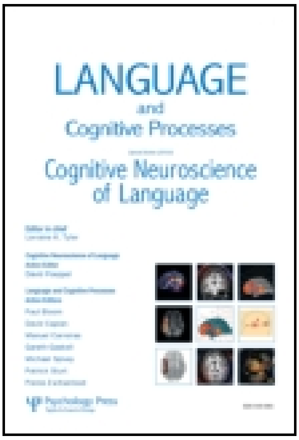

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Evidence for automatic accessing of constructional meaning: Jabberwocky sentences prime associated verbs

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Evidence for automatic accessing of constructional meaning: Jabberwocky sentences prime associated verbs

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A central question within psycholinguistics is where sentences get their meaning. While it has been shown that phrasal constructions are readily associated with specific meanings, it remains unclear whether this meaning is accessed automatically, in the sense of being accessed quickly, and without reflection or explicit instruction. In this study, participants performed a lexical decision task on individual target words which were preceded by abstract skeletal constructions devoid of any meaningful open-class items. For example, an instance of a ditransitive prime was, *He daxed her the norp*. Three target words corresponded to the hypothesised meaning of each construction; that is, semantically congruent words for the English ditransitive were *give, handed,* and *transferred*. We found significant priming effects for congruent over incongruent target words, both for associated targets (which occur regularly within the construction: e.g., *give* and *handed*), and to a lesser extent, for target words that are semantically related to the construction but which rarely occur in the construction (e.g., *transferred* for the ditransitive).

Keywords: Construction grammar; Sentence meaning; Associative priming; Semantic priming.

> "Somehow it seems to fill my head with ideas"—Alice in Wonderland on reading Jabberwocky (*Through the Looking-Glass,* Lewis Carroll)

Where does the meaning of a sentence come from? Chomsky (1957) made famous the sentence, *Colorless green ideas sleep furiously*, arguing that although it is syntactically well formed, it has no meaning. While many poetically minded people objected that the sentence can be interpreted metaphorically in a number of ways (e.g., Chao, 1997), the overall idea that open-class words of a sentence must be combined in ways that make sense in order for a sentence to be interpretable still enjoys widespread currency. In this way, it has regularly been assumed that sentences that contain no meaningful open-class items, such as those in (1), are meaningless:

1. She jorped it miggy.

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For example, this type of "nonsense sentence" has regularly been used in experiments designed to distinguish the contribution of pure form from that of meaning, so as to determine the neural representations of syntax (Friederici, Opitz, & von Cramon, 2000; Mazoyer et al., 1993; Moro et al., 2001; Roeder, Stock, Neville, Bien, & Roesler, 2002; Yamada & Neville, 2007).

Within this perspective, the main verb of the sentence is generally taken to play a pivotal role in interpretation, by specifying the way that overt arguments are related to one another. Almost any traditional grammar book, or beginning logic or linguistic class will likely begin a discussion of sentence types with a classification of verbs according to how many arguments they "take". It is generally assumed, for example, that *sneeze* is intransitive, *kick* is transitive, and *give* requires an agent, a theme, and a recipient. In this way, basic sentence patterns of a language are believed to be determined by syntactic and semantic information specified by the main verb. For example, the ditransitive pattern in (2) appears to be due to the specifications of *give:*

2. Pat gave Sam a book.

But the idea that all meaning comes from lexical items has its critics. If argument structure were projected exclusively from a verb's semantics, we would need special verb senses for each of the verbs in the expressions in (3) (e.g., Goldberg, 1995, 2006; Jackendoff, 2002):

3. a. If time is money then save yourself rich at Snyder's! (Mark Turner, personal communication)

   b. The people of this small town . . . have been unable to pray Mrs. Smith's two little boys home again. (Mark Turner, personal communication)

   c. "his thousands of travelling fans . . . had roared him into the Thomas and Mack Center ring" www.topix.net/wire/world-soccer/manchester-united

   d. She tried to avoid blinking the tears onto her cheeks (Anne Tyler, 1992, Dinner at the Homesick Restaurant, NY: Knopf)

   e. "Demi Moore thinks this will Halle Berry her back to the B List". <from Mr. Brooks movie> (fR. Grush, personal communication 2007)

   f. "I actually had a moth go up my nose once. I . . . coughed him out of my mouth" (bikeforums.net/archive/index.php/t-292132)

That is, we would need a sense of *save* that meant roughly "to cause to become by saving"; a special sense of *pray* "to cause to move by praying"; a special sense of *roar* that entails motion and so on. These senses are implausible in that one does not find languages that devote unique stems to these meanings. For example, it is unlikely that one would find a word *camo*, meaning "to cause to move by coughing" because this is not a situation that is likely to occur regularly enough to warrant a lexical meaning (Goldberg, 2010).

