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Source: *Language*, Vol. 76, No. 4 (Dec., 2000), pp. 833-858

Published by: Linguistic Society of America

Stable URL: <https://www.jstor.org/stable/417201>

Accessed: 14-11-2019 14:32 UTC

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# EXTERNALLY AND INTERNALLY CAUSED CHANGE OF STATE VERBS

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The lexical semantic structures of change-of-state verbs are explored via linguistic theory, corpus analysis, and psycholinguistic experimentation. The data support the idea that these verbs can be divided into two classes, those for which the change of state is internally caused and those for which it is externally caused (Levin & Rappaport Hovav 1995, cf. Smith 1970). External causation change-of-state verbs have been hypothesized to denote two subevents, internal causation change-of-state verbs only one event. Consistent with this difference, the psycholinguistic data indicate that, in both transitive AND intransitive constructions, sentences with external causation verbs take longer to comprehend than sentences with internal causation verbs.\*

**1. LEXICAL SEMANTIC STRUCTURES FOR VERBS.** In both linguistics and psycholinguistics, verbs are thought to play a central role in the meanings of the sentences in which they appear. In this article, we focus on the aspects of meaning that are contributed to sentences by verbs' lexical semantic structures. The lexical semantic structure of a verb represents the portion of the verb's meaning that is relevant to a determination of the syntactic structures in which the verb can appear, and it lays out the verb's arguments and the relations among them. For two classes of verbs, we provide evidence that both the time it takes for people to understand sentences and the kinds of sentences people produce reflect the structures that have been proposed for the verbs in recent work in lexical semantics.

The two classes of verbs we examined are internally caused change-of-state verbs, known by their prototypical member as *bloom*-type verbs, and externally caused change-of-state verbs, known as *break*-type verbs. Intuitively, an internally caused change of state is a change of state for which the means of bringing about the change-of-state event is conceptualized as residing in the entity undergoing the change. Flowers, for example, bloom because of something internal to flowers. An externally caused change of state is conceptualized as coming about because of something external to the entity that undergoes the change of state. The responsibility for a window breaking lies not with the window itself but with some external force.

These definitions are based on intuitions about how verbs are used to describe events. Going beyond intuition is one of the goals of the research described in this article. We provide a semantic diagnostic that can distinguish internally caused from externally caused change-of-state verbs, and we present empirical data that support the psychological reality of differences in the behaviors of the two verb classes. In so doing, we support the general theoretical enterprise that postulates that semantic representations of syntactically relevant information are a significant part of the lexical encodings of verbs.

**2. THEORETICAL BACKGROUND.** The distinction between internal and external responsibility for the events described by change-of-state verbs was introduced by Smith (1970) as a difference in control: an externally controlled event is characterized by the fact that 'external control of the change can be assumed by an agent' (Smith 1970:

\* We would like to thank Beth Levin, Mari Broman Olsen, Roger Ratcliff, Grace Song, and Amy Weinberg, as well as three anonymous reviewers, for helpful comments and discussion. This research was supported by National Institute of Deafness and Communicative Disorders grant DC01240 to Gail McKoon and National Institute of Mental Health grant MH44640 to Roger Ratcliff.

101), whereas an internally controlled event is under the control of the entity engaged in the event and control cannot be given up to another entity (Smith 1970). People control their own shuddering in the sense that monsters cannot shudder them (Smith 1970:107, (35)).

Levin and Rappaport Hovav (1995) broadened Smith's notion from internal versus external control to internal versus external causality and applied the notion to a larger number of verbs, including verbs that describe events engaged in by inanimate entities (e.g., *erode*). Here, we focus on change-of-state verbs. Levin and Rappaport Hovav (1995, Rappaport Hovav & Levin 1998) give an intuitive semantic characterization of internally caused change-of-state verbs such as *bloom* and *erode* as naming 'states that come about naturally in an entity. These states are conceptualized as having their source internal to the entity that changes state' (Rappaport Hovav & Levin 1998:125, cf. Levin & Rappaport Hovav 1995:97). In contrast, 'externally caused verbs by their very nature imply the existence of an "external cause" with immediate control over bringing about the eventuality described by the verb: an agent, an instrument, a natural force, or a circumstance. Thus, consider the verb *break*. Something breaks because of the existence of an external cause; something does not break solely because of its own properties (although it is true that it must have certain properties in order for it to be breakable) . . . Some externally caused verbs (such as *break*) can be used intransitively without the expression of an external cause, but, even when no cause is specified, our knowledge of the world tells us that the eventuality these verbs describe could not have happened without an external cause' (Levin & Rappaport Hovav 1995:92–93).

For Levin and Rappaport Hovav (1995), the distinction between internally and externally caused verbs played a significant role in their account of unaccusativity phenomena. Their semantic definition of the distinction contributed to their ability to give a semantically based explanation of which verbs are unaccusative and which unergative, and of the consequences of a verb's status with respect to unaccusativity for the syntactic structures in which it appears.

Our aim was different, namely, to establish the empirical validity of the distinction and its behavioral consequences. To begin, we describe the lexical semantic representations we have adopted for the two classes of change-of-state verbs, and then give an overview of the empirical studies presented in the remainder of this article.

Following Levin and Rappaport Hovav (1995, Rappaport Hovav & Levin 1998) as well as others (Dowty 1979, Pustejovsky 1991, van Valin & LaPolla 1997), the lexical semantic representation, or TEMPLATE, for externally caused change-of-state verbs such as *break* makes explicit an external cause of the event denoted by the verb, in a causing subevent, and a resulting change of state, in a change-of-state subevent; the two subevents are connected by the relation CAUSE:

(( $\alpha$ ) CAUSE (BECOME (x (STATE)))).

The causing subevent  $\alpha$  can be any of a number of event types, including activities, existing states, achievements, and accomplishments (van Valin & LaPolla 1997). The result subevent denotes an entity  $x$  entering some new state. 'John broke the window' is represented as ((John ACT) CAUSE (BECOME (window (BROKEN)))).

The events described by internally caused change-of-state verbs are conceptualized as having no external cause, and so the lexical semantic template assigned to them shows a simple structure of only one subevent (Rappaport Hovav & Levin 1998:125–26): (BECOME (x (STATE))).

According to recent work in lexical semantics (e.g., Grimshaw 1993), verbal meaning

can be divided into STRUCTURAL meaning, that part of meaning relevant to determining the syntactic structures in which a verb can appear, and CONTENT, all the rest of a verb's meaning. Lexical semantic templates like those just described represent structural meaning, and they group verbs into classes that are semantically defined but syntactically relevant. All the verbs of the internally caused change-of-state class are assumed to have the same template, which is to say that the syntactically relevant part of their meanings is assumed to be the same for all of them. Likewise, the part of meaning that is syntactically relevant is assumed to be the same for all the verbs of the externally caused change-of-state class. It is only in the content parts of their meanings that the verbs within a class are assumed to differ from one another.

Lexical semantic templates show participants in verbal events, but only the participants that are relevant to the groupings of verbs into the semantically defined classes just described. The participants are mapped onto syntactic structures by linking rules (Dowty 1991, Jackendoff 1990, Levin & Rappaport Hovav 1995, van Valin & LaPolla 1997). The template for internally caused change-of-state verbs, for example, shows one participant, *x*, which appears as subject in an intransitive construction (*the flowers bloomed*). The template for externally caused change-of-state verbs shows one participant in the change-of-state subevent, and the other subevent,  $\alpha$ , would have the participants appropriate to its event type.

But there can also be event participants that are associated not with the lexical semantic template for a verb (that is, not with the structural meaning), but instead with the verb's content meaning (Grimshaw 1993, Rappaport Hovav & Levin 1998). *Break*, for example, can have an instrument participant in the breaking event (*John broke the window with a hammer*). The expression of participants licensed by the content part of meaning but not the structural part is optional (Rappaport Hovav & Levin 1998). As we show later, it is such optional, content participants that provide a diagnostic for distinguishing internally caused from externally caused change-of-state verbs. After presentation of all the data, we outline linking rules for both structural and content participants.

It is important to make clear the status of the semantic templates that guide our research. For the syntactically relevant part of meaning, they indicate how an event described by a verb is to be construed. An event described by the internal cause verb *bloom* is to be construed as an internally caused event, and an event described by the external cause verb *break* is to be construed as an externally caused event. Of course, we can imagine how blooming could have external causes (e.g., a gardener's efforts) and we know that breaking requires certain internal characteristics of the object that is broken. But the theoretical claim is that the lexical encoding of a verb does not incorporate all the variety of ways we could imagine describing events denoted by the verb. Instead, it imposes a particular construal on the event.

