Verbs in the lexicon: Why is hitting easier than breaking?

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Abstract

Adult speakers use verbs in syntactically appropriate ways. For example, they know implicitly that the boy hit at the fence *is acceptable but* the boy broke at the fence *is not. We suggest that this knowledge is lexically encoded in semantic decompositions. The decomposition for* break *verbs (e.g.* crack, smash*) is hypothesized to be more complex than that for* hit *verbs (e.g.* kick, kiss*). Specifically, the decomposition of a* break *verb denotes that "an entity changes state as the result of some external force" whereas the decomposition for a* hit *verb denotes only that "an entity potentially comes in contact with another entity." In this article, verbs of the two types were compared in a lexical decision experiment—Experiment 1—and they were compared in sentence comprehension experiments with transitive sentences (e.g.* the car hit the bicycle *and* the car broke the bicycle*)—Experiments 2 and 3. In Experiment 1, processing times were shorter for the* hit *than the* break *verbs and in Experiments 2 and 3, processing times were shorter for the* hit *sentences than the break sentences, results that are in accord with the complexities of the postulated semantic decompositions.*

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verbs, mental representations, processing time

1. Background

Specifying the nature of lexical representations is important for many theories of language processing. We argue that representations for one type of lexical

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item, verbs, contain information that restricts their usage in sentences, and that this information becomes available when a verb is accessed. It is this knowledge that specifies that you can *shake* someone but not *shudder* them, that you can *walk* a dog but not *arrive* a dog, and that you can *gallop* a horse but not *depart* a horse. In this article, we consider verbs like *hit* and *break*.

Hit and *break* denote events that are similar in many ways, and they can even be used to describe the same event. If a car collides with a bicycle causing damage to its frame, the event can be described as either (1) or (2):

(1) *The car hit a bicycle*.
(2) *The car broke a bicycle*.

Both *hit* and *break* can denote force applied to some object, and both can designate some entity as responsible for the application of force. Both can happen in an instant in time.

Nevertheless, the verbs differ in important respects. A long history of research in linguistics, beginning with Fillmore (1970), has explored the differences. For one, it is said that verbs of the *break* class (e.g. *crack, smash, crumple*) occur in anti-causative sentences whereas verbs of the *hit* class (e.g. *kick, batter, kiss*) do not. When the car collides with the bicycle, the event can be described by a causative sentence, as in (2) above, or by an anti-causative, as in (3):

(3) *The bicycle broke*.

But there is no anti-causative for the *hit* sentence in (1)—the event cannot be described as e.g. (4):

(4) **The bicycle hit*.

Second, *hit* but not *break* verbs are said to occur in the conative construction. Conative sentences convey an activity targeted at some entity, e.g. (5).

(5) *John hit at the bicycle.*

In (5), it is possible to convey the meaning that John attempted to cause damage to the bicycle. This is not the case in (6):

(6) **John broke at the bicycle*.

Third, sentences like (7) and (8) can both describe an event that occurred in a limited amount of time but, it is claimed, only (7) can describe an ongoing state (i.e. the bicycle being broken).

(7) *The bicycle was broken.*
(8) *The bicycle was hit.*

This collection of similarities and differences highlights a deeply important question for cognitive psychology: what is it that speakers and comprehenders know such that they can use and understand words according to their proper restrictions? To cite Fillmore (1970):

> it is quite certain that average adult speakers of English simply could not come up with anything like a reliable explanation of how *break* and *hit* are used. And yet probably never in their adult lives have they made a mistake in their use of these words, nor do they use them in ways inappropriate to their intentions. (Fillmore 1970: 120)

In this article, we first summarize a theoretical framework that is intended to represent this knowledge, a framework that is widely used by researchers in lexical semantics. Then we show how the assumptions of this framework can be deployed to explain real-time processing for the verbs themselves (Experiment 1) and the sentences in which they occur (Experiments 2 and 3). In the general discussion (Section 4), we review several alternative theoretical frameworks that could be consistent with our data.