In order to avoid such implausible verb senses, it has been proposed that argument structure patterns are associated with abstract meanings independently of the verbs that appear in them. On this view, verbs can combine with argument structure constructions on the fly to create novel sentences like those in (3). Examples of such *argument structure constructions* are given in Table 1.

TABLE 1
English argument structure constructions

Ditransitive: (Subj) V Obj1 Obj2	X CAUSES Y to RECEIVE Z
Caused-motion: (Subj) V Obj Oblique_{path}	X CAUSES Y to MOVE Z
Resultative: (Subj) V Obj Pred	X CAUSES Y to BECOME Z
Transitive: (Subj) V Obj	X ACTS on Y; X EXPERIENCES Y
Removal: (Subj) V Obj Oblique_{source}	X CAUSES Y to MOVE from Z
Way construction: (Subj_i) V [poss_i *way*] Oblique_{path}	X CREATES PATH & MOVES Z_{path}

Previous work has provided some theoretical and experimental evidence in support of argument structure constructions. Theoretical arguments have typically emphasised the *ad hoc* and implausible nature of the verb senses that would otherwise be required, as just mentioned (see Goldberg, 1995, 2006 for further arguments). Other work has noted that learners use the semantics associated with syntactic patterns in order to figure out what new verbs mean (Fisher, 1996; Gillette, Gleitman, Gleitman, & Lederer, 1998; Landau & Gleitman, 1985); this idea presupposes the idea that the syntactic patterns are associated with meanings independently of the main verb.

Bencini and Goldberg (2000) conducted a sorting experiment with the aim of directly comparing the semantic contribution of the construction with that of the verb. The stimuli were 16 sentences created by crossing four verbs with four different constructions. A sample set of sentences for the verb *throw* is given in Table 2.

TABLE 2
Sample stimuli for sorting experiment

a.	Pat threw the hammer	Transitive
b.	Chris threw Linda the pencil	Ditransitive
c.	Pat threw the key onto the roof.	Caused–motion
d.	Lyn threw the box apart.	Resultative

Participants were asked to sort the 16 sentences, provided in random order, into four piles based on "overall sentence meaning". Participants could sort equally well by verb: for example, all instances of *throw* (a–d) being grouped together, regardless of construction; or they could sort by construction: for example, all instances of the ditransitive construction being grouped together. The stimuli were designed to minimise contentful overlap contributed by anything other than the lexical verb. No other lexical items in the stimuli were identical or near synonyms. Results demonstrated that participants were just as likely to sort by construction as they were to sort by verb, providing evidence that the constructions were as strong a cue to sentence meaning as verbs.

On the multiple sense view, the reason that instances of *throw*, for example, were put into separate piles was because each instance represented a distinct sense which was more similar in meaning to one of the senses of another verb than to the other senses of *throw*. However, the only way for participants to discern which verb sense was involved was to recognise the argument structure pattern and its associated meaning.

That is, the proposed different verb senses all look the same; the only way to determine that a particular sense is involved is to note the particular argument structure pattern that is expressed and infer which verb sense must have produced such a pattern. Therefore, at least from an off-line comprehension point of view, the pairing of argument structure pattern with meaning must be primary.

Kaschak and Glenberg (2000) provided important evidence of constructional meaning through a series of comprehension studies involving novel denominal verbs (Clark & Clark, 1979). In particular, they asked participants to read passages that set up potential transfer contexts such as that in (4):

4. Tom and Lyn competed on different baseball teams. After the game, Tom, who had been pitching, was kidding her about striking out three times. Lyn said, "It was an aberration! I was distracted by your ugly face. I can hit anything to any field using anything!" To prove it, she took her apple over to manager who was recovering from a twisted ankle, and she grabbed his crutch.