It is also important to stress that, with few exceptions, each change-of-state verb is assumed to be represented lexically with only a single template: (become *x* (state)) for internal causation verbs and (( $\alpha$ ) CAUSE (become *x* (state))) for external causation verbs. There are verbs for which more than one lexical template has been suggested; *burn* for example, might have an external causation reading for events like people burning leaves and also an internal causation reading for events like a fire burning brightly (Levin & Rappaport Hovav 1995). But for the great majority of the change-of-state verbs, we assume that there is only one lexical template.

**3. OVERVIEW.** The central hypothesis that guided our research is that sentences with change-of state-verbs are produced and understood through processes that make use

of the verbs' underlying lexical semantic representations. Specifically, we hypothesized that production or comprehension of a sentence with an externally caused change-of-state verb involves understanding that there is a change of state and that it comes about because of an external cause, whereas production or comprehension of a sentence with an internally caused change-of-state verb involves understanding only that there is a change of state. In other words, comprehension of *break* requires understanding a more complex conceptualization of an event than *bloom* does.

In addition, we explicitly hypothesized that the underlying lexical semantic representation of a verb is a part of the verb's meaning that is used by production and comprehension processes whenever the verb is encountered.

To study comprehension processes, we used an acceptability judgment task (experiments 1 and 2): for each sentence in an experiment, subjects were asked to indicate whether or not they thought it was an acceptable sentence. We predicted that judgment times for sentences with external causation verbs would be longer than those for sentences with internal causation verbs because the lexical semantic representations of the external causation verbs are more complex, denoting two subevents, whereas the representations of the internal causation verbs are simpler, denoting only a single event. The experiments confirmed this prediction for both transitive and intransitive sentences.

To study production, we collected large numbers of sentences with change-of-state verbs from a corpus of naturally produced English texts. Our aim was to provide additional empirical support for the distinction between externally and internally caused change-of-state verbs, and simultaneously to provide an independent diagnostic for the distinction. Decisions about whether a change-of-state verb belongs to the internal or the external class have generally been based on intuition, and intuitions are often compelling. A person can be said to break a window but not bloom a rose, suggesting that *break* denotes external causality and *bloom* internal causality. But for some verbs, intuitions are neither clear nor unanimous. *Deteriorate*, for example, is sometimes used transitively, indicating an externally caused change of state (as in *the sea air deteriorated the steel work* from the British National Corpus), but for Levin and Rappaport Hovav (1995), *deteriorate* can only denote internal causality. This kind of problem becomes particularly acute for psycholinguistic experimentation because a reasonably large number of verbs is required for each class of verbs to be tested and it is unlikely that the verbs for an experiment can be restricted to just those for which intuitions are clear.

To search for a diagnostic, we examined large numbers of sentences from the corpus to determine whether there are characterizable differences between sentences with externally caused change-of-state verbs and those with internally caused change-of-state verbs, and to determine whether and how the differences could be related to the lexical semantic representations of the verbs. We describe the results of the corpus studies below.

Overall, the research described here embodies the interplay of three separate sets of considerations. First, there are the hypothesized lexical semantic templates for the two classes of verbs, representations that indicate how the events described by the verbs are conceptualized. Second, there are corpus data that show what kinds of sentences are naturally produced for verbs of one class but not the other, data that can provide a diagnostic to determine whether a particular verb belongs to one or the other of the classes. Third, there are psycholinguistic data on sentence comprehension that show the reflections in psychological processes of the more complex external causation template versus the simpler internal causation template. These considerations fruitfully inform

each other, and they converge on a theoretical description of internally and externally caused change-of-state verbs.

**4. CORPUS STUDIES.** We worked with a corpus of approximately 180 million words of naturally produced English texts, made up of about 93 million words of articles from the *New York Times*, 5 million words of articles from the *Wall Street Journal*, 40 million words of articles from *Time* and *Newsweek* magazines, 6 million words of excerpts of adult prose (usually first chapters of books featured in major newspapers' book reviews), 1 million words of the Brown corpus, 31 million words of conversation from *Larry King Live* and the *MacNeil-Lehrer News Hour*, 1 million words of the Treebank corpus, and 1 million words of excerpts from children's literature. We also occasionally checked sentences for some verbs in the British National Corpus.

We report four corpus studies. The first three use corpus sentences to test two diagnostics that have been previously suggested as distinguishing between internally and externally caused change-of-state verbs, and the fourth explores a new diagnostic.

**4.1. STUDY 1: TRANSITIVITY.** A hallmark of externally caused change-of-state verbs like *break* is that they participate in the causative/inchoative alternation and thus occur in transitive as well as intransitive constructions, whereas internally caused change-of-state verbs like *bloom* have been thought to occur as intransitives only (Levin 1993, Levin & Rappaport Hovav 1995, cf. Smith 1970), based on the unacceptability of sentences like *\*the gardener bloomed the rose*. Study 1, however, shows that the probabilities of occurrence in transitive and intransitive sentences do not distinguish externally from internally caused change-of-state verbs.

We began with the 21 internally caused change-of-state verbs listed by Levin and Rappaport Hovav (1995), examining corpus sentences for all of them except *molder* and *molt*, for which we had too few tokens, and *burn*, which we believe may have both internal and external causation templates. For each verb, we calculated a ratio of the number of uses of the verb in a transitive construction divided by the total of the number of transitive plus intransitive uses. To compute this ratio, we examined all the tokens in the *New York Times* part of the corpus (if there were more than about 700, we looked at only the first 200), counting the transitive and intransitive uses and discarding adjectival and nominal uses. The total number of tokens examined for each verb ranged from 101 to 587. The total number of transitive plus intransitive tokens for each verb ranged from 37 to 510.

Table 1 displays the verbs' probabilities of occurrence in transitive sentences. What is immediately apparent is that some internal causation verbs do appear frequently in transitive constructions. Even for verbs for which the transitive probability is low, there are still examples of transitive constructions, as illustrated.

VERB	PROBABILITY	VERB	PROBABILITY
blister	.22	germinate	.06
bloom	.00	rot	.08
blossom	.00	rust	.14
corrode	.63	sprout	.26
decay	.00	stagnate	.02
deteriorate	.01	swell	.37
erode	.67	tarnish	.98
ferment	.54	wilt	.06
flower	.00	wither	.12

Note: There were two transitive sentences with *bloom*; rounding makes the entry .00.

TABLE 1. Probability of transitive construction.

*bloom*: . . . it [a shrub] blooms white flowers in summer.

*deteriorate*: Dr. Love's administrative incompetencies have severely deteriorated the quality of education for all children . . .

*stagnate*: Marxism has stagnated the economy.

One verb, *tarnish*, stands out because its probability of occurrence in a transitive construction is .98. We return to this verb, concluding that it was misclassified by Levin and Rappaport Hovav (1995) and that it is actually an externally caused change-of-state verb.

The statistics in Table 1 make clear that, contrary to past suggestions, inability to appear in transitive sentences is not a diagnostic for internally caused change-of-state verbs. At first, this might suggest that internal causation verbs can participate in the causative/inchoative alternation in the same way as external causation verbs do. The data presented in study 4 will show that this is not the case.

Although some of the internal causation verbs in Table 1 are quite likely to occur in transitive constructions, others are not. It might be, then, that even though transitivity cannot be used to diagnose individual verbs, it still points to a difference in the two classes of verbs: the internal class can contain verbs that rarely appear as transitives but the external class cannot. To test this possibility, we looked for externally caused change-of-state verbs with a low probability of occurring in transitive constructions. Again, using the *New York Times* part of the corpus, we calculated a ratio of the number of transitive uses divided by the total of the number of transitive plus intransitive uses. Table 2 shows fourteen of the external causation verbs we examined. The total number of tokens examined for these fourteen verbs ranged from 33 to 344; for only three was the number examined less than 100. The total number of transitive plus intransitive tokens for each verb ranged from 10 to 338. The statistics in the table show that, just as with the internal causation verbs, there are external causation verbs that occur rarely in transitive constructions. It is not the case, therefore, that only internally caused change-of-state verbs can have a low probability of occurring transitively. Some of the transitive uses of external causation verbs with a low transitive probability are:

*atrophy*: 'I wondered if sitting on the bench all last year would hurt me', he said. 'You know, atrophy my hitting muscles'.

*fade*: Will it [the April 3 New York primary] fade Jesse Jackson's rainbow?

*vibrate*: . . . extra power would vibrate the spacecraft . . .

