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0096-3445/04/$12.00 DOI: 10.1037/0096-3445.133.3.000

This Construction Needs Learned

Michael P. Kaschak and Arthur M. Glenberg
University of Wisconsin—Madison

Four experiments are presented in which adults learned to comprehend a new syntactic construction in their native language. Experiments 1 and 2 demonstrate that adults quickly learn to comprehend the new construction and generalize it to new verbs. Experiment 3 shows that experience with the novel construction affects the processing of a construction already known to the participants and with which the novel construction is temporarily ambiguous. Experiment 4 demonstrates that the influence of a novel construction on the comprehension of familiar constructions is affected by the processing that occurred while the novel construction was learned. These results are discussed in the context of the constraint satisfaction approach to sentence processing and episodic-processing accounts of memory.

Although the most rapid and successful language acquisition occurs during childhood, there is ample evidence that adults remain capable of learning new linguistic patterns in their native language. Studies from sociolinguistics and experimental psychology document adults' continued ability to learn new words (e.g., Chaffin, 1997; Chaffin, Morris, & Seely, 2001; Markson & Bloom, 1997), phonological patterns (e.g., Dell, Reed, Adams, & Meyer, 2000; Labov, 1994a, 1994b; Onishi, Chambers, & Fisher, 2001), and syntactic constructions (e.g., Kroch, 1989, 2001; Sankoff, 2002). Whereas this phenomenon has been documented in the literature, there have been relatively few systematic studies of the processing mechanisms that support this learning. This is particularly true in the case of adults learning new syntactic constructions.

This research represents an initial attempt to characterize the processes that occur as adults repeatedly encounter, and learn to comprehend, a novel syntactic construction in their native language. This work is aimed at achieving two goals: (a) collecting observations of the online events that occur as readers learn to comprehend a new construction and (b) assessing the extent to which extant learning-based theories of sentence comprehension provide the kinds of processing mechanisms required to account for the readers' behavior. These goals are addressed in four experiments that give readers training on a construction with which they are unfamiliar: the *needs* construction (e.g., "The meal needs cooked"). The experiments are designed to assess both readers' changing performance in reading the needs construction and the way that exposure to the needs construction affects their comprehension of other more familiar types of sentences.

The training in our experiments represents a case in which native English speakers from the upper midwest (all of the research participants in these experiments were from Wisconsin and Minnesota) come into contact with a feature of another English dialect. Specifically, the needs construction is a feature of American English spoken in the northern midlands dialect region, which extends from western Pennsylvania (most notably around Pittsburgh) through Ohio, Indiana, Illinois, parts of Iowa, and regions west of Iowa, extending to the Pacific Ocean (the construction is also a feature of the English dialects spoken in regions of Scotland; for details, see Murray, Frazier, & Simon, 1996; Murray & Simon, 1999, 2001). In discussing the outcome of this exposure to a new construction, we draw a distinction between the claim that our readers are "learning to comprehend" the needs construction (which is our claim) and the claim that the readers have "acquired" the construction.[1] This distinction is drawn because the term *acquisition* is better reserved for cases in which the language user both comprehends and produces the structure in question. Because no attempt is made to monitor the language production of the participants in these experiments, it is impossible to assess the extent to which they have acquired the construction as opposed to learning to comprehend it in the context of the experiment. Fn1

Michael P. Kaschak and Arthur M. Glenberg, Department of Psychology, University of Wisconsin—Madison.

Preparation of this article was supported in part by National Science Foundation Grants BCS-0315434 and INT-0233175 awarded to Arthur M. Glenberg. The experiments reported in this article were part of a dissertation submitted by Michael P. Kaschak in partial fulfillment of the requirements for the doctoral degree at the University of Wisconsin—Madison. We thank the committee members (Jenny Saffran, Maryellen MacDonald, Morton Ann Gernsbacher, and Susan Ellis Weismer) for their insightful contributions to this work. Thanks also to Bryan Webster, Terrina Kip, Ray Becker, and Nick Rydell, who conducted the experiments reported herein. Finally, we are grateful to Nicole McNeil for inspiring this work by introducing us to the quirks of "Pittsburgh-speak."