Participants were asked to paraphrase sentences such as 5a or 5b. Another group was asked to define the denominal verbs involved:

5. a. Lyn crutched Tom her apple to prove her point. (double object)

   b. Lyn crutched her apple to prove her point to Tom (transitive)

Results demonstrated that participants were more likely to decide that transfer had occurred in 5a than in 5b, and were more likely to decide that the novel verb (e.g., *crutch*) was a verb of transfer. In addition, Kaschak and Glenberg demonstrated that different aspects of the *affordances* of the denominal verb played a role in the sentences' interpretations. For example, participants were faster to judge "the crutch is sturdy" as true after a passage like that in (4) than they were to judge "The crutch can help with injuries", despite the fact that helping with injuries is more associated with crutches in general, as determined by Latent Semantic Analysis (Landauer & Dumais, 1997). They conclude that "the syntax specifies a general scene, and the affordances of objects are used to specify the scene in detail sufficient" (p. 508).

Goldwater and Markman (2009) have likewise shown that instances of the middle construction involving novel denominal verbs are more likely to be judged as being nonsensical when followed by purpose clauses than passive constructions involving the same novel verbs:

Middle:

6. ??The ripe tomatoes had sauced well to complement the pasta at the gala dinner.
Passive:

7. The ripe tomatoes were sauced well to complement the pasta at the gala dinner.

They attribute the difference to the fact that only the passive construction requires a (possibly unspecified) agent argument. As in Kaschak and Glenberg (2000), Goldwater and Markman (2009) used novel denominal verbs in order to determine what role the construction played in assigning meaning. The meaning could not be ascribed to a preexisting denominal verb because the verbs were normally only used as nouns.

Kako (2006) makes a similar point by asking for semantic judgments about nonsense words in Jabberwocky-type sentences such as "The rom gorped the blickit to the dax".

These studies collectively argue that argument structure constructions play a role in speaker's ultimate interpretations of sentences. But a critic might argue that all of these tasks lent themselves to strategic responding, since they are all either off-line tasks (Bencini & Goldberg, 2000; Kako, 2006; Kaschak & Glenberg, 2000), or tasks that require sensicality judgments (Goldwater & Markman, 2009). Each of the tasks involved has been explicit, asking participants: "does this make sense?" (Goldwater & Markman, 2009); "what does this mean?" (Kako, 2006); to "paraphrase this sentence" (Kaschak & Glenberg, 2000); or to "sort according to overall sentence meaning" (Bencini & Goldberg, 2000). Work demonstrating a role of constructional meaning in the acquisition of verbs ("syntactic bootstrapping") in younger children is compelling, but the aspects of meaning that have been demonstrated to date have focused primarily on the number of arguments involved (cf. also Goldwater & Markman, 2009).

In fact, there have been virtually no experiments designed to determine whether contentful constructional meaning is accessed quickly, without time for reflection and without explicit instruction. The present study was motivated by this lacuna, as it investigates the possibility of automatically accessed constructional meaning in Jabberwocky-type sentences, using in a speeded lexical decision task. If such meanings are available on a time scale compatible with online sentence comprehension, it would support the idea that constructional meanings play an important role in sentence processing.

MATERIALS

Four abstract constructions were used as primes. These are shown in Table 3. The experimental target words chosen for each construction are provided in Table 4. Each verb was presented in its past tense form.

We consider whether Jabberwocky-type sentences such as those in Table 3 prime words related to their hypothesised meanings. Positive evidence of priming would be evidence that the constructions are associated with meaningful verbs. In particular, we consider whether argument structure constructions prime the following types of words: high frequency (HF) associates, low frequency associates (LF), and semantically related nonassociates (SN). HF associates were chosen to be the verbs that (most) frequently occur in a particular construction. For example, *give* is the most frequent verb that occurs in the ditransitive, accounting for close to half of all tokens of the construction (Goldberg, Casenhiser, & Sethuraman, 2004; Stefanowitsch & Gries, 2003). LF associates are verbs that appear in the construction, but markedly less frequently than the HF associates. For example, *hand* occurs in the ditransitive (e.g.,

TABLE 3
The four abstract phrasal constructions used as primes

Abstract construction	*Constructional frame used to create stimuli*	*Example*
Ditransitive	S/he nonseV-ed him/her the nonseN.	*He daxed her the norp*
Resultative	S/he nonseV-ed it nonseAdj.	*She jorped it miggy*
Caused-motion	S/he nonseV-ed it on the nonseN.	*He lorped it on the molp.*
Removal	S/he nonseV-ed it from him/her.	*She vakoed it from her.*

She handed him something), but less frequently than *give* does. Statistics were gathered from the 400 million word Corpus of Contemporary American English (COCA), and are provided in the Methods section (Table 5).