The fourteen external causation verbs shown in Table 2 were chosen from among all the external cause verbs we examined for several reasons. First, they make the point

EXTERNAL CAUSATION VERBS				INTERNAL CAUSATION VERBS			
LOW		HIGHER		LOW		HIGHER	
VERB	PROB.	VERB	PROB.	VERB	PROB.	VERB	PROB.
TRANS.		TRANS.		TRANS.		TRANS.	
abate	.10	dissipate	.41	bloom	.00	blister	.22
atrophy	.03	fossilize	.60	deteriorate	.01	corrode	.63
awake	.05	fray	.52	germinate	.06	erode	.67
crumble	.05	redden	.24	rot	.08	ferment	.54
explode	.07	splinter	.49	rust	.14	sprout	.26
fade	.01	thaw	.61	stagnate	.02	swell	.37
shrivel	.11			wilt	.06		
vibrate	.03			wither	.12		
MEAN	.06	MEAN	.48	MEAN	.06	MEAN	.45

Note: There were two transitive sentences with *bloom*; rounding makes the entry .00.

TABLE 2. Probability of transitive construction.

that some external causation verbs rarely occur in transitive constructions. Second, they are matched in terms of their frequency of occurrence in English (Francis & Kucera 1982) with the fourteen internal causation verbs shown in the table: the mean frequency of occurrence for the external causation verbs is 6.6 and the mean for the internal causation verbs is 6.1. Third, the two sets of verbs are matched in the probabilities with which they occur in transitive constructions. This matching gives us reasonable sets of verbs with which to examine characteristics of the verbs' transitive and intransitive tokens in studies 2, 3, and 4. For example, in comparing the subjects of intransitives with external causation verbs against the subjects of intransitives with internal causation verbs (as in study 2), we avoid problems such as having the verbs of one set be rarer in the language than the verbs of the other set, or having the verbs of one set but not the other rarely occur as intransitives.

The crucial result of study 1 is that some internal causation verbs occur frequently in transitive constructions. This finding raises the question of how a verb whose semantic template specifies only a single event participant can be associated with a construction that has two syntactic arguments. We postpone addressing this question until study 4, first presenting studies 2 and 3 in which we consider another diagnostic that has been proposed for distinguishing internal from external causation verbs.

**4.2. STUDY 2: SUBJECTS OF INTRANSITIVE SENTENCES.** Some researchers have argued that internally caused change-of-state verbs are limited in the range of arguments that can occur as the *x* participant in their (become *x* (state)) template (Atkins & Levin 1995, Levin & Rapport Hovav 1995). The intuitive notion is that when an internal causation verb denotes an event, the event is construed as coming about only because of some internal property of the entity that is changing state, and so the set of possible entities that can undergo the change should be limited to those that have the required property. In other words, it might seem that only plants could be construed as blooming because only plants have the necessary internal properties. But examination of corpus sentences shows no significant difference between external causation and internal causation verbs in the distributions of the different kinds of entities that the verbs describe as changing state.

Table 3 shows the same verbs as Table 2. For each of the verbs, we looked at 100 sentences randomly chosen from the corpus and examined those in which the verb was used intransitively. We sorted the subjects of these sentences into the five categories shown in the table. Artifacts include all man-made things, Nature includes all natural entities (plants, beaches, seeds, wood, the air), Animate includes all volitional beings (mostly people), and Body Parts includes body parts of animate beings. The Abstract category was used for intangibles, events, and so on. Both authors sorted the subjects of the sentences independently, agreeing for 98 percent of the tokens (100 percent after conferring; this was true for all the categorizations reported in this article).

Analysis of variance on the numbers of sentences in the categories showed that there is no significant difference in the distributions of sentences across the categories for external versus internal causation verbs,  $F(4,104) = 1.0$ , ( $p < .05$  throughout this article). *Bloom* increases the number of tokens in the Nature category for internal causation verbs, and *awake* increases the number in the Animate category for external causation verbs, but overall the distributions are much the same. There is also no significant difference in the total numbers of sentences for external versus internal causation verbs, and there is no significant difference across the five categories in the numbers of sentences that appeared in each ( $F$ 's  $< 1.7$ ).



	ARTIFACTS	NATURE	ANIMATE	BODY PARTS	ABSTRACT
INTERNAL CAUSE					
blister	4		2	1	1
bloom	3	61	4	1	4
corrode	19			1	1
deteriorate	14	2	5	4	37
erode		2			12
ferment		11			3
germinate	1	35			6
rot	16	42	11	2	1
rust	46				1
sprout	23	15	2	14	4
stagnate	9	3	6		36
swell	6	11	9	11	11
wilt	4	12	15		2
wither	1	13	9	4	24
TOTAL:	146	207	63	38	143
EXTERNAL CAUSE					
abate		11			43
atrophy	4	1	2	16	21
awake	2	1	83		1
crumble	36	7	6	2	18
dissipate	4	11			17
explode	46	14	11	5	8
fade	6	6	14	4	29
fossilize		1			2
fray	9	1		3	11
redden	1	6	13	24	
shrivel	1	16	11	3	14
splinter	6	3	2		5
thaw	1	15	1	1	4
vibrate	36	6	5	7	9
TOTAL:	152	99	148	65	182

TABLE 3. Subjects of intransitive sentences.

What the data of Table 3 make apparent is that internal and external causation verbs can occur with the same categories of arguments as intransitive subjects. The internal causation verb *rust* and the external causation verb *crumble* both occur with artifact arguments—*rust* with metal objects that can rust and *crumble* with large structures that can crumble. *Bloom*, internal causation, and *shrivel*, external causation, both occur with plant arguments. People can *wilt* and *wither*, internal causation verbs, and they can *awake*, an external causation verb. All of the verbs except *redden* can occur with abstract arguments.

This result might seem puzzling at first. It contradicts the prediction of earlier researchers that internal causation verbs should be more limited than external causation verbs in their ranges of intransitive subjects. But this prediction overlooked the flexibility and creativity of language use. Many entities can be construed as blooming, for example, in a way consistent with *bloom*'s classification as an internal causation verb, that is, by means of some internal property. Not only flowers can be construed as blooming, but also hope, beauty, and even (perhaps) the Chicago Bears football team.

**4.3. STUDY 3: OBJECTS OF TRANSITIVE SENTENCES.** In an intransitive sentence with a change-of-state verb, it is the subject of the sentence that denotes the entity undergoing the change of state. For example, in *the pipes rusted*, the pipes are changing state. In

a transitive sentence, it is the entity in direct object position that is undergoing the change, as in *the salt water rusted the pipes*. Since earlier researchers predicted that the subject of an intransitive sentence with an internal causation verb would be restricted in range to those entities that have the internal property required by the verb, they also would have predicted that the objects of transitive sentences would have the same restriction. Study 3 disconfirms this prediction. Corpus sentences show the same result as for study 2: no difference between internal and external causation verbs in the distributions of entities described as changing state.

The direct objects of the transitive sentences summarized in Table 4 were categorized into the same five categories as were the subjects of intransitive sentences. The data are the direct objects of the full transitive sentences found among 50 randomly chosen sentences from the *New York Times* part of the corpus plus the direct objects from all the full transitives in all the other parts of the corpus. (Full transitives are sentences for which both subject and object are explicitly stated.) As with the subjects of intransitives, there is no significant difference between external causation and internal causation verbs in the distributions of the direct objects across the five categories ( $F(4,104) < 1.0$ ). There is also no significant difference in the total number of direct objects from sentences with internal causation verbs versus sentences with external causation verbs ( $F(1,26) < 1.0$ ).

	ARTIFACTS	NATURE	ANIMATE	BODY PARTS	ABSTRACT
INTERNAL CAUSE					
blister	3			8	
bloom		1			
corrode	19	1	2	4	22
deteriorate					3
erode	3	4			48
ferment	4				1
germinate					1
rot	2	3		1	2
rust	5				
sprout					
stagnate					1
swell	1	1		3	12
wilt		1			8
wither		7			3
TOTAL:	37	18	2	16	101
EXTERNAL CAUSE					
abate					15
atrophy				1	
awake	2	1	5		6
crumble	5	2			
dissipate		8			26
explode	10	2		2	6
fade					
fossilize	1		1		1
fray	1		1	5	35
reddden	1	5		15	
shrivel		2	1	1	7
splinter	6	3		2	22
thaw	7	12	5	1	23
vibrate	3		1	2	
TOTAL:	36	35	14	29	141

TABLE 4. Objects of full transitive sentences.

But, there is one point of difference between the distributions of direct objects of transitives and the distributions of subjects of intransitives: For the direct objects of transitives, there are significantly more direct objects in the Abstract category than in the other categories, which are all concrete kinds of entities ( $F(4,104) = 7.7$ ). This suggests an interesting difference between the kinds of entities that are described as undergoing a change of state in transitive compared to intransitive sentences. For transitive sentences, the proportion of such entities that are abstract is .57; for intransitive sentences, it is only .26. Why are transitive sentences more likely to be used when abstract entities change state? Perhaps, we speculate, for the speakers or writers of the sentences in the corpus, the concrete entities they spoke or wrote about were likely to change state through some inferable cause or means, whereas for abstract entities, the cause or means of a change of state more likely needed to be made explicit. While listeners or readers might be expected to know how beach erosion comes about, they might not be expected to know how erosion in public morals comes about.