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[1] Our claim that participants are "learning to comprehend" the needs construction is inspired in part by construction grammar (e.g., Fillmore, Kay, & O'Connor, 1988; Goldberg, 1995; Kay & Fillmore, 1999). Construction grammarians claim that language consists of form-meaning pairs. Most relevant for the context of the present work are sentence-level constructions, which pair abstract syntactic patterns with meanings (e.g., the double-object construction [subject–verb–indirect object–direct object] pairs a syntactic form with a meaning of "Subject transfers the direct object to the indirect object," as in, "Mike gave Art a pen"). Thus, in saying that participants are "learning to comprehend" the needs construction, we mean that they are learning a new mapping between an input form and a meaning (for a discussion of a construction-based approach to language learning, see Tomasello, 2000; for a discussion of the role of constructions in language comprehension, see Glenberg & Kaschak, 2002; Kaschak & Glenberg, 2000).

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The claim that participants in these experiments are learning to comprehend the needs construction amounts to the claim that experience with the construction produces changes in the language-processing system such that future encounters with the construction are processed with more facility. Thus, our primary index of learning was the change in reading time that occurs across repeated exposure to the construction. More specifically, claiming that participants are learning to comprehend the needs construction depends on observing a differential speed-up in reading times for this construction relative to the other sentence types in the experiment (whose reading times will also speed up as a result of the participants' adaptation to the experimental tasks). It can be said that participants have learned to comprehend the construction when they read the needs construction as quickly as they read more familiar constructions in their native language. In addition to this primary index of learning, we also collected the reading time from follow-up sentences (see Experiment 1) and accuracy on comprehension questions (see Experiments 2–4) as evidence that whereas the readers are speeding up in processing the needs construction, they nonetheless show evidence of understanding what the sentence means (rather than speeding up because they had stopped paying attention to the task).

In the following pages, we sketch two accounts of the learning processes that occur as readers gain facility in comprehending the needs construction. The first account is based on the *constraint satisfaction approach* to language comprehension (e.g., MacDonald, Pearlmutter, & Seidenberg, 1994; McRae, Spivey-Knowlton, & Tanenhaus, 1998). The constraint satisfaction approach is singled out for consideration because it is a theory of language comprehension that is built on mechanisms that can support language processing and language learning within the same system. As such, it is the most appropriate theory of sentence processing to extend to the comprehension of novel constructions. The second account is based on *episodic-processing* accounts of memory (e.g., Kolers & Roediger, 1984; Whittlesea & Wright, 1997). Although episodic-processing approaches to memory have not previously been applied to sentence processing, they present a set of assumptions about learning that differ from those used in existing formulations of the constraint satisfaction account.

Constraint satisfaction theories of language processing are based on the claim that language users are sensitive to many levels of probabilistic information in their environment. Individuals have been shown to be sensitive to information about the co-occurrence of particular syllables (e.g., Saffran, Aslin, & Newport, 1996), the co-occurrence of particular words (e.g., Landauer & Dumais, 1997), and the relative frequency of occurrence of particular syntactic structures (e.g., Jurafsky, 1996). Probabilistic information forms the foundation of language acquisition (e.g., MacWhinney & Bates, 1989; Saffran et al., 1996) and language processing (e.g., MacDonald et al., 1994; McRae et al., 1998). Indeed, researchers have claimed that language acquisition and language processing are subserved by the same mechanisms, which remain operative throughout the life span (Seidenberg & MacDonald, 1999).

Constraint satisfaction theories propose that sentence processing proceeds by initially activating (in parallel) many possible interpretations for the sentence. The interpretations compete for activation on the basis of probabilistic information from the comprehender's experience with language. More probable interpretations receive higher levels of activation and are thereby more likely to be initially selected as the best interpretation for the sentence; less probable interpretations receive lower levels of activation, lose the competition for selection, and are temporarily inhibited (for a more detailed discussion of the architecture of constraint satisfaction models, see MacDonald et al., 1994; McRae et al., 1998; Spivey & Tanenhaus, 1998).

