30	55	47	91	6.0	10.4	1.5	2.6	3.4	3.5	.95	.23
Manner of motion	29	57	55	94	5.9	9.6	1.5	2.4	3.5	3.0	.86	.32

Note—Subj., subject; Loc., location; Syll., syllables; P–T Rel., prime–target relatedness. The first four columns show mean Kučera–Francis (1967) frequencies for the word from the subject phrase that was used as a test word (e.g., *refugees*), for the verb, for the location that was used as a test word (e.g., *camp*), and for all of the content words of the sentence except the verb. The next two columns show the mean lengths of the sentences in words and syllables. The Real-Life Likelihood and Imagery columns show mean ratings for the sentences on a scale of 1–5, with 1 being *most likely* and *most imageable*. For Relatedness, subjects were asked to rate the relatedness of three pairs of words for each sentence: subject–object, subject–verb, and verb–object (e.g., *refugees–camp*, *refugees–drift*, *drift–camp*). The means of the three pairs are shown in the Relatedness column and the means for the subject–object pair are shown in the Prime–Target Relatedness column. The rating scale was 1–5, with 5 being *most related*. The last two columns show, respectively, the probability that the subject of a verb was animate and the probability that a change of location for the verbal activity was explicitly expressed by a beginning point or an end point.

sentation of the sentences was followed by an intervening unrelated task that took about 15 min. The subjects were then told that the sentences they had studied at the beginning of the experiment would be tested with single-word recognition, and the procedure for this was described. The test words from the experimental sentences, 15 words from filler sentences, and 63 words that had not appeared previously in the experiment were presented in random order, except that the prime words immediately preceded their targets and the prime–target pairs were not in the first 8 positions of the test list. Subjects were instructed to respond quickly and accurately, using the "?/" key for "yes" responses and the "z" key for "no" responses. If a response was correct, the test word was erased from the monitor and there was a 50-msec pause before the next test word. If a response was incorrect, the word "ERROR" was displayed for 1 sec before the 50-msec pause.

RESULTS

Table 4 shows mean response times and accuracy values. The two groups of subjects were combined for ANOVA. As predicted, there was greater priming from a sentence's subject noun to its location noun for the COL sentences than for the MOM sentences. In the COL sentences, the subject and location (e.g., *hostage* and *cell*) are bound together into a single proposition by the COL verb (e.g., *escape*). In the MOM sentences, the subject and location (e.g., *refugees* and *camp*) are in two separate propositions. Comparison of the primed and unprimed conditions showed an average priming effect of 114 msec for the COL sentences. For the MOM sentences, it was only 46 msec. This interaction, the key result of the experiment, was significant with subjects and sentences [$F_1(1,57) = 9.8$ and $F_2(1,25) = 8.1$, all $ps < .05$; $SE = 13.7$]. Post hoc tests showed significant priming for the MOM sentences [$F_1(1,57) = 7.7$ and $F_2(1,25) = 7.9$]. Table 4 has ANOVA values for the other factors.

DISCUSSION

The question with which this article began was how to map sentences to propositional representations of meaning. Should *the hostage escaped from the cell* be mapped onto two propositions or one? And should the mapping be the same for *the refugees drifted into the camp*? The data from the experiment argue that event templates provide answers. The template for COL verbs includes a location, x(BECOME IN LOCATION), whereas the template for MOM verbs, x(MOVE), does not. Consequently, there are two propositions for the *drift* sentence, 1 = (*drifted*, *refugees*) and 2 = (*into camp*, 1), and only one for the *escape* sentence (*escaped*, *hostage*, *cell*).

Of course, examining only two types of verbs with only one experimental paradigm is just a beginning look at the relations between sentence structures and propositions. There are other ways of describing the results that could be consistent with ours. For example, COL and MOM verbs might differ in that location is an argument of COL but not MOM verbs (Conklin, Koenig, & Mauner, 2004; Koenig, Mauner, & Bienvenue, 2003).

Despite the limitations of only two types of verbs and one paradigm, we find the data compelling. Both MOM and COL verbs can be used to describe an entity moving from one location to another, yet their event templates postulate different representations for them, and these representations are reflected in the priming data. The differential priming effect occurred even though the surface structures of the sentences were the same (subject, verb, prepositional phrase).

We think that this result is important for three reasons. First, it shows a direct relation between a verb's meaning, the sentences in which the verb occurs, and propositional representations. As such, it takes a first step toward proposition–sentence relations that are theoretically motivated.

Second, it shows the power of combining lexical semantic research in linguistics with psycholinguistic experiments. The data presented here and data from the lexical semantics literature, such as the resultative constructions mentioned in the introduction, provide independent sources of evidence for the theoretical construct of event templates.

Third, the results demonstrate what we have called "meaning through syntax" (McKoon & Ratcliff, 2003). For both MOM and COL verbs, the sentences had the surface form "subject, verb, prepositional phrase." But at a

Table 4
Mean Response Times (RTs, in Milliseconds) for Correct Responses and Probability of Correct Responses (CRs)

			Primed				Unprimed			
Sentence	Propositions	Group	Prime	Target	RT	*P*(CR)	Prime	Target	RT	*P*(CR)
Manner of Motion (MOM) Verbs x(MOVE)										
The refugees drifted into the camp.	1 = (*drifted*, *refugees*)	1	*refugees*	*camp*	767	.79	*hostage*	*camp*	819	.80
	2 = (*into camp*, 1)	2			750	.78			790	.66
Change of Location (COL) Verbs x(BECOME IN LOC)										
The hostage escaped from the cell.	(*escaped*, *hostage*, *cell*)	1	*hostage*	*cell*	737	.86	*refugees*	*cell*	855	.76
		2			766	.83			876	.75

Note—RTs more than 400 msec slower than the next slowest RT were excluded from analyses. Because some subjects' data were highly variable (and the number of observations per condition was small), this was a more sensible way to eliminate outlier responses than placing a cutoff at 2 or 3 *SD*s above the mean. For response times, there were significant main effects of priming by subjects and by items [$F_1(1,57) = 37.5$, $p < .05$; $F_2(1,25) = 28.6$, $p < .05$] and of verb type by subjects [$F_1(1,57) = 4.7$, $p < .05$; $F_2(1,25) = 1.4$]. For accuracy, there was a significant main effect of priming [$F_1(1,57) = 7.9$, $p < .05$; $F_2(1,25) = 7.9$, $p < .05$]; the main effect of verb type was not significant [$F_1(1,57) = 5.7$; $F_2 < 1.0$], nor was the interaction of priming × verb type (Fs < 1.0).

deeper level, we suggest that MOM and COL sentences have different syntax. The MOM template provides the cause of a MOM activity with no change of location, and the cause maps to subject position in sentences. The COL template provides both an entity affected by a change of location and the location, and the affected entity maps to direct object and then moves to subject position to fulfill the requirement that every sentence have a subject. These differences between the MOM and COL verbs determine the propositions expressed in sentences, which in turn explain the differences in the priming effects that we observed for the two types of verbs.

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