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The Wind Chilled the Spectators, but the Wine Just Chilled: Sense, Structure, and Sentence Comprehension

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Abstract

Anticipation plays a role in language comprehension. In this article, we explore the extent to which verb sense influences expectations about upcoming structure. We focus on change of state verbs like *shatter*, which have different senses that are expressed in either transitive or intransitive structures, depending on the sense that is used. In two experiments we influence the interpretation of verb sense by manipulating the thematic fit of the grammatical subject as cause or affected entity for the verb, and test whether readers' expectations for a transitive or intransitive structure change as a result. This sense-biasing context influenced reading times in the postverbal regions. Reading times for transitive sentences were faster following good-cause than good-theme subjects, but the opposite pattern was found for intransitive sentences. We conclude that readers use sense-contingent subcategorization preferences during on-line comprehension.

Keywords: Sentence processing; Language comprehension; Lexical semantics; Psycholinguistics; Event memory

1. Introduction

Anticipation plays a role in language comprehension. This has been most clearly shown in event-related potential (ERP) research, where a number of studies have found that readers and listeners anticipate specific words or concepts, both in sentences (Federmeier & Kutas, 1999) and in longer discourse (van Berkum, Brown, Zwitserlood, Kooijman, & Hagoort, 2005; van Berkum, Zwitserlood, Hagoort, & Brown, 2003). Comprehenders anticipate upcoming structure as well (MacDonald, 1993; McRae, Spivey-Knowlton, & Tanenhaus, 1998; Trueswell, Tanenhaus, & Garnsey, 1994). In this article, we explore the role played

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by meaning, and verb meaning in particular, in developing structural expectations of this kind.

Knowledge of the verb, on a variety of theoretical accounts, includes knowledge of both the structures it can occur in (encoded, for example, as subcategorization frames) and of general semantic properties of its arguments, or their thematic roles (MacDonald, Pearlmutter, & Seidenberg, 1994). The verb, in other words, tells you a lot—and a number of studies have shown that this information is used to anticipate upcoming structure.

One well-studied example involves what are referred to as a verb's structural biases. Most verbs can occur in a range of structures, but they vary in their probability of doing so, showing a statistical bias toward one structure or another (Connine, Ferreira, Jones, Clifton, & Frazier, 1984; Gahl, Jurafsky, & Roland, 2004; Roland & Jurafsky, 2002). The verb *admit*, for example, can occur in a simple transitive (*John admitted his mistake*) or with an embedded clause or sentential complement (*John admitted his mistake caused a number of problems for everyone*). Statistically, though, it occurs more often in the second. A number of psycholinguistic studies have tested whether comprehenders are sensitive to these verb-specific biases and use them in comprehension. These studies focused on the resolution of the direct object/sentential complement (DO/SC) ambiguity, exemplified above in the second sentence with *admit*. The complementizer *that* is optional in English embedded clauses, and when it is omitted, the noun phrase *his mistake* is temporarily ambiguous between being the direct object of the verb (DO) or the subject of the sentential complement (SC).

The question of interest has been how people resolve this ambiguity, and thus what sources of information are used at specific time points during comprehension. If comprehenders rely on the overall transitivity bias of English, or a general heuristic of assuming the simplest structure, they should initially interpret any postverbal noun phrase as the direct object, and only re-analyze that interpretation if subsequent information shows that it was incorrect (Ferreira & Henderson, 1990). In contrast, if they immediately take verb-specific information into account, then their interpretation should vary with a number of other factors, including the bias of the verb (Ford, Bresnan, & Kaplan, 1982). This led to an active debate, with results that initially favored the first approach (Ferreira & Henderson, 1990). Subsequent research, however, found that verb bias has an early influence on the interpretation of the structurally ambiguous noun phrase: Readers are more likely to interpret it as the direct object after a DO-biased verb but as the subject of a sentential complement after a verb that is SC-biased (Trueswell, Tanenhaus, & Kello, 1993), even when plausibility is taken into account (Garnsey, Pearlmutter, Meyers, & Lotocky, 1997). Although there continues to be some disagreement on the topic (see Kennison, 2001), currently verb subcategorization bias is widely accepted as a viable source of information about upcoming structure.

1.1. Verb meaning-structure relations in direct object/sentential complement ambiguities

But what, precisely, is the nature of that information? Work in theoretical linguistics points to a clear, though complex, relationship between the meaning of a verb and the structural frames it can occur in (Goldberg, 1995; Jackendoff, 1983; Levin, 1993; Pesetsky,

1995). In previous work, we have argued that verb bias is one facet of this more general relationship (Hare, McRae, & Elman, 2003, 2004).