1.1. *A lexical decomposition framework*

The strong, central hypothesis on which our analyses and experiments are based is that the syntactic structures in which a verb occurs are controlled by a part of the meaning of the verb (e.g. Beavers 2006; Beavers and Francez In press; Davis and Koenig 2000; Jackendoff 1972; Levin 1993; Levin and Rappaport Hovav 1995; Pustejovsky 1991; Rappaport Hovav and Levin 1998; Tenny 1994; Van Valin and LaPolla 1997). In the approach that motivated our experiments, this part of a verb's meaning is a semantic decomposition of the events that a verb may denote. Semantic decompositions can take several forms (e.g. Dowty 1979; Goldberg 1995; Levin and Rappaport Hovav 1995; Pinker 1989; see Section 4 below). Here, we make use of the decompositions defined by Rappaport Hovav and Levin (1998), which we label 'event templates.'

Event templates are intended to lay out the parts of verbs' meanings that are relevant to syntax in such a way as to explain the constructions in which the verbs occur. Following Levin and Rappaport Hovav (1995), *break* verbs have the externally-caused change-of-state template, α CAUSE x (BECOME IN STATE), which denotes some entity x coming to be in some new state as the result of some force external to x, designated by α—as in (2), repeated here in (9):

(9) *The car broke the bicycle.*

In (9), the car did something that caused the bicycle to break. Anti-causative sentences, as in (3) repeated here in (10), are assumed to have exactly the same

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structure except that the external force α is not explicitly expressed (Koontz-Garboden 2009; Levin and Rappaport Hovav 1995; but see Grimshaw 1990).

(10) *The bicycle broke.*

Hit verbs form one of several subclasses of verbs that share the activity template x(ACT). x(ACT) denotes some entity x engaging in some activity. Each subclass is specified for its particular type of activity (Rappaport Hovav and Levin 1998). For example, manner of motion verbs (e.g. *limp*, *trot*) are activity verbs that involve x engaging in an activity of movement. *Hit* verbs involve x engaging in an activity directed at coming in contact with some other entity. We designate subclasses with lower case descriptors. x (ACT-move x) specifies the kind of activity for manner of motion verbs and x (ACT-contact y) specifies the kind of activity for *hit* verbs. In (1) repeated here in (11), the car is the entity engaged in the hitting activity. The bicycle is the entity with which the car comes in contact, but the activity need not result in a change of state, e.g. the bicycle need not be damaged (Beavers 2006; Beavers and Francez In press).

(11) *The car hit the bicycle.*

Through their templates, verbs provide the skeletons of meaning on which sentences are built (Tenny 1994). In so doing, a verb's event template represents only part of its meaning, the part that can provide structures for sentences. All the verbs of a class or subclass have the same template. All *hit* verbs have the x (ACT- contact y) template and all *break* verbs have the externally-caused change-of-state template. As a beginning for initial investigations of lexical decompositions, we assume that a verb has only one template (unless it has unrelated meanings, e.g. *bolt*).

Event templates, by definition, describe how the linguistic system construes events. The car/ bicycle event can be construed either as a breaking event, which entails a change of state for the bicycle that is caused by the car, or a hitting event, which is simpler in that it does not entail a change of state. *Break* can be used only when there is truly a change of state whereas *hit* has the freedom to describe an event regardless of whether a change of state occurs (Beavers In press; Koontz-Garboden 2009; Levin and Rappaport Hovav 1995). Because event templates do not directly represent real world events, only the linguistic system's construals of them, they can be perfectly compatible with impossible events. For instance, the event described in (12) cannot happen in the real world but the sentence is consistent with *break*'s template, as is the anti-causative in (13).

(12) ?*The car broke the air.*
(13) ?*The air broke.*

The templates for *hit* and *break* verbs can explain the three differences that we mentioned above between the sentences in which *hit* and *break* verbs can occur. (i) *Hit* but not *break* verbs occur in the conative construction because the conative construction does not entail a change of state for a contacted entity. (ii) *Break* but not *hit* verbs can denote a continuing state because *break* verbs denote a state in which an entity comes to exist and *hit* verbs do not. (iii) *Break* but not *hit* verbs can occur in the anti-causative construction because they necessarily denote a change of state and *hit* verbs do not.

Ideally, verbs in naturally produced sentences would always behave in accord with the three contrasts just listed, and indeed they almost always do (overall, the frequencies with which they occur in non-predicted constructions are as low as 1%). However, although rare, there are exceptions. For example, in examinations of naturally-produced sentences from large corpora of texts, we have found that some verbs that have been designated by lexical semanticists as *break* verbs can sometimes occur in what might appear to be conative sentences, such as (14).