Setting this point aside, the conclusion from studies 2 and 3 is clear: For the sentences with the change-of-state verbs we examined, there is no significant difference between external causation and internal causation verbs with respect to the categories of the entities described as changing state. Study 4 does find a significant difference between sentences with the two kinds of verbs, but it is a difference in the other participants involved in the change of state events, not the participants that change state.

**4.4. STUDY 4: SUBJECTS OF TRANSITIVE SENTENCES.** For change-of-state verbs, the subjects of transitive sentences denote the cause of the change of state or the means by which it comes about. It is here that the lexical semantic templates predict a difference between internal and external causation verbs.

For the external causation verbs, the lexical semantic template, (( $\alpha$ ) CAUSE (become  $x$  (state))), encodes a subevent separate from the change-of-state subevent. The subject of a transitive sentence is generally linked to this separate subevent. Because it represents a separate subevent, the subject is not tightly constrained by the change-of-state subevent. For *break*, for example, any of a large variety of kinds of entities and events (people, instruments, natural forces, activities, etc.) can be conceptualized as the cause of the breaking event.

For the internal causation verbs, in contrast, the lexical semantic template, (become  $x$  (state)), encodes only the change-of-state event, which has only the one structural participant,  $x$ . A second participant in the event is licensed not by the semantic template but instead by the content part of a verb's meaning. Because it is licensed by the content part of meaning and because it is part of the same subevent as the change of state, the participant should be an entity that is intrinsically involved in the change of state. If something is said to erode a beach, this cannot be just any something—not a person, not a shovel—it must be something that participates intrinsically in erosion, like wind or water.

It is therefore predicted that external and internal causation verbs differ in the ranges of entities appearing as subjects of transitive sentences: External causation verbs should allow a wider range of subjects. The relevant data are shown in Tables 5 and 6, which for each verb give the subjects of the full transitive sentences found among 50 randomly chosen instances of each of the verbs from the *New York Times* part of the corpus plus all the full transitives for each verb from the rest of the corpus. Table 5 gives the data for sentences with concrete direct objects and Table 6 gives the data for sentences with abstract direct objects.

	ARTIFACT	NATURE	ANIMATE	ABSTRACT
INTERNAL CAUSE				
blister	6	4	1	
bloom				
corrode		23		3
deteriorate				
erode		7		
ferment		2	2	
germinate				
rot		5		
rust		5		
sprout				
stagnate				
swell		3		2
wilt		1		
wither		7		
TOTAL:	6	57	3	5
EXTERNAL CAUSE				
abate				
atrophy				1
awake			3	4
crumble		1	5	1
dissipate	3	1	1	3
explode			10	4
fade				
fossilize			1	1
fray				7
reddden	2	8	1	8
shrivel		2		2
splinter	5	4		2
thaw	1	7	14	3
vibrate			2	4
TOTAL:	11	23	37	40

TABLE 5. Subjects of full transitive sentences with concrete objects.

When the entity that undergoes a change of state is concrete, such as an artifact or an animate being, then we can guess, and we can expect others to agree with us, what kinds of entities will be inherent to the change of state. Most of the internally caused change-of-state verbs, like *erode*, describe natural processes, and so it is natural forces (wind, heat, rain) that we expect to find as participants in internally caused changes of state. The data in Table 5 confirm this prediction: The subjects of transitive internal causation verbs are almost all natural entities (57 out of 71 instances); heat blisters, water corrodes, wind erodes, microorganisms ferment, water rots and rusts and swells, cold wilts, and summers wither, all natural forces participating in internally caused events. There are few instances of other kinds of subjects. The few exceptions occur when people are indirectly responsible for an event (blistering paint or fermenting beer) or when abstract entities are expressed as responsible, perhaps metaphorically, as in *a face corroded by jealousy* or *French hearts swelled by righteous outrage*.

For externally caused change-of-state verbs, in contrast, the data show no restriction on the entities that appear in subject position—the subjects are distributed across all four categories. The difference in the distributions of subjects in Table 5 for internal and external causation verbs is significant by analysis of variance,  $F(3,78) = 4.6$ . Representative tokens for the externally caused verbs (other than those with people as subject) include: *earthquakes crumble freeways*, *terror awakes a person*, *wind dissi-*

	ARTIFACTS	NATURE	ANIMATE	ABSTRACT
INTERNAL CAUSE				
blister				
bloom				
corrode		1	2	19
deteriorate				3
erode			5	43
ferment			1	
germinate				1
rot	1			1
rust				
sprout				
stagnate				1
swell			2	10
wilt		1		7
wither				3
TOTAL:	1	2	10	88
EXTERNAL CAUSE				
abate			9	6
atrophy				
awake			2	4
crumble				
dissipate		1	10	15
explode			3	3
fade				
fossilize				1
fray			1	34
reddden				
shrivel				7
splinter			2	20
thaw			9	14
vibrate				
TOTAL:	0	1	36	104

TABLE 6. Subjects of full transitive sentences with abstract objects.

*pates gases, the texture of leaves explodes raindrops, necessities fossilize a (rock) band, abstract events fray nerves, man-made-chemicals reddden tomatoes, Bush's gaffe redddens Republican faces, droughts shrivel crops, ordeals shrivel people, hurricanes splinter trees, the sun thaws soil, success thaws people, and power vibrates a spacecraft.*

In sum, when the entity undergoing a change of state is concrete, internal and external causation verbs differ significantly in the range of entities that appear as their transitive subjects. In contrast, sentences that describe abstract entities changing state show a different picture. When an abstract entity is conceptualized as undergoing an internally caused change of state, almost anything can be construed as a contributing factor, inherent to the change-of-state process. Many things can be construed as being involved in *rotting the minds of the young*, ranging from natural substances to other people to behaviors (the corpus sentence said that movies, which we classify as artifacts, *rot the minds of the young*). Table 6 shows the data for transitive sentences when the direct object is an abstract entity (such as minds). There is no apparent difference between the kinds of entities that appear as subjects for the external and internal causation verbs. The notable aspect of the data is the preponderance of abstract subjects: When an abstract entity is described as changing state, it is most often something else abstract that contributes to the change. Examples from the corpus include: *the music industry is being rusted away by home taping* and *drastic fines abated global warming*. The

larger number of abstract than other categories of subjects is significant by analysis of variance,  $F(3,78) = 96.9$ .

We draw two important conclusions from the data of study 4. First, for concrete entities undergoing a change of state, we have identified a statistically reliable difference between sentences with internal versus external causation verbs, supporting a distinction between the two classes of verbs. The verb *tarnish* illustrates that the difference between the two classes of verbs can be used as a diagnostic. In discussion of study 1, we suggested that *tarnish* might have been misclassified as an internal causation verb by Levin and Rappaport Hovav (1995). It should instead be classified as an external causation verb because the subjects of transitive uses of *tarnish* fit the pattern for external causation verbs, not internal causation verbs. For the 11 full transitive *tarnish* sentences in the corpus, 3 have animate subjects and the other 8 have abstract subjects.

The second conclusion from study 4 concerns the data for the sentences describing abstract entities changing state; these data emphasize that speakers and writers use the verbs to place a particular construal on an event. In describing the effect of movies on young minds as rotting, the writer conveys a metaphorical, internally caused process that is abetted by the negative qualities of movies.

**4.5. DISCUSSION.** The corpus data from the four studies show how creatively and flexibly language is used. All manner of things can be construed as capable of blooming, movies can be construed as inherent to mental processes, and so on. Corpus data remove the limitations of our abilities to generate examples, and in so doing, allow us to discern patterns of usage that would not be apparent in the sentences we alone could produce.

At the same time, however, speakers and writers do not use language completely freely. The data for subjects of transitive sentences with concrete objects (Table 5) show a constraint: For internally caused change-of-state verbs—verbs that mostly refer to the changes of state of natural entities—the participant that is not the one changing state is generally a natural force. To be sure, speakers and writers can, on occasion, violate the constraint. They can use language figuratively, as when hearts are swelled by outrage, and they can extend a verb's template to add an animate instigator of an internal process, as when people ferment wine (Levin & Rappaport Hovav 1995, Rappaport Hovav & Levin 1998), although this appears to happen rarely. Also, of course, speakers and writers make errors. But statistically, as shown in Table 5, the subject of a transitive use of an internal causation verb is constrained to be a natural force that can participate in the event described by the internal causation verb.