If this is correct, it has implications for the four DO/SC ambiguity studies mentioned above. Although two of these found convincing evidence for the early use of verb bias information (Garnsey et al., 1997; Trueswell et al., 1993), two others failed to find effects (Ferreira & Henderson, 1990; Kennison, 2001). One possible explanation for the discrepancy is that overall verb bias is not quite the right metric. If bias effects are indeed based on the comprehender's awareness of meaning–structure relationships, then they should also reflect the more fine-grained knowledge concerning the fact that when a verb allows two structural frames, its meaning often differs in the two cases. Many verbs used in studies of the DO/SC ambiguity are polysemous, with related meanings generally referred to as different senses, in contrast with words that have unrelated meanings, such as the river and financial meanings of *bank* (Klein & Murphy, 2001; Rodd, Gaskell, & Marslen-Wilson, 2002). Consider the verb *grasp*, which, like a number of English verbs, varies in meaning between a concrete physical sense and a more abstract or metaphorical one. This sense difference correlates with structure: When *grasp* is used to mean “take hold of,” it invariably occurs with a direct object (*John grasped the handrail*), never a sentential complement. When used to mean “manage to understand,” on the other hand, it can occur with a direct object (*John grasped the concept*) but is statistically biased toward a sentential complement (*John grasped that she wanted him to stop talking*).

In an earlier set of corpus analyzes, we found a strong correlation between a verb's senses and the structures—direct object or sentential complement—in which it occurs (Hare et al., 2004). Importantly, these sense-specific biases were not necessarily consistent with the overall bias of the verb. To determine whether this might explain the earlier equivocal results, we determined the sense of the verb that was used in each item in the earlier studies and matched these with their sense-contingent structural biases. In doing so, we found that consistency between the verbs' sense-based biases and the bias category of the verb as it was used in the four previous experiments predicted whether an influence of verb bias was found. This strongly suggests that comprehenders in those studies relied not on overall verb bias, but on the bias of the specific senses used in each case.

We then explicitly tested this suggestion in a self-paced reading study (Hare et al., 2003). We devised prior contexts to bias readers toward either a DO-promoting or an SC-promoting sense for a set of relevant verbs. These two contexts were then followed by a target sentence containing the verb and a postverbal SC, and these were presented to readers in a moving-window self-paced reading experiment. As predicted, the sense-biasing context influenced structural expectations. Readers had little difficulty with a postverbal SC following an SC-biased sense of the verb, but they showed substantially more difficulty when the DO-biased sense was promoted by the context.

1.2. Verb meaning–structure relations and transitivity

These results show that comprehenders do make use of sense–structure relationships as they process structurally ambiguous sentences, anticipating a direct object or sentential

complement based on the sense of the verb. But this raises another question: Is the use of sense–structure contingencies typical of comprehension, or only applicable to a narrow case of ambiguity resolution—that is, to the correct interpretation of a relatively infrequent ambiguity that arises only because the complementizer *that* can be deleted? It is conceivable that in cases like this, when the task is particularly difficult because the information available in the input underdetermines the interpretation, and overall biases of the language may push in the wrong direction, extra information must be recruited to help resolve the ambiguity. If so, sense-based biases might not have such a strong influence on the interpretation of other, more frequent structures.

We find this unlikely, however, given the range of information that has been shown to influence comprehension in cases where it appears unnecessary (Farmer, Christiansen, & Monaghan, 2006) or even completely irrelevant to the task (Federmeier & Kutas, 1999). Results like these suggest that comprehension is opportunistic, taking advantage of all available information in all situations. Thus, it is somewhat surprising that in a recent study, McKoon and MacFarland (2000) apparently found no evidence of structural bias effects with two of the most common, basic structures of English, the transitive and intransitive. The first goal of that study was to test their prediction that internal causation verbs (like *ferment*) would require less processing time than external cause verbs like *break*, because the former are analyzed as having a less complex lexical representation (Levin & Rappaport Hovav, 1995). In addition, the authors pointed out that their predictions contrast with the constraint-based view that comprehenders are sensitive to a verb's probability of occurrence in a particular structure. The second stated goal of their study was therefore to manipulate transitivity bias of their verbs and test whether it affected the results.

McKoon and MacFarland (2000) used 28 change of state verbs, classified by lexical semantic category (internal or external cause, McKoon & Ratcliff, 2003) and by probability of occurring in the transitive. The set of verbs was biased toward the intransitive overall, but individual probabilities varied, thus allowing the authors to split them into two groups, referred to as higher probability (mean probability transitive = .46, range = .22–.67) and lower probability ($M = .06$, range = 0–.14). Each verb was used in transitive and intransitive sentences like *The apple growers fermented the cider* and *The cider fermented*. Participants read the sentences and judged their acceptability. Decision latencies and percentage of sentences judged as acceptable were analyzed for an influence of lexical semantic class and transitivity probability. Transitive and intransitive sentences were tested in separate experiments. There was an effect of lexical semantic class in both experiments, with longer judgment times and lower acceptability ratings for external cause than internal cause verbs. In apparent contradiction to a verb bias account, transitivity bias had no effect on either measure. Instead, the internal-external distinction was found for sentences with both lower and higher probability verbs.