(14) *John ripped at the paper*.

Whether this is a conative is not entirely clear because, to some readers, *ripped at the paper* does not pass a standard test for conatives. For these readers, a sentence like (14) does not pass the test that the paper can be unaffected, in which case a sentence such as (15) is unacceptable (see Beavers 2006, for a full discussion of conative constructions).

(15) ?*John ripped at the paper but the paper wasn't actually ripped.*

In the experiments reported here, we took a different tack: we asked whether the event template framework could be supported with real-time processing data. In Experiment 1, we tested *break* and *hit* verbs in lexical decision, and in Experiments 2 and 3, we tested them in transitive sentences.

2. Experiment 1: Lexical decision

In lexical decision, participants decide whether strings of letters are English words. The template for *break* verbs, α CAUSE x (BECOME IN STATE), is more complex than the template for *hit* verbs, x (ACT-contact y). For *break* verbs, there are two sub-events (the causing event and the change-of-state event) whereas for *hit* verbs, there is only one (the activity event). Also, *break* verbs have two primitives, CAUSE and BECOME IN STATE, whereas *hit* verbs have only one, ACT. For either or both of these reasons, we hypothesized that *break* verbs are more complex than *hit* verbs.

Our reasoning for Experiment 1 was that, if the meanings of words contribute significantly to lexical decisions, if event templates are encoded in the lexicon

Table 1. *Verbs used in Experiment 1*

Hit Verbs	*Break* Verbs
bang	heal
batter	wrinkle
bite	split
caress	crumple
hit	break
kick	crack
kiss	fade
knock	freeze
lick	thaw
nudge	hush
pat	tilt
pinch	rip
slap	fold
swipe	scorch
tap	smash
touch	tear

as parts of verbs' meanings, and if event templates are a large enough part of verbs' meanings that they affect lexical decision response times (Gennari and Poeppel 2003), then response times to *break* verbs should be longer than response times to *hit* verbs.

2.1. *Method*

There were 16 pairs of verbs, each made up of one *hit* and one *break* verb (Table 1), that were matched on seven factors known to affect lexical decision response times (Table 2): Kucera-Francis frequency (KF) for the verb, as a verb and as a noun; subjective ratings of frequency, ratings of imageability, length in letters and syllables, and number of different meanings (as defined by WORDNET, Princeton University 2010). For each participant, the 32 *hit* and *break* verbs, plus filler words and pronounceable nonwords, were distributed randomly in a list of 384 items, half words and half nonwords (the first 15 items were practice items).

Test items were presented one at a time on a PC monitor with responses collected on the PC's keyboard. Participants pressed the "?/" key if a test item was a word, the "zZ" key otherwise, as quickly and accurately as possible. Incorrect responses were followed by the message "ERROR" displayed for 900 ms. The 25 participants in this experiment, the 32 in Experiment 2, and the 22 in Experiment 3 earned credit for an introductory psychology course at Ohio State University.

Table 2. *Mean values for the items in Experiment 1 (lexical decision) and Experiments 2 and 3 (sentence comprehension)*

	Experiment 1		Experiments 2 and 3	
	Hit	*Break*	*Hit*	*Break*
Verb frequency as verb (KF[1])	29.1	33.6	16.8	19.3
Verb subjective frequency ratings[2]	3.1	3.1	2.7	2.8
Verb imagery ratings[3]	4.2	4.3	4.3	4.1
Length: letters (Experiment 1) or words (Experiment 2)	4.4	4.8	5.0	5.0
Length: syllables	1.1	1.1	6.5	6.4
Verb senses as verb[4]	5.1	5.3	5.3	5.3
Verb senses as noun	4.3	4.3	—	—
Verb frequency (KF) as noun	10.1	7.3	—	—
Probability transitive[5]	—	—	.88	.83
Subject frequency (KF) as noun	—	—	231.1	234.8
Object frequency (KF) as noun	—	—	54.1[6]	60.6[7]
Sentence imagery ratings[8]	—	—	4.4	4.2
Sentence plausibility ratings[9]	—	—	4.6	4.6
Sentence duration ratings[10]	—	—	2.5	2.3
Relatedness: subject and verb[11]	—	—	2.3	2.2
Relatedness: object and verb	—	—	2.9	3.0
Relatedness: subject and object	—	—	2.7	2.7