The corpus data, therefore, establish a diagnostic with which to distinguish between internally and externally caused change-of-state verbs. The verbs are distinguished not by their abilities to occur in transitive constructions, nor in their ranges of entities that can undergo a change of state (their intransitive subjects and transitive objects), but rather in their ranges of transitive subjects. This finding accords with the lexical semantic templates that have been proposed for the verbs. The templates represent internally caused verbs as describing events in which an entity undergoing a change of state is also responsible for the change; control cannot be given up to any other entity. Thus, when internal causation verbs are used transitively, the entity in subject position does not control the change of state but rather is an inherent participant in it. It follows, therefore, that the entities that appear as transitive subjects for internal causation verbs are generally restricted to entities that can participate in the denoted change of state. In contrast, for external causation verbs, there is no such restriction.

**5. PSYCHOLINGUISTIC EXPERIMENTS.** We began with the hypothesis that the processes by which people produce and understand sentences are sensitive to the differences

in meaning that are made explicit in the verbs' lexical semantic representations. For production, the corpus data show a difference between the sentences people produce with externally caused change-of-state verbs versus the sentences they produce with internally caused change-of-state verbs, and the nature of the difference is predicted by the verbs' lexical semantic representations. We turn now to psycholinguistic experiments to investigate sentence comprehension.

The representations we assume are repeated here, for externally caused change-of-state verbs:

(( $\alpha$ ) CAUSE (BECOME (x (STATE))))),

and for internally caused change-of-state verbs:

(BECOME (x (STATE))).

The representation for external causation verbs is more complex in that it is made up of two subevents compared to only one for internal causation verbs. We assume that understanding a sentence requires understanding the relations given by the sentence's verb via its lexical semantic representation. Our prediction, therefore, is simply that sentences with external causation verbs will take longer to understand than sentences with internal causation verbs. In experiment 1, we tested this prediction with intransitive sentences and in experiment 2, we tested it with transitive sentences.

Our predictions and assumptions contrast sharply with a view that is currently popular in psycholinguistics, namely, that language behavior is largely determined by statistical regularities in language use. MacDonald et al. (1994) espouse a prototypical version of this view. In their model, the lexical entry for a verb includes all of the argument structures and syntactic structures in which it can occur along with the frequency of occurrence of each structure. For example, the representation of *thaw* would include its possible argument structures ( $\langle$ agent, patient $\rangle$  for *John thawed the turkey*;  $\langle$ patient $\rangle$  for *the turkey thawed*;  $\langle$ agent, patient $\rangle$  for *the turkey was thawed*) and its possible syntactic structures (transitive for *John thawed the turkey* and *the turkey was thawed by John*; intransitive for *the turkey thawed*), with each argument structure linked to its appropriate syntactic structure. With each possible argument structure-syntactic structure combination is stored its frequency of occurrence in the language. It is assumed that the human sentence processor makes use of the frequency information in such a way that a sentence of a more frequent type for a verb will take less time to comprehend than a sentence of a less frequent type for that verb. Models like this in which language processing is based on statistical information have been labeled **CONSTRAINT-BASED MODELS** to indicate that processing depends not only on the various structures in which some linguistic element can and cannot occur but also on real-world constraints imposed by the statistics of how the element has been used in the language.

We implemented a test of constraint-based models by varying the probabilities with which verbs occur in transitive versus intransitive constructions in the corpus. The verbs used in intransitive sentences in experiment 1, listed in Table 2, orthogonally manipulate external versus internal causation and the probability of occurrence in transitive versus intransitive constructions. For the 14 internal causation verbs, eight had low probabilities of occurring in transitive constructions (mean = .06) and six had much higher probabilities (mean = .45). Likewise, for the 14 external causation verbs, eight had low probabilities (mean = .06) and six had much higher probabilities (mean = .48).

In both experiments, we used an acceptability judgment task: For each sentence in an experiment, subjects were asked to decide, yes or no, whether they thought it was

an acceptable sentence. The acceptability judgment task was used because, when the unacceptable sentences are completely unacceptable, as they were in experiments 1 and 2, the task gives a good measure of the differences in comprehension times between sentences of different amounts of processing difficulty. When the unacceptable sentences are completely unacceptable, the judgment part of responding to a sentence is easy, as it is in this sample sequence from experiment 1: *The bed lay a permit, The wiring walked, The flowers bloomed, The award retreated, The wind abated, Love slept the chair*. Because making the judgment is so easy, it takes up relatively little of the total processing time for a sentence, so that much of the response time for a sentence reflects the processes of understanding the sentence. In addition, the task is well suited for measuring comprehension because a high level of accuracy requires subjects to comprehend the sentences. Lack of comprehension is reflected in errors. Finally, the task is attractive because subjects can be instructed to respond as quickly as possible, thus keeping to a minimum variance in response times that is extraneous to variables of interest, while still requiring good comprehension to keep accuracy levels high.

**5.1. EXPERIMENT 1.** In experiment 1, one acceptable intransitive sentence was constructed for each of the 28 verbs in Table 2. If the complexity of a verb's lexical semantic template plays a role in comprehension, then responses for sentences with internal causation verbs should be faster than responses for sentences with external causation verbs. If occurrence statistics play a role in comprehension, then responses for sentences with verbs more likely to occur in intransitive constructions should be faster than responses for sentences with verbs less likely to occur in intransitive constructions.

#### METHOD

##### Materials

The sentences constructed for the internal causation verbs were matched to the sentences constructed for the external causation verbs on several dimensions. The mean Kucera-Francis (Francis & Kucera, 1982) frequencies of the verbs were 6.1 for internal causation verbs and 6.6 for external causation verbs. Each sentence contained exactly three words: an article or possessive pronoun, a noun, and the verb, the verb always in past tense. Each sentence with an internal causation verb was paired with a sentence with an external causation verb of about the same Kucera-Francis frequency, and the Kucera-Francis frequencies of the nouns of the two sentences were also roughly equal. The sentences are shown in Appendix 1.

The sentences were closely modeled on intransitive uses of the verbs in the corpus. For each verb, the noun that was the subject of the experimental sentence was (in all but three cases, two external causation verbs and one internal causation verb) the kind of entity that was most frequently used as subject for that verb in intransitive constructions in the corpus: *The wind abated* was taken from corpus sentences about wind abating and *The flowers bloomed* was taken from corpus sentences about flowers blooming.

There were also four sets of filler sentences that were not part of the experimental design: 72 acceptable transitive sentences, 72 unacceptable transitive sentences, 12 acceptable intransitive sentences, and 30 unacceptable intransitive sentences. These sentences were included in the experiment so that there would be an approximately equal number of acceptable and unacceptable sentences, and so that there would be some variety in the types of sentences. Typical examples of the unacceptable fillers



are: *The philosophers smiled directions*, *The teacher roared the old computer*, *The toaster allowed*, and *The license told*.

### Procedure

All stimuli were displayed on the screen of a PC monitor. The experiment began with 35 lexical-decision test items, used for practice with the PC keyboard. Then the experimental and filler sentences were displayed in 14 lists of 12 sentences per list. At the beginning of each list, subjects pressed the space bar to begin the list. The sentences were then displayed one at a time. Subjects were to read each sentence and press the ⟨?/⟩ key if it was an acceptable sentence, the ⟨z⟩ key if it was not. After a key press, the screen was cleared and there was a 500 ms pause before the next sentence.

Each list of 12 sentences consisted of one experimental sentence with an external causation verb, one with an internal causation verb, and 10 fillers, four acceptable and six unacceptable. The sentences were presented in random order except that each of the two experimental sentences was immediately preceded by an acceptable filler.

### Subjects

Twenty Northwestern University undergraduates participated in the experiment for credit in an introductory psychology course. All the subjects for the experiments reported in this article are native speakers or have spoken English at least since the age of five. Although the Kucera-Francis frequencies for some of the verbs used in the experiments are low, the verbs are known by the Northwestern undergraduate population, as evidenced by lexical decision experiments we have conducted in which accuracy on the verbs is about 95 percent or better.

### RESULTS

For the experimental sentences, mean judgment times for correct responses were calculated for each subject and each item, and means of these means along with probabilities of 'yes, acceptable', responses are shown in Table 7. Mean judgment time for correct responses to acceptable filler sentences was 2080 ms (.92 probability of a 'yes' response) and mean judgment time for correct responses to unacceptable filler sentences was 2103 ms (.86 probability of a 'no' response).

The data of experiments 1 and 2 were analyzed by analyses of variance with subjects as the random variable, reported as F1, and with sentences as the random variable, reported as F2.

As predicted from the relative complexity of the internal versus external causation verbs' lexical semantic templates, judgments for sentences with external causation verbs took significantly longer than judgments for sentences with internal causation verbs, about 150 ms longer,  $F(1,19) = 5.4$  and  $F(2,1,26) = 4.5$ . The standard error of the means was 48 ms.