Constraint satisfaction theories can approach readers' ability to learn to comprehend the needs construction in a relatively straightforward manner. On first encountering a string of words such as "The meal needs cooked," there are a couple of possibilities available to the comprehender. One possibility (the correct one) is that the sentence is a deviant version of the familiar structure exemplified by "The meal needs to be cooked." Another possibility is that "The meal needs cooked. . . " is the beginning of a longer sentence (e.g., "The meal needs cooked vegetables to make it complete"). At this point, the sentence can either terminate after the word *cooked* or continue in a manner consistent with the needs construction (e.g., "The meal needs cooked given that dinner is in half an hour"). Both contingencies support the interpretation that this new sentence is a deviant version of the more standard ". . . needs to be cooked . . . " sentence pattern.

To borrow a metaphor from connectionist models, when the comprehension system arrives at the solution that "The meal needs cooked" means something akin to "The meal needs to be cooked," a correction signal will be sent to adjust the model weights. Because the needs construction is a new pattern, the change in the weights will be relatively large. With repeated exposures to the needs construction, these large weight changes produce the rapid acquisition of the new pattern. The learning can be rapid even when exposures to the needs construction are interspersed with the reading of other familiar sentence structures because the familiar structures will produce comparatively small changes in the weights (thereby not substantially disrupting the changes associated with the needs construction).

On the basis of this learning mechanism, constraint satisfaction theories make the following predictions regarding how exposure to the needs construction will affect processing of other types of sentences: First, because the connectionist formalisms adopted by constraint satisfaction theories are good at pattern generalization, it is expected that readers who learn the needs construction will readily generalize the construction to new verbs that share the semantic and pragmatic properties of "needs" (e.g., "wants"; Levin, 1993). Second, exposure to the needs construction should have an impact on the way that sentences such as "The meal needs cooked vegetables to make it complete" are processed. Because this prediction is important for the experiments presented here, the primary sentence types used in these studies are labeled as follows:

1. *The meal needs to be cooked* given that dinner is in an hour. (*standard* construction)
2. *The meal needs cooked* given that dinner is in an hour. (*needs* construction)
3. *The meal needs cooked vegetables* to make it complete. (*modifier* construction)

Sentence 1 is called *standard* because it is the standard version of the needs construction used in the dialect of our participants. Sentence 2 is an example of the needs construction. Sentence 3 is called the *modifier* construction because it uses the postneeds participle as a modifier for the ensuing noun.

According to constraint satisfaction theories, when readers who have previously encountered the needs construction encounter a sentence beginning "The meal needs cooked . . . ," they face an ambiguity: Is "cooked" the end of the clause, or a modifier for an upcoming noun? Depending on the specific implementation of the constraint satisfaction approach, there are two possibilities for how exposure to the needs construction will affect processing of the modifier construction. First , because of the strong changes in the weights produced by recent experience with the needs construction, the needs interpretation of the ambiguity in the sentence may be preferred. The preference for the needs interpretation functions both to speed processing of the needs construction and to slow the processing of the modifier construction. This is because the *modifier* interpretation of the sentence initially loses the competition for selection in processing the sentence (and is temporarily inhibited). The second possibility is that exposure to the needs construction will have little influence on the reading of the modifier construction. This prediction is based on the observation that the participants have far more experience with the modifier construction than with the needs construction. Whereas a limited set of exposures to the needs construction may be sufficient to speed the comprehension of that construction, this limited set of exposures may be insufficient to alter the composition of the network weights enough to substantially affect the way that the familiar modifier construction is processed.

An alternative approach to readers' ability to learn to comprehend the needs construction can be sketched in terms of the episodic-processing approach to memory (e.g., Kolers, 1973, 1979; Morris, Bransford, & Franks, 1977; Whittlesea & Wright, 1997). Episodic-processing theories start from the observation that when a particular stimulus is encountered, there are many possibilities for processing that stimulus. For example, if you see a word on the side of a building, you can do many things with the word. You can pronounce the word, compare the word with other words on the building, or describe the shape and color of the letters in the word. Episodic-processing accounts claim that your memory for the word incorporates elements of the processing that was done on the word. That is, your memory of the word will be different, depending on whether you pronounced the word, labeled the color of the word, or did something else. Episodic-processing effects have been observed in a wide range of experimental settings (e.g., Hintzman, 1986; Jacoby, 1983; Kolers, 1973, 1976, 1979; Roediger, Weldon, & Challis, 1989; Whittlesea, 1987; Whittlesea & Brooks, 1988).