From our perspective, though, this result is not particularly surprising, given that bias was computed over all uses of the verb. The change of state verbs used in their study have two senses: the causative, in which one participant causes a change of state in another, and the inchoative (coming-into-being) sense, with a single participant that undergoes the

change of state itself (Levin, 1993). The sense differences are reflected in the sentence structures used to describe such events. Causatives, which have two participants, occur in the transitive (*he broke the vase*), with the cause as the subject and the affected participant as the direct object. Inchoatives, having only an affected participant, occur in the intransitive (*the vase broke*), with that participant as the subject.

Hence, the sense of the verb systematically differs between transitive and intransitive sentences. Furthermore, as the example above with *fermented* shows, the subject noun phrase in McKoon and MacFarland's (2000) experimental sentences changed between the transitive and intransitive versions. This is a crucial difference between conditions, because the nature of the grammatical subject correlates with sense for these verbs (McKoon & Ratcliff, 2003, 2005). Thematic fit between the verb and the initial noun phrase signals verb sense, and sense in turn signals structure. Specific types of entities or objects that fit the role of cause or instrument for the event occur as subject in the causative sense, whereas entities capable of undergoing the specified change of state occur as subject of the inchoative. If readers are sensitive to these more fine-grained probabilities, then they should interpret *fermented* as a causative when it follows *apple growers*, but as an inchoative when it follows *cider*. Because these senses correlate with transitive and intransitive structures, respectively, the properties of the subject noun phrase should constrain structural expectations, leading the reader to expect a direct object in the first case but not in the second. The McKoon and MacFarland results are consistent with this—sense-based biases were appropriate for the structure in which the sense was used, so no differences would be expected, and none were found.

If this interpretation is correct, then it should be possible to change structural expectations by changing the nature of the grammatical subject. McKoon and MacFarland tested this only indirectly because the structure in each sentence was consistent with the expectations established by the subject noun phrase, leading to null effects.

2. Experiment 1

We tested more directly for the on-line use of sense–structure correlations in the interpretation of potentially alternating verbs. In two experiments, we manipulated the grammatical subject of change of state verbs and examined whether this minimal context activates different verb senses and hence leads to different expectations for postverbal structure. In Experiment 1, we tested whether this sense manipulation influences reading time in intransitive sentences.

2.1. Method

2.1.1. Participants

Twenty-eight undergraduates at Bowling Green State University and the University of Western Ontario participated for partial class credit or were paid for their time. All participants were native English speakers who reported normal or corrected-to-normal vision.

2.1.2. Materials

An initial set of 62 change-of-state verbs was chosen from Levin (1993) and McKoon and MacFarland (2000, 2002). The final set of items was chosen from these verbs based on three on-line norming studies that were run to elicit native speaker intuitions about potential causes and affected entities.

2.1.2.1. Norming: In the first set of norms, participants were asked to produce good causes for each verb. They were presented with 62 questions of the form, “Who or what tends to break things?” one for each verb, and asked to list up to five responses for each, giving the first word or words that came to mind. Participants were also told that many of the verbs might have more than one meaning, and they were free to let their responses fit different meanings. A total of 63 participants completed these questions.

The same set of 62 verbs was used concurrently in a second set of norms in which we asked participants to supply good themes or patients. Participants were asked to complete short sentence fragments like “_____ broke” or “_____ got broken.” The *get*-passive was used so that participants would interpret this as a verb, not an adjective, which is the more common use of the standard *was*-passive for change of state verbs (*it was broken*). Active and passive voice were presented on two different lists, so each participant saw all items in the same voice. Forty-two participants completed this questionnaire, 21 on each list.

From these norms, we chose 33 verbs that showed consistency in participants’ production of a good cause or good theme. These were used in a sentence completion study to measure the extent to which they would influence the sense of the verb. Sentence fragments were created using the verb and initial noun phrase, as in *The brick shattered _____*. Two sentence fragments were created for each verb, one with a good cause as subject, the other with a good theme. Items were rotated across two lists so that each participant saw each verb in a single context. Each participant saw half of the verbs following a good-cause subject, and half following a good theme. An additional 40 filler items of varying syntactic structures were created, with each filler truncated at varying points. Items were presented in a different random order for each participant. Forty participants completed these fragments, 20 per list.

2.1.2.2. Items: We selected 18 verbs for which the choice of subject (good theme or good cause) reversed the structural completion percentages. Although not all items showed equally strong bias, the fragments with a good-cause subject were predominantly completed as a transitive ($M = .83$, range = .54–1.00), whereas the good-theme fragments were predominantly completed as an intransitive ($M = .95$, range = .69–1.00).

Two intransitive sentences were written for each verb, one with a good cause as subject, and the other with a good theme (see the Appendix). To ensure that the critical regions were identical across conditions, the verb was followed by a plausible continuation that was identical in each sentence for at least four words. An example pair with the verb *shatter* is given below.

Good cause: The brick shattered into tiny pieces when it hit the floor.

Good theme: The glass shattered into tiny pieces when it hit the floor.