Sentences with external causation verbs were also less likely to be judged acceptable. One sentence with an external causation verb, *The bullet splintered*, was judged unac-

	EXTERNAL CAUSE		INTERNAL CAUSE	
	JUDGMENT TIME (MS)	PROBABILITY 'YES'	JUDGMENT TIME (MS)	PROBABILITY 'YES'
All sentences	1551	.91	1400	.96
Low probability transitive	1561	.92	1392	.96
Higher probability transitive	1538	.90	1413	.96

TABLE 7. Results for experiment 1.

ceptable with probability .50, for which we have no explanation. The mean probability of a 'yes' response given in Table 7 does not include this sentence. Without this sentence, the difference in probability of 'yes' responses between sentences with external causation verbs and internal causation verbs was not significant,  $F(1,19) = 2.9$  and  $F(1,26) = 2.6$ .

In contradiction to constraint-based models, the data in Table 7 show that the internal-external difference held whether the sentences contained verbs with low probabilities of occurring in transitive constructions or higher probabilities, and that low versus higher probability of transitive usage did not significantly affect judgments. Despite the fact that the difference in transitive usage probabilities was large (about .06 versus .46), mean judgment times and probabilities of 'acceptable' judgments for sentences with verbs of low versus higher transitive probabilities were within one standard error of each other.

The Kucera-Francis frequency values for the verbs had a mean of only about 6, and nine of the internal causation and nine of the external causation verbs had frequencies less than 6. We checked that the internal-external difference held for these verbs that occur relatively rarely, and it did: The means were 1469 ms (.94 probability of a 'yes' response) for the sentences with internal causation verbs and 1577 ms (.87 probability of a 'yes' response) for the sentences with external causation verbs.

Finally, we looked at whether pre-experimental associations between the words in a sentence could have affected judgment times. We paired the noun and verb from each sentence (e.g., for the sentence *the flowers bloomed* the pair was *flowers-bloom*) and asked twelve subjects to rate how related the words of each pair were on a scale of 1 to 5 (5 = most related). The mean rating for the pairs from the external causation verb sentences was 2.83, lower than the mean for the pairs from internal causation verb sentences, 3.60. However, for seven of the external and seven of the internal pairs, the mean ratings were approximately equal (averaging 3.42 and 3.25, respectively). For these sentences, the internal-external difference in judgment times was still large, 1419 ms (.95 probability of responding 'yes') and 1580 ms (.91 probability of responding 'yes').

Considering all the sentences, pre-experimental associations had only a small and unreliable effect on sentence judgments. For the external causation verb sentences for which the word pairs had ratings higher than the mean rating, sentence judgment times averaged 1580 ms (.91 probability of a 'yes' response; mean rating = 3.33), SLOWER than the judgment times for sentences for which the pairs had ratings lower than the mean; for these sentences, judgment times averaged 1515 ms (.92 probability of a 'yes' response; mean rating = 1.94). The same comparison for the sentences with internal causation verbs (mean rating = 3.60) gave mean judgment times FASTER when the rating was higher: 1378 ms (.96 probability of a 'yes' response; mean rating = 4.22) and 1414 ms (.96 probability of a 'yes' response; mean rating = 3.26). What is noteworthy is that the effect of pre-experimental associations between the two content words of a three-word sentence on acceptability judgments is not reliable, in comparison to the large and reliable effect of internal versus external causation verbs.

**5.2. EXPERIMENT 2.** Experiment 1 shows that a three-word intransitive sentence takes longer to judge acceptable when its verb is an externally caused change-of-state verb than when it is an internally caused change-of-state verb. Judgment times were affected by this difference in causality, a difference captured by the verbs' lexical semantic representations. Judgment times were not significantly affected by differences in the

frequency with which a verb is used transitively nor by differences in how strongly associated pre-experimentally the verb is to the noun in its sentence.

The aim of experiment 2 was to replicate the external-internal difference in judgment times with transitive sentences. If the difference in judgment times observed with intransitive sentences is due to a difference in lexical semantic representations, then judgment times for transitive sentences should be longer with external than with internal causation verbs, just as they were for intransitive sentences.

The design of experiment 2 was the same as that of experiment 1, with sentences for 14 external causation verbs and 14 internal causation verbs. For each of the two sets, the probability that the verbs occur in transitive sentences in the corpus was very low for eight of the verbs and higher for six of the verbs.

#### METHOD

##### Materials

All but four of the verbs were the same as those used in experiment 1. Four replacements were used to allow us to better match the sentences with external causation verbs to the sentences with internal causation verbs. The external causation verbs, *fade*, *shrivel*, *fossilize*, and *splinter* were replaced with *proliferate* (probability transitive = .02), *mellow* (probability transitive = .15), *oxidize* (probability transitive = .21), and *stiffen* (probability transitive = .62). With these replacements, the mean Kucera-Francis frequency for the external verbs was 5.4, the mean probability transitive for the eight low probability verbs was .06, and the mean probability transitive for the six higher probability verbs was .44. The same set of internal causation verbs was used as in experiment 1, and so their statistics are the same as reported there.

For each verb, two acceptable transitive sentences were constructed. The sentences all had the structure NP V NP. In all cases, the subject and object noun phrases for each verb were typical of those found with the verb in transitive sentences in the corpus. For example, we found *explode* occurring in a full transitive sentence most often with people exploding bomblike things, so the experimental sentences with *explode* used people as their subjects and nuclear devices and missiles as their objects. *Wilt* usually occurs in transitive sentences with heat or the sun as subject and plants or (groups of) people as object. Accordingly, we constructed experimental sentences with *wilt* that used heat and the sun as subjects and people and plants as objects. The sentences are shown in Appendix 2.

Across all the sentences, the mean number of words per sentence was 5.61 for the sentences with external causation verbs and 5.68 for the sentences with internal causation verbs. Each sentence with an external causation verb was paired with a sentence with an internal causation verb of about the same Kucera-Francis frequency, and the frequency values of the words in the sentences other than the verb were also roughly equated.

There were also pools of filler sentences: 100 acceptable and 86 unacceptable, that were not part of the experimental design. The fillers included a variety of transitive and intransitive sentence structures. Examples of unacceptable sentences are: *Quality drifted the portrait*, *A girl yelled the stool*, *The meaning loves my dog*, *The restaurant proved*, *The toaster allowed*.

##### Procedure

The procedure was generally the same as for experiment 1. The experimental and filler sentences were displayed in 14 lists of 18 sentences per list. Each list of 18 sentences was made up of two sentences with external causation verbs, two with internal

causation verbs, eight acceptable filler sentences, and six unacceptable filler sentences. For each verb, the two sentences that used that verb did not appear in the same list. Half of the experimental sentences were immediately preceded by an acceptable filler sentence (the results were not significantly affected by this manipulation). Otherwise, the order of the sentences in a list was randomly determined.

#### Subjects

Twenty Northwestern University undergraduates participated in the experiment for credit in an introductory psychology course; none of them had participated in experiment 1.

#### RESULTS

The mean judgment times for correct response times for each subject and item were calculated for the experimental sentences, and means of these means, along with probabilities of a 'yes, acceptable' response, are displayed in Table 8. For the filler sentences, the mean response time for correct responses to acceptable fillers was 1934 ms (.89 probability of 'acceptable') and the mean for correct responses to unacceptable fillers was 2004 ms (.82 probability of 'unacceptable').

As predicted from the verbs' lexical semantic templates, judgment times were significantly longer for sentences with external causation verbs than for sentences with internal causation verbs,  $F(1,19) = 6.2$  and  $F(1,13) = 5.4$ . The standard error of the mean judgment times was 32 ms. Subjects were also less likely to judge sentences with external causation verbs acceptable,  $F(1,19) = 20.0$  and  $F(1,13) = 11.7$ .

For verbs with Kucera-Francis frequencies less than the overall mean frequency (less than 6), the external-internal difference was still large: 2284 ms (.84 probability of a 'yes' response) versus 2151 ms (.97 probability of a 'yes' response), respectively.

Table 8 shows the data broken down by the verbs' low versus higher probabilities of transitive usage. For internal causation verbs, sentence judgment times were slower for the verbs with low probability of transitive usage, an effect that was not significant,  $F's < 2.5$ . For external causation verbs, sentences were less likely to be judged acceptable for the verbs with low probability of transitive usage, significantly so for the analysis with subjects as the random variable ( $F(1,19) = 17.9$ ) but not with items as the random variable ( $F(2,12) = 3.9$ ). The speed/accuracy trade-off in the data makes it difficult to assess the effect, but in general, there appears to be no reliable effect of probability of transitive usage. The main point is that the external-internal difference appears reliably both for verbs of low and higher probabilities of transitive usage.