We also included semantically related nonassociate target verbs in order to investigate whether purely semantic priming as well as associative priming would be evident. These were verbs that do not generally occur in the corresponding construction, but are semantically related to the meaning that has been hypothesised for the construction. For example, the meaning of *transfer* captures the hypothesised meaning associated with the ditransitive construction, and yet the verb itself rarely occurs in that frame (e.g., ?*She transferred him something*). (Quantitative data is given in Table 5.) The particular verbs chosen for each of four verbs are provided in Table 4.

TABLE 4
Experimental target words for each construction

Constructions	*High frequency associate*	*Low frequency associate*	*Semantically related nonassociate*
Ditransitive	*Gave*	*Handed*	*Transferred*
Resultative	*Made*	*Turned*	*Transformed*
Caused-motion	*Put*	*Placed*	*Decorated*
Removal construction	*Took*	*Removed*	*Ousted*

If the results demonstrate priming, it would provide evidence that the "nonsense sentence" primes were not, after all, completely nonsensical. If the ditransitive, for example, devoid of a contentful verb or any open-class lexical items, primes *gave*, it would provide evidence that the abstract pattern is associated directly with this verb. It is possible that constructions with nonse-words prime *only* the highest frequency verbs that can occur in them (such as *gave* in the ditransitive), because by hypothesis, the constructions are closely associated with these verbs. Or it may be that only HF or LF verbs that can appear in the construction are primed, but semantically related nonassociates are not primed, because it may be that priming requires compatibility of the verb in the construction. The strongest finding would be that all three types of verbs are primed by their respective abstract constructions. The overarching goal of the study is to determine whether there exists evidence in favour of abstract semantics being automatically associated with syntactic frames that contain no open-class lexical items, without recourse to possible reflective strategies.

METHODS

Participants

Forty Princeton undergraduate students, aged 18–23, participated in exchange for course credit. All participants were native English speakers.

Procedure

Participants performed lexical decisions following sentential primes. In particular, they were instructed that they would be presented with a phrase written in black, directly followed by a "word" written in green. They were to read the sentence aloud, and then respond as quickly as possible, pressing "1" if the green "word" was a real word and "2" if it was a nonword.

Construction primes. Stimuli included four different abstract constructions that included nonsense open-class items (See Table 1). The four constructions were completely abstract since all of the open-class items were nonsense words. These nonsense words were drawn randomly from predetermined lists of 25 items that did not overlap with the probe nonwords. Prime sentences were created using all nonsense open-class words. Nonse words were chosen randomly from a set of 75 forms that had the typical morphophonological form of verbs (25), nouns (25), or adjectives (25). Each nonse-word appeared randomly (with replacement) in the constructions. Example sentences for each construction type were given in Table 3.

Lexical targets. The target words of interest were high or low associates of one of the constructions, or words that were semantically related to one of the constructions, but which did not regularly occur in the construction. In order to classify verbs, we searched the 400 million word on-line COCA. The frequencies of each of the target words in the relevant construction type are provided in Table 5.

TABLE 5
Raw frequencies of target words in their congruent construction. Based on 400+ million word COCA corpus

Construction (search string)	*High frequency associate*		*Low frequency associate*		*Semantically related, nonassociate*	
Ditransitive (V pronoun the N)	*Gave*	2,365	*Handed*	362	*Transferred*	0
Resultative (V it Adj)	*Made*	19,833	*Turned*	184	*Transformed*	1
Caused-motion (V it on the N)	*Put*	591	*Placed*	224	*Decorated*	0
Removal (V proN from pronoun)	*Took*	394	*Removed*	17	*Ousted*	0

The general procedure was the same throughout the experiment (see Figure 1). Participants were first presented with a fixation cross (3 seconds), then an abstract phrasal construction which they quickly read aloud (1000 ms), then after a brief fixation (300 ms), they were presented with the target word, and had to decide whether it was a word or nonword. Participants were instructed to respond as quickly as possible to the target which directly followed, indicating via button press whether it was a real word or nonword. Half of the target words were words, half nonwords.