Logan's (1988, 2002) work on skill acquisition provides an example of how an episodic-processing approach can be applied to readers' increasing facility in processing the needs construction. In the initial stages of training, readers encounter the needs construction and must engage in a sequence of processing to arrive at a meaning for the sentence (perhaps processing of the sort suggested by the constraint satisfaction account of sentence processing). When the readers encounter the needs construction again, they can draw on this previous processing episode to aid in comprehending the current sentence. The comprehension of the second sentence also leaves a trace of the processing that went into arriving at a meaning for the needs construction. As these processing episodes accumulate, they become easier to retrieve, speeding processing of the needs construction.

Like the constraint satisfaction theory, the episodic-processing approach suggests that previous experience with language will play a strong role in determining how language is processed in the present. Hintzman's (1986) MINERVA 2, a general episodic memory model, demonstrates how an episodic-processing account can be formalized in a way that is sensitive to the same kinds of probabilistic information in the linguistic input that connectionist models are. Thus, episodic-processing theories are largely compatible with constraint satisfaction models of language processing and make largely the same predictions. However, they differ from constraint satisfaction theories in that they claim that one's memory for linguistic events is sensitive to the processing that was performed during those events, rather than being sensitive only to the relative probabilities of different processing outcomes.

Episodic-processing theories make many of the same predictions about learning the needs construction that were made by the constraint satisfaction approach. As episodes of processing the needs construction accumulate in memory, the construction gets easier to process. Once the reader has learned to comprehend the needs construction, the construction should generalize to new verbs. As in the case of the constraint satisfaction account, generalization to new verbs is largely driven by the similarity between the needs construction and new sentences such as "The dog wants walked." For example, the fact that both sentences share the same structure fosters the retrieval of needs-processing episodes to support the comprehension of the novel wants sentences.

One place where the predictions of the episodic-processing theory differ from those of the constraint satisfaction approach is in the effect of the needs construction on the modifier construction. As discussed earlier, the first few times participants read a sentence such as "The meal needs cooked given that dinner is in half an hour," they will initially interpret the sentence as an example of the modifier construction. It is not until they reach the word *given* that they realize this interpretation is incorrect. That is, the first few episodes of processing the needs construction will involve having initially selected a *modifier* interpretation of the sentence. Contrary to the predictions of the constraint satisfaction theory, the episodic-processing theory claims that the incorrect *modifier* interpretation is not inhibited once the meaning of the sentence is revised. Rather, it lingers in the comprehension system and becomes a part of the processing trace for the needs construction (at least during these early trials when participants are unfamiliar with the needs construction; see Christianson, Hollingworth, Halliwell, & Ferreira, 2001; Traxler, Pickering, & Clifton, 1998, for data supporting the idea that the incorrect interpretation of ambiguous sentences is not always discarded during language comprehension).[2] When readers later encounter a sentence that begins "The meal needs cooked . . . ," the incoming sentence retrieves processing episodes from the recently encountered examples of the needs construction. The retrieved processing episodes include traces of having selected the Modifier interpretation of this early part of the sentence. That is, at the point in the sentence where the reader has encountered the words *needs cooked,* the comprehension system

[2] The episodic-processing account advanced here makes a distinction between saying that a potential sentence interpretation is activated and saying that that interpretation has been selected. In many sentence-processing models, several potential sentence interpretations are activated in parallel, but only one is selected (even if it is the wrong interpretation; e.g., Trueswell, 1996). On the episodic-processing account, interpretations that are selected (and that create a garden path that needs to be revised later) become a part of a processing trace for that sentence; interpretations that receive some initial activation, but are not selected, do not become a part of the processing trace.

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retrieves processing episodes that can support the comprehension of either the needs construction or the modifier construction. To borrow a description from Bock and Griffin (2000), the comprehension system is now "tuned" to handle processing of both the needs construction and the modifier construction. As a consequence, the episodic-processing account predicts that recent experience with the needs construction should facilitate processing of the modifier construction.