Although animacy of the initial NP does correlate to some extent with good cause versus good theme, we did not only manipulate animacy. Rather, we manipulated the thematic fit between the agent and theme of each event as denoted by the verb. Thus, although many items did indeed use a human good cause and an inanimate good theme, a number of others used inanimate causes and themes (as in the example above), and still others used initial NPs that are difficult to classify (e.g., *Her confidence eroded*).

Test items were rotated across two lists so that each participant read one sentence containing each verb, with half of the target sentences containing a good cause and half a good theme, so that they did not read the same verb twice. Twenty practice and 40 filler sentences of various types were added to the lists. Each trial was followed by a yes-no comprehension question. Filler and test items were pseudo-randomized to ensure that test items did not occur in the first few trials of the study, and at least one filler always intervened between test items.

2.1.2. Procedure

The experiment was conducted on a Macintosh computer using PsyScope (Cohen, MacWhinney, Flatt, & Provost, 1993). A Carnegie Mellon University button box was used to collect decision latencies with millisecond accuracy. Each trial began with the target sentence left-justified and presented with each non-space character replaced by a dash (-). All critical regions of the target sentence plus a minimum of one word were included on the first line. Participants read each sentence in a one-word-at-a-time moving-window fashion in which they made their way through the text by pressing the response button to reveal the next word, with the previous word reverting to dashes. A yes/no comprehension question followed each item.

The main experiment was preceded by 20 practice trials, after which the subject took a short break. Sentences during the experiment were presented in blocks of 20, with a break following each block. The session lasted approximately 30 min.

2.1.3. Design

Separate analyses of variance were conducted on the reading latencies at the verb (*shattered*), the next two-word region (*into tiny*), and the following two words (*bits when*). The factor of interest was bias of the initial noun phrase (transitive-biasing vs. intransitive-biasing). Bias was within participants (F_1) and items (F_2). List was included as a between-participants dummy variable and item rotation group as a between-items dummy variable to stabilize variance that may result from rotating participants and items over lists (Pollatsek & Well, 1995). Effects involving these dummy variables are not reported.

2.2. Results

Reading times for each region are presented in Table 1 (with standard errors) and in Fig. 1. As is clear, the appropriate sense of the verb was promoted by the context of a good

Table 1

Mean reading times for Experiment 1, intransitive sentences and Experiment 2, transitive sentences

Condition	Region		
	Verb	First Two Words	Second Two Words
Experiment 1, intransitive sentences			
Good-cause subject	435 (33)	420 (20)	409 (30)
Good-theme subject	439 (31)	395 (24)	381 (24)
Difference	-4	25 *	28**
Experiment 2, transitive sentences			
Good-cause subject	478 (35)	418 (23)	407 (25)
Good-theme subject	462 (29)	463 (28)	441 (21)
Difference	16	-45**	-34**

Note: Standard errors in parentheses.

**Significant by participants and items; *significant by participants.

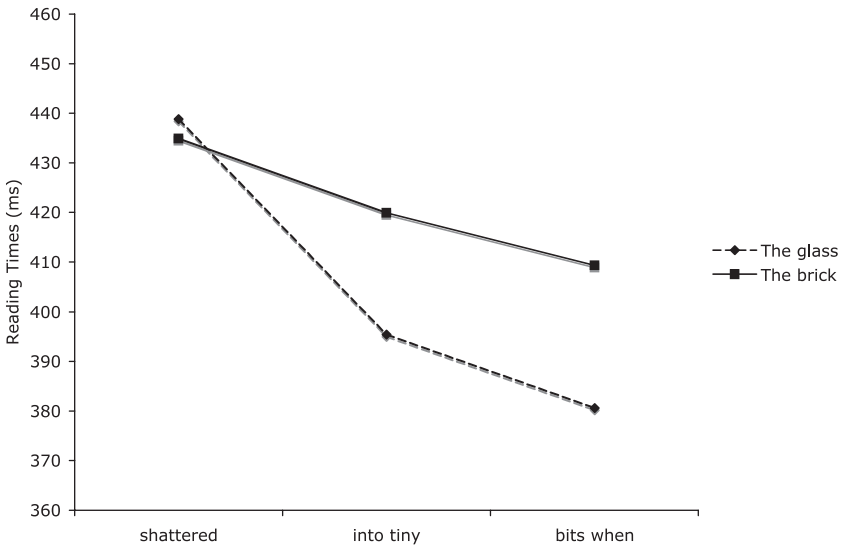


Fig. 1. Mean reading times for Experiment 1, intransitive sentences.

cause or good theme as subject, and this modulated the expectation for the related structural frame, resulting in a bias effect in the postverb regions. Participants were faster to read the intransitive continuation following the inchoative-inducing good-theme subject than following the good cause.

2.2.1. Verb region (*shattered*)

As would be expected given that the verb was plausible following both animate and inanimate subjects, there were no differences at this point, $F < 1$ in both analyses.