Notes. [1] KF: Francis and Kucera (1982) norms; [2] Verb subjective frequency ratings: participants were asked to judge how frequently they encountered a word on a 1–5 scale, with 5 most frequent; [3] Verb imagery ratings: participants were asked to judge how well they could form an image of a word on a 1–5 scale, with 5 most imageable; [4] Verb senses: from WordNet (Princeton University 2010); [5] Probability transitive: probabilities were calculated from two large corpora, the British National Corpus and a 300 million word corpus we have constructed from fiction and non-fiction texts; [6] without *eye* (KF > 500); when *eye* included, Verb KF averages 93.2; [7] without *food* (KF > 100); when *food* included, Verb KF averages 72.1; [8] Sentence imagery ratings: participants were asked to judge how well they could form an image of a sentence's content on a 1–5 scale, with 5 most imageable; [9] Sentence plausibility ratings: participants were asked to judge how likely the event described in the sentence was to happen on a 1–5 scale, with 5 most likely; [10] Sentence duration ratings: participants were asked to judge how long the event described in the sentence would take on a 1–5 scale, with 5 the longest duration; [11] Relatedness ratings: participants were asked to judge how related the two words were (subject and verb, subject and object, verb and object) on a 1–5 scale, with 5 most closely related.

2.2. *Results and discussion*

Response times (see Table 3) were 28 ms shorter for *hit* than *break* verbs, a difference significant by participants and items analyses of variance, $F1(1,24) = 8.4$ and $F2(1,15) = 6.5$ ($p < .05$.)

This difference is reasonably large, about 5% of baseline, and given that other factors known to affect response times were matched between the two

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Table 3. *Mean response times (in ms) and probabilities of "word" responses (Experiment 1) and "acceptable sentence" responses (Experiment 2)*

Experiment	Task	*Hit*	*Break*
1	Lexical Decision	614 ms (.97)	642 ms (.97)
2	Transitive sentences	1865 ms (.90)	2043 ms (.87)

Note. There were no significant differences in the probabilities correct for either experiment.

types of verbs, it provides support for the hypothesis that lexical decompositions, here implemented as event templates, are a part of verbs' lexical representations.

3. Experiments 2 and 3: Comprehension of transitive sentences

In these experiments, we measured reading times for transitive *hit* and *break* sentences. Our prediction was that reading times for the *break* sentences would be longer than reading times for the *hit* sentences. *Break* transitives—unlike *hit* transitives—require understanding that the entity in object position undergoes a change of state. For example, the event denoted by (16), with a *break* verb, should take longer to comprehend than the event denoted by (17), with a *hit* verb.

(16) *The workmen chipped the tiles.*
(17) *The workmen banged the tiles.*

In Experiment 2, we measured processing difficulty for transitive sentences presented as a whole in order to look jointly at comprehension of the individual words and end-of-sentence integration and wrap-up processes. We used an acceptability judgment task. Participants were asked to respond "yes" or "no" according to whether a sentence was acceptable. The task was made extremely easy by using filler sentences that were either fully acceptable or maximally unacceptable, e.g.

(18) *The ceiling smiled the day.**
(19) *The building jumped black.**

Whole-sentence difficulty is often measured with a self-paced reading task in which a participant presses a key to indicate when he or she has finished reading a sentence. However, McKoon and Macfarland (2002) showed that response times for judgments of sentence acceptability with fillers like (18) can be more sensitive than self-paced reading times: The patterns of data are the same for acceptability-judgment response times as for self-paced sentence reading times, but there is less variability in the former.

In Experiment 3, we investigated whether the difference in difficulty between *hit* and *break* verbs appeared earlier than the ends of sentences. We used a "stop making sense" task (e.g. Mauner et al. 1995). In this paradigm, the words of a sentence are presented one at a time. Participants press a "yes" key to read each next word of the sentence until the sentence no longer makes sense to them, at which point they press a "no" key. For example, with sentence (19), participants might respond "yes" for *the*, "yes" for *building*, and "no" for *jumped.*

The same *hit* and *break* sentences were used for both experiments. The verbs of the sentences were matched on the same variables as for Experiment 1 and the sentences were matched on the 9 variables shown in Table 2. Because the sentences were transitive, it is especially important that the *hit* and *break* sentences were matched on the probability with which they occur in transitive sentences. In our corpora, the probabilities of transitive sentences for the verbs used in the experiments were 0.88 and 0.83, for *hit* and *break* verbs respectively.