Participants received feedback on each trial on whether their response was correct or not, or whether they took too long (> 1000 ms) to respond. Feedback screens were presented for 500 ms each, after which a new trial would begin.

The dependent measure was reaction time, and the independent variable was prime type. In order to control carefully for length, frequency, and other factors, we

+	"Construction Phrase"	+	"Target Word"
(3000 ms)	(1000 ms)	(300 ms)	(up to 1000 ms)

Figure 1. Basic structure for a priming trial.

compared reaction times to the *same* set of words, systematically varying whether the prime construction was either congruent or incongruent with the target word, across participants. For example, when *gave* was preceded by the ditransitive construction (e.g., *He jorped him the brap*), it was "congruent"; when *gave* is preceded by the removal construction, it was incongruent.

Practice. After the task was explained to participants, they proceeded to a practice phase in which they were given 12 training trials, half of which were real words and the other half nonwords (see stimuli). The practice phase was needed to train participants to read the Jabberwocky sentences within the 1000 time window (pilot work revealed that a more natural, relaxed reading time for these sentences would have been 1200–1400 ms). These training stimuli were only used during the practice phase. New items were used during the experimental trials. The purpose of the practice phase was to get participants properly adjusted to the speed of the experiment. Although many participants found it difficult at first, by the end of the practice trials, all participants felt confident continuing.

Experimental structure

Experimental trials were divided into three blocks based on the three priming categories: HF Associative, and LF Associative, and Semantic Nonassociative (SN). Four experimental words were seen for each experimental block. Participants were randomly divided into two groups such that each group saw two experimental words of each type (HF, LF and SN) in a congruent context, and the other two of each type in an incongruent context. In this way, each participant witnessed two words in each block in a priming context and two words without a relevant prime (see Table 6).

That is, all participants in both groups saw each experimental word exactly once. Twenty participants (Group 1) saw and responded to *gave* and *took* after congruent constructions—that is, after the ditransitive and the removal constructions, respectively, and responded to *made* and *put* after incongruent constructions—after the caused-motion and the resultative constructions, respectively. A second group of 20 participants (Group 2) saw the reverse, as shown in Table 6. Responses to each particular target word after congruent and incongruent primes were then compared between subjects (see Table 7).

Again, the *same* target words were used following incongruent constructions to determine baseline RTs for each word (between subjects).

Different types of nonwords and real words were presented during different blocks. Each block consisted of two phases: An "acclimatisation" phase (12 trials), explained below, and an "experimental" phase (8 trials). The overall structure of the experiment was as follows:

TABLE 6
Target words and the prime construction given to each of two groups of participants

Prime words	*Group 1*	*Group 2*
Gave, Handed, Transferred	Congruent (ditransitive)	Incongruent (removal)
Made, Turned, Transformed	Incongruent (caused-motion)	Congruent (resultative)
Put, Placed, Decorated	Incongruent (resultative)	Congruent (caused-motion)
Took, Removed, Ousted	Congruent (removal)	Incongruent (ditransitive)

TABLE 7
Average difference in RT organised by construction and verb

Construction	High frequency associate		Low frequency associate		Semantically related, nonassociate	
Ditransitive	*Gave*	137	*Handed*	135	*Transferred*	106
Resultative	*Made*	86	*Turned*	−35	*Transformed*	−7
Caused-motion	*Put*	104	*Placed*	82	*Decorated*	6
Removal	*Took*	120	*Removed*	128	*Ousted*	132
AVERAGE		111		77		59

1. Practice (12)
   -Break-
2. Acclimatisation (12 trials: 6 words and 6 nonwords)
3. HF associates (8 trials: 4 experimental words and 4 nonwords)
   -Break-
4. Acclimatisation (12)
5. LF associates (8)
   -Break-
6. Acclimatisation (12)
7. Semantically related nonassociates (8)