2.2.2. First two words (into tiny)

Reading times at the first two-word region after the verb were 25 ms shorter in sentences with a good-theme subject than for those with a good cause. This effect was significant by participants, $F_1(1,26) = 4.58, p < .05$; but not by items, $F_2(1,16) = 2.15, p > .1$.

2.2.3. Next two words (bits when)

Reading times were 29 ms shorter in the good-theme than in the good-cause sentences, resulting in an effect of bias in both analyses, $F_1(1,26) = 7.09, p < .02, F_2(1,16) = 12.42, p < .01$.

2.3. Discussion

Reading times to intransitive sentences were significantly faster following an inchoative-biasing good-theme subject, compared to those with a causative-biasing good cause. This pattern is expected if readers interpret the verb based on the sense-biasing subject noun phrase and anticipate that the sense-biased structure will follow.

It is unlikely that the lack of an effect by items in the first two-word region contradicts the sense-based anticipation account, given the significant effect by participants in that region. It is more probable that a subset of items was less strongly biasing or less informative about the structure. In a similar vein, we acknowledge that nuances of meaning may make some of our items less appropriate as inchoatives. For example, *bend*, as used here, could be interpreted as stative; *grow tired* has been analyzed as a predicate complement, and *the children collected* as the children acting collectively in a reciprocal way. Our central claim—that the nature of the grammatical subject influences the interpretation of the verb, which in turn influences structural expectancies—holds for these items regardless of these semantic subtleties. Nonetheless, we tested whether these items unduly influenced our results by removing them and re-running the by-items analysis. At the second two-word region, the resulting 31 ms difference between conditions (compared to 29 ms with the full set of items) remains significant; $F_2(1,13) = 7.56, p < .02$. Results at the first two-word region failed to reach significance, as in the full analysis.

Before discussing the results in detail, we test the same question using transitive stimuli. If our account is correct, we should continue to observe an effect of bias in the postverbal regions, this time due to shorter reading times following causative-biasing subjects.

3. Experiment 2

In Experiment 1, intransitive sentences with change-of-state verbs were read faster when the subject was a good theme compared to when it was a good cause of the action denoted by the verb. The converse should also be true: Transitive sentences should be read faster in the regions following the verb when the subject is a good cause because this context should lead readers to expect a causative, transitive use of the verb.

3.1. Method

3.1.1. Participants

Twenty-four undergraduates from Bowling Green State University or the University of Western Ontario participated for partial class credit or were paid \$10 for their time. All participants were native English speakers who reported normal or corrected-to-normal visual acuity.

3.1.2. Materials

Transitive stimuli were created using the same 18 subject-verb pairs used in Experiment 1 (see the Appendix). The two sentences of a pair differed in their subject: Each verb was used with the same good-cause and good-theme subject as in Experiment 1. Here, however, the verb was followed by a direct object that was plausible in both cases. Once again the sentences were identical for at least four words after the verb and then were allowed to vary so that both versions made sense. An example pair with the verb *shatter* is given below.

Good cause: The brick shattered the fragile goblet when they bumped together.

Good theme: The glass shattered the fragile goblet when they bumped together.

As before, test items were rotated across two lists. Each participant responded to all verbs and to equal numbers of good-cause and good-theme sentences, but they never saw the same verb twice. The same fillers and practice items were used as in Experiment 1.

3.1.3. Procedure and design

Each was identical to that of Experiment 1.

3.2. Results

One item was dropped due to experimenter error (a misspelling in the subject noun phrase). Mean reading times for each region are presented in Table 1 (with standard errors) and in Fig. 2. As in Experiment 1, the appropriate sense of the verb was promoted by the context of a good cause or good theme as subject, and this influenced expectations about upcoming structure. An effect of bias was found in both the first and second postverbal regions, due to the fact that participants read transitive sentences faster following the transitive biasing good-cause subject than the intransitive-biasing good theme.

3.2.1. Verb region (*shattered*)

Again, as predicted, there were no differences at the verb, $F < 1$ in both analyses.

3.2.2. First two words (*the fragile*)

Reading times at the first two-word region after the verb were 46 ms shorter in sentences when the subject was a good cause (*brick*) than when it was a good theme (*glass*), $F_1(1,22) = 9.98, p < .01$; $F_2(1,15) = 9.19, p < .01$.