We also checked whether the *hit* and *break* sentences were different in terms of the durations of the events they expressed, that is, in terms of the duration of the event expressed by a sentence in its entirety (for this, we used subjective ratings, see Table 2). It might be thought that sentential events expressed by *break* verbs would be rated as longer in duration than sentential events expressed by *hit* verbs because *break* verbs denote two sub-events whereas *hit* verbs denote one sub-event. However, there is no necessary correspondence between the duration of a sentential event and the number of sub-events denoted by the verb in the sentence. The templates for the *hit* and *break* verbs simply relate the entities of the event to each other in terms of causality, activity, and/or change of state. In Table 2, we report the mean ratings: the events of the sentences with *hit* verbs were rated as somewhat (although not statistically significantly) longer than the events of the sentences with *break* verbs.

3.1. *Method*

All of the materials were the same for the two experiments. There were 11 pairs of transitive sentences, one of each pair with a *break* verb and the other with a *hit* verb (see Table 4). The sentences of a pair were matched to each other in terms of the statistics in Table 2. Furthermore, some words were used in both sentences for some of the pairs. Examples of the pairs, with the *hit* sentence first, include:

(20) a. *The workmen banged the nails.*
b. *The workmen chipped the tiles.*

(21) a. *The acid stung my eye.*
b. *The oven thawed my food.*

A counter-balanced design was used with participants, sentences, and *hit* versus *break* verbs as the factors (one pair of filler sentences was used to make 12

Table 4. *Sentences from Experiments 2 and 3*

Hit sentences	*Break* sentences
The workmen banged the nails.	*The workmen chipped the tiles.*
The king slapped the rebel.	*The king crushed the protest.*
The assistant patted the dough.	*The assistant ripped the script.*
The maidens caressed my feet.	*The boulders shattered my feet.*
The boys bit the candy.	*The boys smashed the bottles.*
The man beat the oxen.	*The man tore the tickets.*
The breeze tickled my neck.	*The monk fractured his neck.*
The teenagers battered the suspects.	*The teenagers rumpled the sweaters.*
The sheriff nudged my elbow.	*The stones cracked my windshield.*
The jay pecked the treats.	*The stove scorched the treats.*
The warrior kicked my jaw.	*The warrior snapped my jaw.*
The acid stung my eye.	*The oven thawed my food.*

pairs for counter-balancing; this pair was not included in data analyses). With this design, each participant saw only one sentence of each pair.

For each participant, there were 192 test sentences. The 11 experimental sentences, 96 unacceptable filler sentences, and 85 acceptable filler sentences were presented in random order (with the first 16 for practice). The number of words in the filler sentences ranged from 3 to 7 (mean 4.1).

In Experiment 2, all the words of a sentence were presented at once. Participants were instructed to respond as quickly and accurately as possible, with the "?/" key on the PC's keyboard for an acceptable sentence and the "zZ" key for an unacceptable sentence.

In Experiment 3, the words were presented one at a time. Participants were instructed to respond "yes" (with the "?/" key) for each word of a sentence until it stopped making sense, at which point they were to respond "no."

3.2. *Results and discussion*

3.2.1. *Experiment 2.* Despite being matched on all the factors in Table 2, judgments were significantly faster for the *hit* transitive sentences than the *break* transitive sentences, $F1(1,31) = 10.0$ and $F2(1,11) = 7.2$ (see Table 3). The difference was 178 ms, 10% of baseline. This difference is consistent with our hypotheses that the lexical representations of verbs reflect their event-template complexity and that processing times for sentences are, in part, determined by this complexity.