The reason for including the acclimatisation phases was to condition participants to attend carefully to target forms in order to avoid floor effects in response times. If words had been sufficiently distinct from nonwords, the task would have been quite easy and might well have led to insufficient variability in response times. We therefore included target words and nonwords that were minimally different from each other and from the experimental items in that block. For example, in the HF associate block, the experimental words were *gave*, *put*, *make*, and *took*. The words in the acclimatisation phase included verbs that are phonetically similar to those in the experimental phase (e.g. *have*, *met*, *stood*, *saw*), as well as nonwords that are also phonetically similar (*stook*, *puv*, *goot*, *gade*). In each acclimatisation phase, participants saw six nonexperimental real verbs and six nonwords. In each experimental phase, participants saw the four experimental words, as well as four nonwords.

There was no transition from the acclimatisation phase to the experimental phase of each block. From the participant's perspective, the practice phase was simply followed by three seamless blocks. The ratio of related word trials to unrelated trials was 1–10 in each block.

After each block, participants were shown a break screen, telling them that they had finished block 1 or 2 of three. They were asked to press a space bar to continue whenever they felt ready. Participants typically only paused long enough to read the break screen before continuing on to the next block.

RESULTS

There were 480 possible data points. Only response times of the 12 experimental words that were accurately responded to as words within the 1000 ms time window were analysed. We removed 55 of these (< 11.5%) due to either an incorrect response or because no response was registered within 1000 ms. This provided a total of 425 data points, with a range of 13–20 data ($M = 18$) for each cell (mean RT = 608 ms).

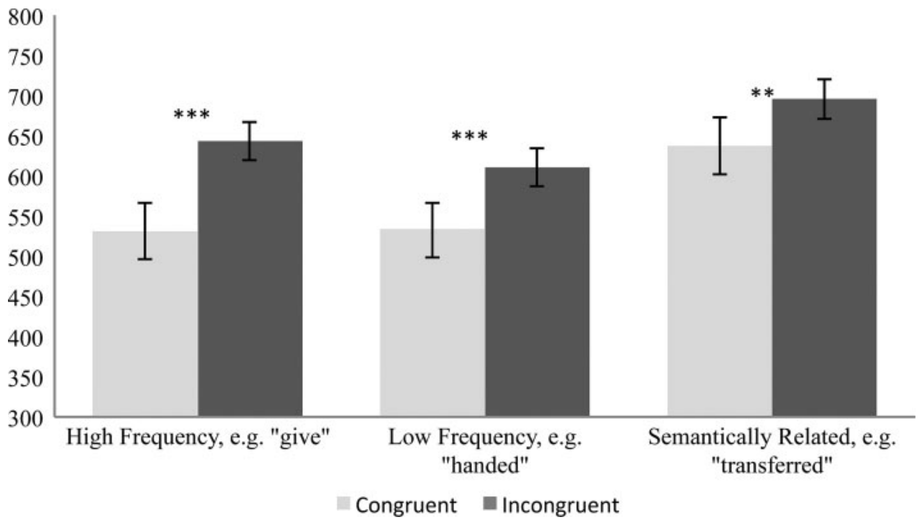

Figure 2. Reaction times for congruent and incongruent presentations, by category of target with example words given for the ditransitive construction.

By subtracting the reaction time for a given word after a congruent sentence from the reaction time for the same word after an incongruent sentence, we determine the extent of priming.

We find an overall main effect of primed over unprimed by-subject, $F1(1, 430) = 50.9$; $p < .001$. Considering each of the three conditions in turn, we find significant priming for HF and LF associates, $F1(1, 136) = 43.5$, $p < .001$; $F1(1, 153) = 21.7$; $p < .001$, and for semantically related nonassociates, $F1(1, 140) = 6.9$, $p = .009$ (see Figure 2).