Another way to test the constraint-based processing view is to consider the match between the experimental sentences and sentences that are naturally produced. For the six external causation and six internal causation verbs with higher probabilities of occurring in transitive sentences in the corpus, we looked at whether the probability with which the experimental sentences were matched by corpus sentences affected

	EXTERNAL CAUSE		INTERNAL CAUSE	
	JUDGMENT TIME (MS)	PROBABILITY 'YES'	JUDGMENT TIME (MS)	PROBABILITY 'YES'
All sentences	2220	.86	2069	.96
Low probability transitive	2230	.81	2131	.96
Higher probability transitive	2210	.93	1963	.96

TABLE 8. Results of experiment 2.

judgment times. For example, if the subject of the experimental sentence was a person and the object was a man-made thing, then we calculated the probability with which person-man-made-thing sentences appeared among the full transitives in the corpus. A constraint-based model might predict that sentences more like those frequently used in the language would have shorter judgment times than sentences less like those frequently used. For each of the two sets of sentences, we calculated the mean probability of corpus match and then divided them into three sentences for which the probability was above the mean and three for which it was below the mean. For the internal causation verbs, the experimental sentences that were more like the corpus sentences had SLOWER judgment times (2039 ms, .96 probability of a 'yes' response) than the experimental sentences that were less like the corpus sentences (1888 ms, .96 probability of a 'yes' response), and for the external causation verbs, the judgment times were about the same whether the experimental sentences were more or less like corpus uses of the verbs (for the higher probability of match sentences: 2207 ms, .91 probability of a 'yes' response, and for the lower probability of match sentences, 2214 ms, .94 probability of a 'yes' response).

To check whether pre-experimental associations among the content words of the sentences could have affected the results, we asked subjects (who had not participated in experiments 1 or 2) to rate pairs of words from the sentences according to how related they were (on a scale of 1 to 5, 5 = most related). For each sentence, there were three pairs to be rated, the subject noun and the verb, the verb and the object noun, and the subject noun and the object noun. Four subjects rated each one of the pairs (12 subjects total). The mean rating for the pairs from sentences with external causation verbs was 2.58, and for internal causation verbs it was 2.96. Eliminating three of the internal causation verbs' sentences changed the mean rating for the remainder of the internal causation verb sentences to 2.65, roughly equal to the rating for the external causation verb sentences. Eliminating these three items from the analyses of judgment times, the mean for internal causation sentences was 2078 ms (.96 probability of a 'yes' response), little different from the mean for all the internal causation sentences.

Combining all the sentences, there was no significant effect of pre-experimental relatedness. We combined judgment times for the higher rated half of the external and internal causation sentences and compared them to judgment times for the lower rated half; the means were 2128 ms (.92 probability of a 'yes' response) and 2144 ms (.91 probability of a 'yes' response), respectively, not significantly different ( $F$ 's  $< 1.0$ ).

**5.3. SUMMARY OF EXPERIMENTS.** Experiments 1 and 2 show processing differences between sentences with internally caused change-of-state verbs and sentences with externally caused change-of-state verbs. Judgment times were longer for sentences with external causation verbs, with both transitive and intransitive sentences. Neither probability of transitive use of a verb, nor pre-experimental associations between a verb and the other words in its sentences, could account for the observed differences in judgment times. The data, therefore, provide strong empirical support for the psychological reality of differences between the two classes of verbs, differences that are in accord with their lexical semantic templates.

**6. GENERAL CONCLUSION.** We began with the hypothesis that verbs describing externally caused changes of state are more complex than verbs describing internally caused changes of state because the external causation verb has two subevents in its lexical semantic representation, whereas the internal causation verb has only one. This hypothesis was originally supported with intuitions about verb meanings (Levin & Rappaport

Hovav 1995, Smith 1970), but in this article empirical support is provided with corpus data and psycholinguistic experimental data.

In the corpus data, the observed difference between sentences with external causation verbs and sentences with internal causation verbs reflects the difference in the verbs' lexical semantic templates. For externally caused change-of-state verbs, the lexical semantic template (( $\alpha$ ) CAUSE (become ( $x$  state))) represents the causing event ( $\alpha$ ) as relatively independent of the change of state. Thus, the kinds of entities that can figure in the causing event should be relatively unrestricted. The corpus data confirmed this prediction; the subjects of transitive sentences with external causation verbs were spread across artifacts, natural entities, animate beings, and abstract entities and events.

In contrast, in the lexical semantic template of an internally caused change-of-state verb, (become ( $x$  (state))), there is only the single change-of-state event with only the one structural participant ( $x$ , the entity that changes state). If there is a second participant, it is licensed by the content part of the meaning, and it should be an inherent participant in the event, that is, an inherent participant in the change of state. Consistent with this analysis, the entities that appeared as transitive subjects of corpus sentences were restricted in range: Internally caused change-of-state verbs generally describe natural changes of state and, when the entities described as changing state were concrete, the subjects of transitive sentences with these verbs were mostly natural forces.

The contrast between the ranges of the transitive subjects for the internally versus externally caused change-of-state verbs provides a diagnostic for distinguishing the two classes of verbs. Defined as it is in terms of the kinds of entities participating in the events described by the verbs, it is a semantic diagnostic. This is appropriate, given that the postulated theoretical distinction between the classes lies in their semantic template.

We stress, however, that the diagnostic is not exact and that there is an important reason why it is not: A verb is used to denote a conceptualization of an event. Although there may be many ways to describe an event, a speaker or writer chooses a verb to present one particular conceptualization. For example, the sad state of the pyramids might be construed as internally caused and so described as *deteriorating*, or it might be construed as externally caused and so described as *crumbling*. Moreover, both *deteriorate* and *crumble* can be used not only to describe pyramids but also people, society, morals, minds, the quality of education, and many other things. The variety of events to which speakers and writers can apply a single verb is wide, and it is made especially wide by figurative and metaphorical uses.

Given the flexibility and creativity of verb usage, it might be thought surprising that a diagnostic based on verb usage can actually distinguish internally from externally caused change-of-state verbs. The verbs of both classes describe change-of-state events, and, in many cases, the difference between describing a change-of-state event as internally versus externally caused is difficult, intuitive, and based on subtle considerations. Nevertheless, the corpus data show that users of language do, statistically, obey the different constraints of the lexical semantic templates of the verbs of the two classes.

We have not yet discussed how the lexical semantic templates of the internal and external causation verbs are associated with the syntactic structures of the sentences in which the verbs appear. There are two components to the syntax-semantics interface. First, an assumption common in the literature is that, in order for sentences to be interpretable, elements in the syntax must be linked to the semantic representation, and elements in the semantic representation must be realized in the syntax. Recent proposals (e.g., Grimshaw & Vikner 1993, Rappaport Hovav & Levin 1998, Van Hout 2000)

have extended such well-formedness conditions to event-based lexical semantic representations, so that each event or subevent must be identified by an element in the syntax. Second, there is the question of how event participants specified in the semantic representation are associated with specific syntactic positions. This is generally effected by linking rules (Dowty 1991, Jackendoff 1990, Levin & Rappaport Hovav 1995, 1996, van Valin & LaPolla 1997). While any of these systems should be adaptable to our data, for expository purposes, we follow Dowty (1991), who lists five proto-agent properties: volitional involvement in the event described by the verb, sentience, causing the event, movement (relative to another participant in the event), and existence independent of the event; and five proto-patient properties: undergoing a change of state, being the incremental theme of the event, being causally affected by another participant, being stationary relative to movement of another participant, and not having an independent existence. Dowty's selection principle states that the argument with the greater number of proto-agent properties becomes the subject and the argument with the greater number of proto-patient properties becomes the direct object in a transitive construction. For externally caused change-of-state verbs, then, argument realization is fairly straightforward: The external cause will become the subject of a transitive use and the entity changing state will become the direct object. For an intransitive use of an external causation verb, our claim is that the lexical representation of the verb is still the same—that it still has the external cause subevent—but this information is unexpressed in an intransitive use. We leave open the question of how this occurs (Levin & Rappaport Hovav 1995 suggests existential binding). But however it occurs, the single expressed argument, the entity that changes state, is lexicalized in direct object position, thus giving rise to the unaccusative behavior characteristic of these verbs (Levin & Rappaport Hovav 1995).