3.2.2. *Experiment 3.* The data are shown in Table 5. For reading times, analyses of variance were conducted with two factors, *hit* versus *break* verbs, and test position: the verb, the article that followed the verb, and the noun that followed the article (the last word of the sentence). Not surprisingly, there was

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Table 5. *Mean Judgment Times and Probability of "Acceptable" Responses for Experiment 3*

	Verb	Article	Noun
Hit sentences	846 ms (.94)	577 ms (.99)	776 ms (.97)
Break sentences	935 ms (.91)	592 ms (.98)	827 ms (.98)

a main effect of test position (F1(2,42) = 46.2 and F2(2,20) = 57.8). There was also the predicted main effect that response times for sentences with *hit* verbs were faster than response times for sentences with *break* verbs (F1(1,21) = 7.3 and F2(1,10) = 9.2). This difference occurred at the verb itself: response times were 7% shorter for the *hit* than the *break* verbs, consistent with the results for lexical decision in Experiment 1. The difference also occurred at the final word of the sentence (a 10% difference). The difference was smaller at the article that preceded the noun, but the interaction between the two factors, test position and type of verb, was not significant (Fs < 2.7).

For the probabilities with which participants judged the words of the sentences as making sense, analyses of variance were conducted with the same two factors. For reasons that are not clear, participants were less likely to judge the verb as making sense than the article and the noun (Table 5). This difference was significant, F1(2,42) = 5.5 and F2(2,20) = 23.4. All other Fs were less than 1.9.

4. General discussion

We return here to Fillmore's (1970: 120) point: "it is quite certain that the average adult speaker of English simply could not come up with anything like a reliable explanation for how *break* and *hit* are used." To this we add that neither could the average adult speaker come up with the precise meanings of verbs that structure the syntax of sentences. Nevertheless, these meanings, realized here by event templates, played a prominent role in processing for the verbs themselves in Experiment 1 and for transitive sentences in which the verbs occurred in Experiments 2 and 3.

The hypothesis with which we began the experiments was that the complexity of lexical decompositions of verbal meaning has observable effects on online processing times. This hypothesis has received support from a number of previous experiments. McKoon and Ratcliff (2003, 2005) compared manner of motion verbs like *limp* and *trot* to *break* verbs. Manner of motion verbs are said to be like *hit* verbs in that they denote only an activity (although an activity of x (ACT-move x), not x (ACT-contact y)). Thus, like *hit* verbs, manner of motion verbs are simpler than *break* verbs. In accord with this, McKoon and Ratcliff found shorter lexical decision response times for manner of motion than *break* verbs and they found shorter reading times for intransitive sentences with

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manner of motion verbs, as in (22), than intransitive sentences with *break* verbs, as in (23).

(22) *The player limped*.
(23) *The chicken thawed*.

In another pair of experiments, McKoon and Ratcliff (2008) compared change of location verbs (e.g. *arrive*, *descend*) to manner of motion verbs (e.g. *drift*, *limp*). Change of location verbs denote a particular type of change of state, one in which an entity necessarily moves from one location to another. Unlike *break* verbs, an external cause is not entailed (e.g. Dowty 1979; Carrier and Randall 1992; Goldberg 1995; Pinker 1989; Rappaport Hovav and Levin 1998; Simpson 1983; Tenny 1994; Van Valin and LaPolla 1997). *Arrive,* for example, denotes an event in which some entity comes to be at some location without any entailment of an external cause. In contrast, manner of motion verbs denote an activity that entails neither a change of location nor an external cause. In this sense, it has been argued, manner of motion verbs are simpler than change of location verbs. McKoon and Ratcliff supported this analysis in two ways. They found that response times in lexical decision were significantly shorter for manner of motion verbs than change of location verbs and they found that reading times for intransitive sentences were significantly shorter for manner of motion verbs, as in (24), than change of location verbs, as in (25).

(24) *The passengers stumbled.*
(25) *The passengers descended*.

In other experiments (McKoon and Macfarland 2000, 2002), verbs of a class called *bloom* verbs (e.g. *wither, deteriorate*) were compared to *break* verbs. Verbs of the *bloom* class have been said to denote a change of state that cannot be externally caused, and therefore they denote only one sub-event, which makes them simpler than *break* verbs (e.g. Levin and Rappaport Hovav 1995; Rappaport Hovav and Levin 1998). Consistent with this, McKoon and Macfarland found faster lexical decision responses, faster reading times for unacceptable transitive sentences (e.g. (26a)–(26b)) and faster reading times for acceptable intransitive sentences for *bloom* verbs than *break* verbs (e.g. (27a)–(27b)). All of these data (McKoon and Macfarland 2000, 2002; McKoon and Ratcliff 2003, 2005, 2008), support the hypothesis that verbal complexity affects processing times for verbs and the sentences in which they occur.