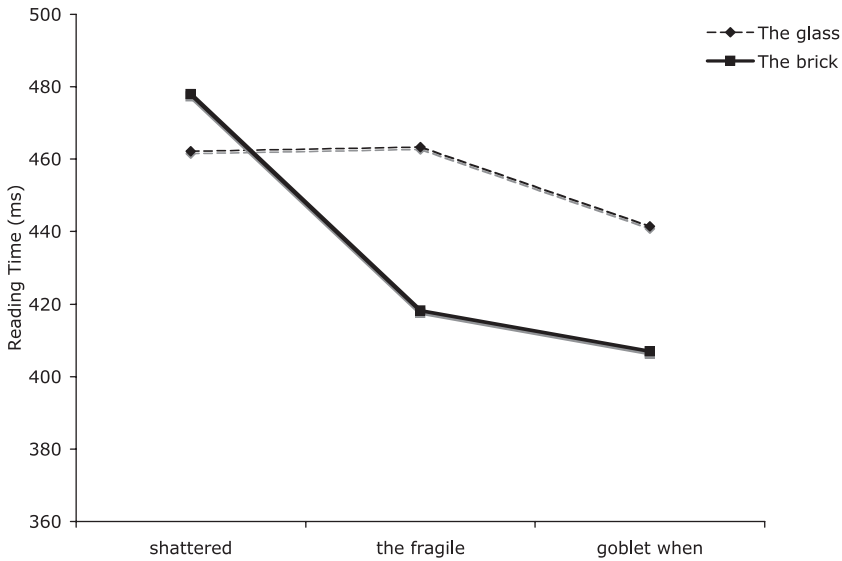


Fig. 2. Mean reading times for Experiment 2, transitive sentences.

3.2.3. Next two words (*goblet when*)

Reading times were 34 ms shorter in the good-cause than in the good-theme subject sentences, $F_1(1,22) = 7.58, p < .02$; $F(1,15) = 5.59, p < .05$.

3.3. Discussion

These results are consistent with the interpretation that readers interpret a change-of-state verb as a causative when the subject is a good cause, an inchoative when the subject is a good theme, and anticipate the sense-contingent structure as a result. The effect of the sense manipulation is shown early, from the first two-word region after the verb. Note that this is, in some cases, even before the direct object is complete. Seven of the 15 items have a determiner and adjective preceding the noun in the direct object noun phrase, so the noun itself does not appear until the next region. This might conceivably have worked against us, delaying the bias effect. But although the direct object noun has not yet been encountered, there is strong evidence in this two-word region that the structure will be transitive—the verb is followed by a determiner and an adjective, ruling out an intransitive structure. The lack of a delay shows that comprehension opportunistically takes advantage of even this partial information.

There is one possible alternative reason why the good-cause sentences resulted in faster reading times. Six items contained a postverbal pronoun prior to the direct object, and these pronouns had a referent in the initial noun phrase of the good-cause sentences, but not in the good theme sentences. We reanalyzed the data without these sentences. There remained an influence of the causal status of the initial noun phrase: postverbal region (423 ms vs. 463 ms), $F_2(1,9) = 30.65, p < .001$; the next two words (403 ms vs. 435 ms),

$F_2(1,9) = 16.53$, $p < .01$. Therefore, the results cannot be due to the presence of these pronouns.

4. General discussion

In two experiments we examined whether comprehenders are sensitive to the relationship between meaning and structure in language, focusing on change-of-state verbs like *grow*, which have two senses that are expressed in different structures. We used as a testing ground the transitivity alternation, which is extremely common in English. Reading times to transitive and intransitive sentences varied with the grammatical subject: Intransitives were read faster in the postverbal region when the subject was a good theme relative to when it was a good cause, whereas the opposite held true for transitives. Readers anticipated upcoming structure based on the sense of the verb, which was cued by the biasing subject noun phrase.

These results are consistent with our earlier finding (Hare et al., 2003) that a short discourse context influences the interpretation of a sense-ambiguous verb and consequently the interpretation of the DO/SC ambiguity. They also offer an explanation for the lack of a transitivity bias effect in McKoon and MacFarland (2000). In that study, structural bias was assumed to remain constant across all uses of the verb. Instead, as the current results show, it varies with sense. Indeed the evidence suggests that structural anticipation is a fundamental part of comprehension and reflects the comprehender's awareness of meaning–structure correlations.

How is this information represented? One formerly dominant view was that the information initially used in sentence processing is strictly grammatical, and comprehenders preferentially interpret a postverbal noun phrase as direct object regardless of extra-grammatical information like sense-based structural biases. Clifton (1993) argued for this view on the basis of studies investigating the resolution of the late-closure ambiguity, which arises in sentences like *Before the police stopped, the Datsun disappeared into the night*. If the comma between the main clause and the preposed adverbial is deleted, *the Datsun*, at the point when it occurs, could ambiguously be either the direct object of *stopped* or the subject of an upcoming verb, such as *disappeared* in this case. This work was in response to Stowe (1989), who found that extra-grammatical information about thematic role fillers influenced how readers interpreted the ambiguity. Stowe manipulated subject animacy, predicting that comprehenders would assume, based on their world knowledge, that animates are typically agents and inanimates are typically themes. If this is the case, then an animate subject would be interpreted as a good agent for the verb, and *the Datsun* would be interpreted as the theme, resulting in an ambiguity effect at the following verb. An inanimate subject, on the other hand, would itself be interpreted as theme. In this case, *the Datsun* would be interpreted as subject of an upcoming verb, so there should be no ambiguity effect. This is precisely the pattern that was found.