For intransitive uses of internally caused change-of-state verbs, the mapping from lexical structure to syntax is the same as for the intransitive uses of externally caused change-of-state verbs. The single expressed argument is the entity affected in the change of state and so it is lexicalized as direct object, again giving rise to unaccusative behavior (Levin & Rappaport Hovav 1995). For transitive uses of the internal causation verbs, both the affected participant (*x*) and the optional participant inherent to the change of state are expressed. The optional participant has one proto-agent property, independent existence, whereas the affected participant has no proto-agent properties and several proto-patient properties; thus the optional participant is lexicalized as the transitive subject.

The corpus data brought to light sentences with internal causation verbs used in transitive constructions, sentences that were unexpected given previous research. Nevertheless, the analysis of the sentences in terms of Dowty's linking system shows that these sentences and how they are mapped from their verbs' underlying semantic representations can be understood in terms of syntax-semantics mappings that had already been proposed for other phenomena.

Turning now to the psycholinguistic experiments, sentences with external causation verbs had longer acceptability judgment times than sentences with internal causation verbs, as would be expected from the greater complexity of the structures of the external causation verbs. It is important to note how large the external-internal difference in judgment times was. In experiment 1, the difference was about 150 ms on a baseline of about 1500 ms, and in experiment 2, the difference was about 200 ms on a baseline of about 2200. In both cases, the effect size is about 10 percent, quite large for sentence acceptability judgments. We suggest that the elements of meaning reflected in the lexical

semantic representation of a verb have a relatively large effect on the comprehension processes that understand a sentence using the verb.

Overall, then, both the corpus and the experimental data are remarkably in accord with the hypothesized event-based lexical semantic representations. But is there another possible interpretation of the data? One possibility is that the observed differences come from the content parts of the meanings of the verbs, not the structural part that is captured in the lexical semantic template. To our knowledge, there is no articulated theory of content meaning that would predict the observed data, that is, no theory of content meaning distinguishes between all verbs of externally caused change of state on the one hand and all verbs of internally caused change of state on the other.

Although the data are in accord with the lexical semantic structures we have postulated, the essential characteristics of the structures could be rewritten in other theoretical systems. The approach proposed in Jackendoff 1996 serves as an example. Jackendoff represents the events denoted by verbs as relations among entities, with the relations evolving over time. For externally caused changes of state, we could assume that the causing subevent occurred independently of the change-of-state subevent, with each subevent evolving across its separate time course (with the restriction that the causing subevent would have to begin before the change-of-state subevent). For internally caused changes of state, we could assume that the single subevent evolved through time as the changing entity progressed into its new state. If, as with the verbs we studied, a natural force was inherently involved in the process, then that force could be bound through time to the progress of the change of state. With these assumptions, the representation of an externally caused event would be more complex than the representation of an internally caused event, and if the representations underlying the verbs were assumed to be the same whether the verbs were used transitively or intransitively, then the representations would be consistent with the data we have presented.

Our data could also be viewed as consistent with Goldberg's constructionist theory of lexical structure (Goldberg 1995). In this theory, the lexical representation of a verb lays out the participants in the event denoted by the verb, and whichever of the participants are obligatorily expressed are said to be 'profiled'. For internal causation change-of-state verbs, the participant changing state would be profiled and the other, optional, participant that we have labeled *y* would not be. For external causation verbs, the participant changing state would be profiled and participant(s) involved in the causing event ( $\alpha$ ) would not be. Goldberg assumes that the same lexical representation underlies all constructions in which a verb is used, and so her theory would be consistent with our data.

The strongest aspect of the psycholinguistic data in terms of placing constraints on theory is that the difference in acceptability judgment times between external and internal causation verbs appeared with both transitive and intransitive sentences. Our interpretation of this finding is that, for any verb that is not ambiguous, the lexicon contains a single lexical semantic structure for the verb, and this structure is always involved in comprehension of sentences in which the verb is used, no matter what the sentences' syntax. In other words, an intransitive sentence with an external causation verb (e.g., *atrophy*) is understood as denoting a complex event with an external cause subevent as well as a change of state even though no external cause is specified. And a transitive sentence with an internal causation verb (e.g., *erode*) is understood as denoting a single event with the entity in subject position being part of the change-of-state event.

This interpretation runs counter to other claims in the literature. In some approaches (Pustejovsky 1991, van Valin & LaPolla 1997), it has been proposed that change-of-



state verbs have different representations in their transitive and intransitive uses. The representation of *John closed the door*, with the external causation verb *close*, includes a causing subevent while the representation of *The door closed* does not. By this view, *closed* in *The door closed* would have the same, single-event, structure as internal causation verbs, thus predicting no difference in comprehension times between intransitive sentences with internal causation verbs and intransitive sentences with external causation verbs.

Most saliently, our data contradict J. A. Fodor's frequent claim (e.g., Fodor et al. 1975, Fodor et al. 1980, Fodor & Lepore 1998) that there exist no psycholinguistic data that support the notion of lexical decomposition. To be sure, the decomposition of verbs into the event structures described in this article is quite different from the decomposition of *bachelor* into *unmarried man*, the kind of decomposition that Fodor has often discussed (see also Kintsch 1974). Nevertheless, event structures are decompositions of a part of verb meaning, and we believe we have presented strong evidence in support of such decompositions.

The most compelling aspect of the data presented here is the power gained by combining corpus analysis and psycholinguistic experimentation with linguistic theory, demonstrating how theoretical work and empirical work can inform each other. Current work in lexical semantics has provided a fine-grained and broad-based approach to the theoretical treatment of verbs. Our empirical results support one view of verbs' lexical semantic structures, disconfirm possible alternative views, and also raise questions of theoretical linguistic interest. In addition, the convergence of linguistic theory and empirical data allowed us to find differences in the processing of causative and noncausative verbs, showing evidence for the psychological reality of lexical decomposition, evidence that in the past has proved elusive (Kintsch 1974, Fodor et al. 1975).

#### APPENDIX 1: SENTENCES USED IN EXPERIMENT 1

##### EXTERNAL CAUSATION VERBS

The wind abated.  
His skills atrophied.  
The residents awoke.  
The concrete crumbled.  
The missile exploded.  
The signal faded.  
The crops shriveled.  
The fan vibrated.  
The smoke dissipated.  
The bones fossilized.  
The string frayed.  
His skin reddened.  
The bullet splintered.  
The turkey thawed.

##### INTERNAL CAUSATION VERBS

The flowers bloomed.  
The roof deteriorated.  
The seeds germinated.  
The potatoes rotted.  
The beams rusted.  
The economy stagnated.  
The leaves wilted.  
The roses withered.  
Her skin blistered.  
The metal corroded.  
The beaches eroded.  
The cider fermented.  
The seedlings sprouted.  
His knee swelled.

#### APPENDIX 2: SENTENCES USED IN EXPERIMENT 2

##### EXTERNAL CAUSATION VERBS

The police abated violent crime.  
The doctors abated infectious diseases.  
The illness atrophied the lower leg.  
The stroke atrophied the right brain.  
The fire alarm awoke the residents.  
The telephone call awoke the reporter.  
The French chef crumbled the cheese.  
The nervous teenager crumbled the cigarettes.  
The scientists exploded the nuclear device.  
Religious extremists exploded the bomb.  
The opera singer vibrated the notes.

##### INTERNAL CAUSATION VERBS

The plants bloomed yellow blossoms.  
The trees bloomed pink flowers.  
The heavy traffic deteriorated the bridge.  
The harsh climate deteriorated the roads.  
The local florist germinated the seeds.  
The amateur botanist germinated the corn.  
The rare disease rotted the potatoes.  
The flood water rotted the carpets.  
The constant rain rusted the car.  
The salt water rusted the machinery.  
Communism stagnated the country's economy.

The famous violinist vibrated the strings.	The regulations stagnated private investments.
The huge radiators dissipated the heat.	The intense heat wilted the crowd.
The strong winds dissipated the clouds.	The bright sun wilted the roses.
The scandal frayed party unity.	The severe drought withered the crops.
The lengthy strike frayed tempers.	The late frost withered the tulips.
The wind reddened the baby's face.	The intense sun blistered the paint.
The sunset reddened the evening sky.	The hot sauce blistered his tongue.
The cook thawed the holiday turkey.	Acid rain corroded the building.
The mild temperatures thawed the soil.	The detergent corroded the fine silver.
The senators proliferated government subsidies.	The storm eroded the beach.
The politicians proliferated welfare programs.	The river eroded the rocks.
Age mellowed the rebel leader.	The yeast cultures fermented the beer.
Marriage mellowed the rock star.	The apple growers fermented the cider.
The solution oxidized the scrap metal.	The plants sprouted tender buds.
The water oxidized the iron beam.	The trees sprouted tiny leaves.
The weather stiffened his joints.	The violent storms swelled the sea.
The starch stiffened his shirts.	The rainy season swelled the rivers.

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[Received 3 May 1999;  
revision received 22 November 1999;  
accepted 9 March 2000]