(26) a. *The cloud bloomed justice.*
b. *The cloud broke justice.*

(27) a. *The flower bloomed.*
b. *The glass broke.*

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The hypothesis is also supported by data from experiments by Gennari and Poeppel (2003), who explored a general distinction between event verbs and state verbs (Dowty 1979; Jackendoff 1990; Moens and Steedman 1988; Pustejovsky 1991; Rappaport Hovav and Levin 1998; Smith 1991; Vendler 1967). States are constant over time whereas events are not. *Hit* verbs and *break* verbs are eventive in that for both, something changes over time. In contrast, state verbs, such as *love*, *trust* and *belong*, denote meanings that do not change over time. Gennari and Poeppel argued that the lexical structure of events is more complex than that of states. Consistent with this, they found that lexical decision response times were shorter for state verbs, as in (28), than for event verbs, as in (29), and that reading times for transitive sentences were shorter for state than event verbs.

(28) *The retired musician loved his second child very much.*
(29) *The retired musician built his second house from scratch*.

Our interpretation of all of these data is that increased complexity in the lexical representations of verbs leads to increased processing time. However we do not have a model that describes in detail and quantitatively exactly how this happens. Even for the most basic of our tasks, lexical decision, there is no generally agreed-upon model that can fully explain response times and the effects on them of such variables as word frequency (for a review, see Ratcliff et al. 2004). A simple idea is that the amount of processing time depends upon the amount of information that must be made accessible to working memory, where working memory is the point at which a lexical representation becomes available for further processing such as making a lexical decision or putting together the meaning of a sentence. However, it remains to be seen whether and how this idea could be implemented in various models of lexical access (e.g. Balota and Spieler 1999; Coltheart et al. 2001; Grainger and Jacobs 1996; Plaut 1997; Seidenberg and McClelland 1989).

4.1. *Other approaches to verbal meaning*

We have postulated that verbal meanings are represented lexically as event decompositions, in particular, event templates. This approach has received considerable support from in-depth analyses of the many syntactic constructions in which individual verbs can occur, in particular from the analyses detailed by Levin and Rappaport Hovav (1995) and Rappaport and Levin (1998). Event templates have also worked well in motivating our investigations of the effects of verbal meaning on processing times.

The essential element of event templates for our purposes is that they lend themselves to measuring the complexity of verbs' lexical representations. However, there are other approaches in which complexity can be defined in ways that make them consistent with the data from our experiments. First, consider two decompositional theories, one proposed by Jackendoff (1996) and the other by Goldberg (1995).

As with event templates, Jackendoff (1996) hypothesizes that the events denoted by verbs represent relations among entities. However, he emphasizes how the relations among the entities evolve over time. For *break* verbs, we could assume that the causing sub-event occurs independently of the change-of-state sub-event, with each sub-event evolving across its separate time course (with the restriction that the causing sub-event would have to begin before the change-of-state sub-event). For *hit* verbs, we could assume that there is only a single sub-event that evolves over a single time course. With these assumptions, the representation of an external cause event would be more complex than the representation of a *hit* event, and therefore consistent with the results of our experiments.

In Goldberg's constructionist theory (Goldberg 1995), 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 external cause verbs, there could be one sub-event for which the participant changing state would be profiled and a second sub-event for which the participant involved in the causing event would not be profiled. For *hit* verbs, the participant engaged in the activity template could be profiled. If it is assumed that an external cause verb always involves two sub-events and a *hit* verb only one, then the additional complexity of the external cause event could lead to slower processing times.

Whether decompositions are defined in terms of event templates, the evolution of events over time, or the semantic representations that underly profiles of events, they can all be understood as consistent with the data from our experiments. In this respect, we note, the data at least appear to contradict the claim that J. A. Fodor has made in his early reasearch (e.g. Fodor et al. 1975; Fodor et al. 1980; Fodor and Lepore 1998) that there exist no psycholinguistic data that support the notion of lexical decomposition (see also Kintsch 1974).

Another way of looking at verbal meanings is to list their semantic entailments, that is, the truth conditions that they place on the events they describe. Dowty (1991) describes four entailments for the subjects of sentences and four for the direct objects (see also Beavers 2006; Davis and Koenig 2000). In Dowty's system, entities in subject position are entities that cause the event denoted by the verb, that have volitional involvement in the event, that are sentient, and that move relative to the other participant(s) in the event. Entities in direct object position undergo changes of state, they change incrementally over the time of the event, they are causally affected by another participant in the event, and they are stationary relative to movement of another

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participant in the event. It is not mandatory that entities in subject position fulfill all four subject entailments or that entities in object position fulfill all four object entailments. Rather, an entity in subject position should have more subject entailments than the entity in object position, and the entity in object position should have more object entailments than the entity in subject position.