Clifton (1993) argued that the self-paced grammaticality task used in Stowe's study lacked the temporal resolution to detect initial syntactic effects. He consequently tested the same manipulation with eyetracking, on the assumption that this would show earlier effects

than self-paced reading. The results at the disambiguating verb replicated Stowe's findings but also suggested difficulty at the postverbal noun phrase (*the Datsun*) in the inanimate-subject condition. This is consistent with the purely syntactic account: The difficulty could indicate that readers initially interpreted *the Datsun* as the direct object. Clifton noted that Stowe's explanation would predict this result as well, but he argued that the syntactic account was preferable because it was more parsimonious and "if one looks closely enough it is possible to find the operation of a specialized grammatical processor" (p. 242). Subsequent work casts serious doubt on this claim, however. Using head-mounted eyetracking, Tanenhaus, Spivey-Knowlton, Eberhard, and Sedivy (1995) measured responses to a structural ambiguity from the earliest possible moment and saw no evidence of a specialized grammatical stage. We thus see no grounds for assuming a strictly syntactic explanation for the current findings.

Could the necessary information be strictly lexical instead? One possibility is that each sense of the verb has its own subcategorization frame and individual information on the thematic roles that the verb could assign to its arguments. We agree that our effects are role driven, but evidence accruing over the last 20 years argues that the fit of a given noun phrase to the verb's thematic roles is influenced by more than purely linguistic knowledge (Tanenhaus & Carlson, 1989). McRae, Ferretti, and Amyote (1997) looked at the role of thematic fit in readers' interpretation of fragments like *The gambler manipulated* (which can continue as a simple transitive ...*manipulated the dealer* or as a reduced relative clause ...*manipulated by the dealer*). *Gambler* is a good agent of *manipulate*, and this should lead readers to anticipate a transitive continuation and show processing difficulty when the continuation involved a reduced relative instead. This prediction turned out to be correct when adjectival modifiers were consistent with the agent role (*shrewd heartless gambler*) but not when the noun was modified to make it more patient-like (*young naive gambler*), showing that the fit of a noun phrase to the theme role is influenced by its properties. Kamide, Altmann, and Haywood (2003) demonstrated that thematic fit is also influenced by the nature of the agent. In an eyetracking study, participants looked preferentially at a picture of a merry-go-round when hearing *The girl will ride...* but at a motorcycle when the agent of *ride* was *man*. Both cases exploit pragmatic information about how the world works, information that is not assumed to be part of one's lexical knowledge.

We suspect that the set of contextual cues that must be taken into account in order to predict the appropriate meaning–structure relationship will turn out to be uncomfortably large for a lexically based solution. The discomfort is that at some point, the standard view of the lexicon will not easily accommodate what might in principle turn out to be an unbounded number of factors that must be taken into account to explain expectancies regarding the probability of upcoming arguments, complements, and other sentential elements. As we discussed above, the processing of a temporarily ambiguous structure can be affected in a verb-specific way not only by the identity of a noun phrase but also by modifiers that alter its character (e.g., whether a "gambler" is "shrewd" or "naive," McRae et al., 1997). Expectations regarding the probable patient of a verb may depend not only on the verb (e.g., that "drink" entails that the patient be potable) but the specific agent (Bicknell, Elman, Hare, McRae, & Kutas, 2008; Kamide et al., 2003). These

expectations can also be altered by the specific instrument that is used with the verb (Matsuki, Chow, Hare, Elman, & McRae, 2008) or reversed by discourse context (Race, Klein, Hare, & Tanenhaus, 2008).

It is noncontroversial that pragmatic, extra-linguistic information influences comprehension (Jackendoff, 2003). The question is how directly and how immediately such factors affect the processing of a sentence as it is being comprehended. What is significant in the studies we refer to, and a number of others, is that there are compelling indications that the effects of this world knowledge are immediate. This suggests to us that what is needed is an account in which our knowledge of events and situations in the world is brought to bear immediately on sentence comprehension as it unfolds in time.

In relation to this, we note that such knowledge can be activated even in response to single words, independent of any larger context. In a paired auditory lexical decision task with a short (200 ms) interval between prime and target, Moss, Ostrin, Tyler, and Marslen-Wilson (1995) found priming from instrument nouns to nouns denoting objects on which the instrument is typically used. Moss et al. concluded that on hearing the instrument noun, comprehenders activate functional information on how it is typically used. Using short stimulus onset asynchrony priming tasks, we have also found that single words activate schematic event knowledge: Verbs referring to common events prime typical event participants (Ferretti, McRae, & Hatherell, 2001), as do event nouns and typical event locations (Hare, Jones, Thompson, Kelly, & McRae, in press).

Overall, these results argue strongly that pragmatic, event-based relations are activated rapidly even as single words are encountered. This suggests to us that rather than enriching the lexicon even further, what is needed is an account in which our knowledge of events and situations in the world is brought to bear immediately on sentence comprehension as it unfolds in time. From this perspective, words might best be viewed as cues that may be used to access event knowledge, and it is that knowledge that guides our expectancies and processing. We have outlined such an account elsewhere (Elman, 2009) and are currently exploring the implications of this account through both experimentation and modeling.