Effects are expected to be weaker when considering performance by-item because we had relatively few items. Yet we still find an overall priming effect, $F2(2, 23) = 11.05$, $p < .01$. There is also no significant decrease in priming across HF associates, LF associates, and semantic nonassociates, either in terms of a main effect, $F2(2, 11) = .690$, $p = .526$, or when groups are compared pairwise [HF vs. LF: $F2(2, 7) = .654$, $p = .450$; LF vs. Sem: $F2(2, 7) = .118$, $p = .743$; HF vs. Sem: $F2(2, 7) = 1.907$, $p = .216$]. Considering each group on its own, we find significant priming for both HF associates, $F2(2, 7) = 125.8$, $p < .001$, and LF associates, $F2(2, 7) = 7.2$, $p = .036$. We do not find a significant priming effect by-items for the semantically related nonassociates, $F2(2, 7) = 1.6$, $p = .25$.

If we consider each of the four *constructions* in turn by-subject, we find significant priming of the ditransitive, $F1(1, 106) = 44.6$, $p < .001$, the caused-motion, $F1(1, 114) = 7.76$, $p = .006$, and the removal constructions, $F1(1, 98) = 18.02$, $p < .001$. The only construction that does not show significant across the board priming is the resultative, $F1(1, 106) = .79$, $p = .364$. When considering the constructions by-item, the caused-motion and the resultative do not reach significance, $F2(2, 2) = 4.5$, $p = .16$ and $F2(2, 2) = .163$, $p = .725$, respectively, but the ditransitive and the removal constructions do, $F2(2, 2) = 167.1$, $p = .006$ and $F2(2, 2) = 361.2$, $p = .003$, respectively.

DISCUSSION

We compared the reaction times for target words following the construction that is expected to prime them (congruent) with reaction times for the same target words following one of the other three constructions (incongruent). Overall, the same words were recognised significantly faster after instances of semantically related constructions than after instances of unrelated constructions, when analysed both by-items and by-subjects. The fact that the by-items analysis was significant overall is particularly striking since we used relatively few items (three for each of four constructions). More specifically, both strong and weak associates of constructions were primed by the Jabberwocky sentences, by-items and by-subjects. The priming of semantically related nonassociates was significant by-subjects only. Since purely semantic priming is well known to be weaker than associative priming (Lucas, 2000), the fact that the effect was somewhat more fragile for nonassociates is not unexpected.

When considering individual constructions, the weakest results were found for one particular construction: the resultative construction, which did not exhibit priming either by-subject or by-item. In order to understand why this might have been the case, recall that priming was determined by comparing reaction times after the congruent construction to reaction times after an incongruent construction. The "incongruent" construction in this case was the caused-motion construction (??*She made/turned/transformed it into the room*). However, the target verbs can appear in the caused-motion construction with a metaphorical change of state interpretation as in 8:

8. She made/turned/transformed the clay into a vase.

Moreover, we used sentences such as *He lorped it on the molp*, using the preposition *on* which can readily be interpreted as a locational adjunct, and can in that capacity be used with transitive uses of the relevant verbs:

9. She made the model on the table.

10. She turned the car on the street.

11. She transformed the clay on the table.

Thus, the null effect in the case of the resultative may have been due to the fact that the "incongruent" construction was not altogether incongruent.

There may well be more than one mechanism underlying priming in lexical decision tasks as three separate mechanisms have been proposed (Neely, Keefe, & Ross, 1989). These include automatic spreading activation (Collins & Loftus, 1975), automatic semantic integration (De Groot, 1984), and a more strategic expectancy-based priming (Tweedy, Lapinski, & Schvaneveldt, 1977). While it may ultimately be possible to subsume all three types under a general heading (Plaut & Booth, 2000; Ratcliff & McKoon, 1988), only expectancy-based priming has been argued to be nonautomatic in the sense of requiring fairly long interstimulus intervals ($>$ 500 ms), and being amenable to conscious strategy. Since we have been assuming that the priming involved in the present study *is* automatic, it is important to explain why, by discussing the three proposed mechanisms.