For both *break* verbs and *hit* verbs, the entities that are subjects of transitive sentences can carry all four subject entailments, but they must at least carry the one that they are the cause of the denoted event (that is, that they are the entity responsible for the event). It is in the object position that the two types of verbs differ. For *break* verbs, the entity in object position must undergo a change of state and it must be causally affected by another participant in the event. For *hit* verbs, neither of these entailments is required. Thus, when the verbs are inserted into sentences, the entailments required for the objects of *break* verbs are greater in number than those required for the objects of *hit* verbs. If this larger number is taken to mean that transitive sentences with *break* verbs are more complex than transitive sentences with *hit* verbs, then the longer sentence-processing times we found could be explained. Assuming additionally that the lexical representations of verbs encode their required entailments, then the finding of longer lexical decision response times for *break* than *hit* verbs could be explained.

Not discussed yet are two non-decompositional frameworks for which assumptions might be inconsistent with our data. One proposes that the lexical entry for a verb lists all the syntactic structures in which the verb can occur (e.g. MacDonald et al. 1994; McRae et al. 1998). Under this proposal, *hit* and *break* verbs would both have representations for transitive sentences and so, everything else being equal, their transitive sentences should not be differentially difficult. Of course, everything else might not be equal. It could be that *break* verbs have more possible syntactic structures than *hit* verbs, thus slowing processing for *break* verbs (and sentences that contain them) relative to *hit* verbs. A second proposal is the same as the first in that a verb's lexical entry lists all possible syntactic structures, but in addition, each structure has assigned to it the probability with which it occurs with the verb in naturally-produced sentences (e.g. Jurafsky 1996). If sentence comprehension times depended solely on these probabilities—and all else were equal—then response times for the *hit* sentences in our experiments should not have been shorter than response times for the *break* sentences because the probabilities with which the verbs occur in transitive sentences are almost identical (0.83 and 0.88, as mentioned above). These two proposals share a problem, which is that there currently exist no complete lists of the syntactic structures in which verbs occur. Compiling such lists would require decisions about what structures count as different structures and what structures do not. This is a granularity problem in

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that it is not clear how fine the distinctions that count as separate structures should be. Nevertheless, future research could find lists of syntactic structures for verbs that are consistent with our data.

5. Conclusion

As we have just described, there are several frameworks in which assumptions about verbal meaning can be consistent with our data. For the three decompositional approaches (event templates; Jackendoff 1996; Goldberg 1995), the mapping from lexical representation to complexity is transparent in that *break* verbs have two sub-events whereas *hit* verbs have only one. For lexical entailments, we added the assumption that entailments are part of verbs' lexical representations so that the representations would include the appropriate relative complexities for *break* and *hit* verbs.

The point here is not that our results rule out one or another of these views. Instead, the differences we found in processing times between *break* verbs and *hit* verbs, 5–10% of baseline response times, should constrain further development of lexical semantic theories.

In conclusion, we note that the distinction between syntactically relevant parts of verbal meaning and other parts has support from neuropsychological data. Kemmerer (2003) tested two brain-damaged patients. They were able to pass a verb-picture matching task that required them to make subtle discriminations in syntactically irrelevant parts of verbs' meanings. But they were not able to pass a syntactic judgment test that required knowledge about a verb's ability to occur in the "body-part" construction, a construction in which an activity is directed "on" a body part. The patients could not correctly discriminate that the construction can occur with *hit* verbs, as in (30), but not *break* verbs, as in (31).

(30) *She hit him on the rib.*
(31) *She broke him on the rib.**

Kemmerer and Wright (2002) found another dissociation with aphasic patients. These patients passed a verb-picture matching test but, for the same verbs, they were unable to pass a syntactic test that required knowledge of which verbs can take the "un-" prefix (e.g. *unwrap* vs. *unboil*). From these data and the results of our experiments, we suggest that syntactically-relevant meaning lies near the heart of language understanding.

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