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Appendix

Each set of sentences is ordered in the following manner:

- Intransitive-biased initial noun phrase, intransitive sentence.
- Transitive-biased initial noun phrase, intransitive sentence.
- Intransitive-biased initial noun phrase, transitive sentence.
- Transitive-biased initial noun phrase, transitive sentence.

1. Bend

- The pipe bent towards the ground to connect to the underground line.
- The ironworker bent towards the ground to connect the plug to the outlet.
- The pipe bent the car door when he slipped and dropped it.
- The ironworker bent the car door when he slipped and fell against it.

2. Break

- The window broke into a hail of sharp fragments of glass when he slammed it down too quickly.
- Her husband broke into a hail of sharp recriminations when she forgot to pick up the car at the repair shop yet again.
- The window broke his hand because he slammed it shut too fast.
- Her husband broke his hand because he slammed it down too hard on the table.

3. Burn

- The popcorn burned rather badly after remaining on the stove too long.
- The chemist burned rather badly after remaining in the sun too long.
- The popcorn burned his fingers when he grabbed a handful from the pan.
- The chemist burned his fingers when he grabbed the hot pan.

4. Change

- Her feelings changed from cold to friendly after he apologized for his accidental insult.
- His teacher changed from cold to friendly after he apologized for putting so little effort into his work.
- Her feelings changed his earlier plan to delay the date of the wedding.
- His teacher changed his earlier plan to delay the date of the final exam.

5. Chill

- The wine chilled through the afternoon but they never bothered to open it.
- The wind chilled through the afternoon but they never bothered to put sweaters on.
- The wine chilled the spectators who stood drinking it on the terrace.
- The wind chilled the spectators who stood drinking wine on the terrace.

6. Collect

The rainwater collected in the damp playground and the littlest kids jumped in the puddles.

The children collected in the damp playground and the littlest kids jumped in the puddles.

The rainwater collected dead leaves, insects, and other debris.

The children collected dead leaves, insects, and other debris in the yard.

7. Crack

The plate cracked in several places when Fred dropped it.

The hammer cracked in several places when Fred dropped it.

The plate cracked the glass tabletop when Fred dropped it.

The hammer cracked the glass tabletop when Fred dropped it.

8. Dissipate

The smoke dissipated after the rioting mob broke up and went home.

The police dissipated after the rioting mob broke up and went home.

The smoke eventually dissipated the rioting mob, to everyone's relief.

The police eventually dissipated the rioting mob, to everyone's relief.

9. Erode

Her confidence eroded to nothing after a series of failures.

The storm eroded to nothing after a series of downpours.

Her confidence eroded his hopes of building a winning case against her in court.

The storm eroded his hopes of building a house on the cliff.

10. Flower

The plants flowered in the new location because of the extra sunlight there.

The gardener flowered in the new location because of her friendly co-workers there.

The plants flowered the front yard in vibrant colors.

The gardener flowered the front yard in vibrant colors.

11. Grow

The child grew tired and grumpy after a long day of playing.

The farmer grew tired and grumpy after a long day of work in the fields.

The child grew soy beans and corn for a school project.

The farmer grew soy beans and corn as a cash crop.

12. Halt

The soldiers halted when they spotted the enemy in front of them.

The policemen halted when they spotted the suspect in front of them.

The soldiers halted the suspicious car at the checkpoint.

The policemen halted the suspicious car at the checkpoint.

13. Improve

His grades improved after intensive training in useful techniques for studying.

The tutor improved after intensive training in useful techniques for holding a child's interest.

His grades improved his self-image and increased his confidence.

The tutor improved his self-image and increased his confidence.

14. Shatter

The glass shattered into tiny bits when it hit the floor.

The brick shattered into tiny bits when it hit the floor.

The glass shattered the fragile goblet when they bumped together.

The brick shattered the fragile goblet when they bumped together.

15. Sink

The speedboat sank below the surface but fortunately a tanker was nearby to help.

The iceberg sank below the surface but fortunately the tanker managed to avoid it.

The speedboat sank the small ship when they collided.

The iceberg sank the small ship when they collided.

16. Splinter

The wooden beam splintered with a loud bang as it struck the concrete floor.

The bullet splintered with a loud bang as it struck the concrete floor.

The wooden beam splintered his femur as it hit his leg.

The bullet splintered his femur as it hit his leg.

17. Split

The tree split in two pieces as it crashed to the pavement.

The ax split in two pieces as it crashed to the pavement.

The tree split the fence rail right in half as it crashed down during a hurricane.

The ax split the fence rail right in half as it crashed down through it.

18. Wither

The old man withered to nothing after a long and difficult year of sickness.

The drought withered to nothing after a long and difficult year.

The old man withered the plants in the garden that he forgot to water.

The drought withered the plants in the garden that went weeks without water.