Spreading activation is based on the idea that there exist links of varying strength between entities in semantic memory. Activation of a concept spreads activation outward to other concepts that it is linked to. Spreading activation is automatic in that it occurs on short time scales and it does not require attention or awareness (Poser & Snyder, 1975). A second automatic process of semantic integration or semantic matching is also widely recognised (De Groot, 1984; Neely et al., 1989). This process is thought to occur after the target word is initially accessed but before the lexical decision is made (Neely et al., 1989; Seidenberg, Waters, Barnes, & Tanenhaus, 1984) as a by-product of "integrating a lexical element into a higher-order representation of the entire sentence or discourse" (Chwilla, Hagoort, & Brown, 1998, p. 534). Semantic integration priming has been found at ISIs as short as 240 ms (Neely, 1977). This priming occurs even when the proportion of related targets to unrelated targets is low, so that participants are not likely to anticipate that a related word may appear. The N400 ERP component, generally recognised to be automatic, has been argued to be caused by the same semantic integration process (Chwilla et al., 1998).

When intervals between stimuli are 500 ms or longer, it has been argued that speakers are capable of generating an expected set of candidate targets on the basis of the prime (Chwilla et al., 1998; De Groot, 1984). This expectancy-based priming has been argued to be strategic insofar as a greater priming effect is found when the proportion of related targets in the experiment is high (> 75%). That is, if it is reasonable to expect that upcoming targets may be related to a preceding word, participants show a stronger priming effect, as if they have directed attentional resources to considering related words.

Our design was not specifically designed to test for different types of priming, but the design and results are most naturally interpreted as involving the automatic, semantic matching process. Participants had only 1000 ms to read full Jabberwocky sentences aloud. They had to read very quickly to accomplish this since reading these sentences at a more natural pace takes 1200–1400 ms. Reading was followed only by a short 300 ISI, well below the 500 ms believed to be necessary for expectancy-based priming. Further arguing against the expectancy-based account is the fact that the proportion of related targets was quite low: only one in five real words was related to its prime sentence and only half of target words were real words. That is, only 10% of trials involved a related word. Finally, both spreading activation and expectancy-based priming would predict that strong associates should have shown more priming than weak associates, in the former case because the spreading is assumed to be directional and in the latter case because the higher frequency associates are by definition more expected, given the prime. We did not find this in our results; instead the priming did not decrease significantly across groups (cf. also Becker, 1980; Neely, 1977). These factors support the idea that the priming involved in the present study involved an automatic semantic-matching process.

It might be suggested that evidence of priming is not the same as demonstrating that the construction "has" meaning. This critique raises the thorny issue of the nature of meaning. At the least, we have demonstrated that constructions prime meaningful words that occur in them, both with HF and with markedly lower frequency words. It has been argued that associative priming is a type of semantic priming (McRae & Boisvert, 1998). In fact, Thompson-Schill, Kurtz, and Gabrieli (1998) found that associates only show priming if they are semantically related. It is left for future work to determine conclusively whether semantically related nonassociates are primed by constructions since the present evidence was mixed on this point: priming was significant by-subjects but not by-items.

In any case, it is sufficient to note that each construction primed associated meaningful words. If, for example, the ditransitive makes one activate *give*, then this provides a cue to interpretation. In fact it has been argued that words "have" meaning in much this way: they serve as cues that combine to direct a comprehender to an interpretation (Elman, 2009). The findings lend strong support to the idea that argument structure constructions convey meanings that are accessed on short enough time scales to be relevant to on-line sentence interpretation.

The present results do not speak to the question of whether argument structure constructions are necessarily phrasal or whether they may be conceived of as lexical templates (Müller, 2006; Rappaport Hovav & Levin, 1998). But the present work provides evidence that the meanings associated with argument structure constructions can be accessed quickly and without explicit strategy.

CONCLUSION

There is a growing trend towards distinguishing a verb's inherent or "core" lexical semantics from the semantics associated with the grammatical structures in which the verb can occur (e.g., Goldberg, 1992, 1995; Jackendoff, 1997; Muller, 2006; Rappaport Hovav & Levin, 1998). At the same time, there is also much work that presupposes that all meaning comes from words. The present findings indicate that phrasal abstract constructions are associated with semantics even when they contain no open-class lexical items, and that the meaning is accessed quickly and without explicit instruction. Constructions prime not only main verbs with which they regularly occur, but they also prime main verbs that are low frequency associates and to some extent, semantically related nonassociates. This evidence of semantic priming indicates a tight link between syntax and semantics in the domain of argument structure. That is, argument structure constructions are associated with meanings. In this way, Alice was right when she noticed that the sentences of Jabberwocky "filled her head with ideas".

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