Experiment 1

The purpose of Experiment 1 was twofold. First, whereas work in sociolinguistics suggests that adults are capable of learning to comprehend new constructions in their native language (e.g., Kroch, 1989, 2001), we are aware of no experimental studies of this phenomenon. Experiment 1 was designed to take a first step toward filling this gap by demonstrating adults' ability to learn to comprehend new construction in their native language in an experimental setting. The second aim of this experiment was to demonstrate that adults could learn to comprehend the needs construction under different training conditions. As discussed below, some participants were exposed to the needs construction by reading examples of the construction embedded in a series of short texts. Others were exposed to the needs construction by hearing examples of the construction embedded in a series of short conversations.

Experiment 1 was conducted in three phases. In Phase 1, the participants were told that they were going to engage in a norming study. The participants were to listen to a tape containing 10 short conversations and rate each conversation on a couple of dimensions (e.g., "How friendly was the conversation?"). Half the participants heard conversations that contained examples of the needs construction (there were five tokens of the construction used across the 10 conversations), whereas the other half did not hear any examples of the construction. Phase 2 of the experiment was a delay period that was estimated to last between 2 and 4 min.

Phase 3 of the experiment was a reading task. Participants were asked to read passages such as the example in Appendix A. Each passage began with an introduction that established an interaction between two characters. Following the introduction, participants read one of two critical sentences: a needs sentence ("The grass needs cut.") or a standard sentence ("The grass needs to be cut"). The subsequent follow-up sentences were manipulated as a check to be sure that the participants comprehended the critical sentences properly. Half of the time the follow-up sentence was consistent with the meaning of the critical sentence ("The grass had been growing all summer, and was high yet again"), and half of the time it was inconsistent with the meaning of the critical sentence ("The grass had burned out earlier in the summer, and hadn't grown at all since then"). Each passage concluded with a wrap-up sentence.

The primary measure of learning in this experiment was the reading time of the critical sentences. Initially, participants should read the (unfamiliar) needs sentences more slowly than the (familiar) standard sentences. If the participants learn to turn the novel needs form into a meaning with alacrity, this difference should be attenuated by the end of the experiment. The reading time of the follow-up sentences was intended as a check to ensure that the participants were deriving the correct meaning from the needs construction. A standard finding in the text-reading literature is that sentences that are consistent with the meaning of the preceding text are easier to read than those that are inconsistent with the preceding text (e.g., Glenberg, Meyer, & Lindem, 1987; Kintsch, 1988; O'Brien & Albrecht, 1992). Thus, if readers know that "The floor needs cleaned" means something akin to "The floor needs to be cleaned," they should read the consistent follow-ups faster than the inconsistent follow-ups throughout the reading task. Finally, to assess whether participants learned to comprehend the needs construction in the listening task, we looked at the reading times of the first few critical sentences in the reading task. If the participants who heard the needs construction in the conversations picked up on the form (i.e., they learned to turn the form into a meaning), they should initially read the critical needs sentences faster than the participants who did not hear any needs sentences in the conversations.

Method

Participants. The participants were 50 introductory psychology students from the University of Wisconsin—Madison; they received extra credit in exchange for their participation. For this and all other experiments reported here, participation in the experiment was restricted to individuals who grew up in Wisconsin or Minnesota. That readers from Wisconsin and Minnesota are unfamiliar with the needs construction was verified by pretesting. In a grammaticality judgment task given to 60 introductory psychology students from these states, all of the participants rejected the needs construction as ungrammatical.

Materials. Forty-eight critical texts of the sort depicted in Appendix B were generated for this experiment.[3] Another 48 texts of similar format (but without needs sentences and manipulated follow-up sentences) were generated to serve as fillers. The 48 critical texts and 48 filler texts were divided into two sets of 48 texts (Set A and Set B, each containing 24 critical and 24 filler passages). Each set was read by roughly half the participants. Fn3

Fifteen conversations were recorded for the conversation-rating task. The conversations were improvised around a set topic (e.g., last night's basketball game) by undergraduate members of the lab. Each conversation lasted between 50 and 110 s. Five of the conversations were designated as "filler" conversations and appeared in both the needs-training condition and the control condition. The remaining 10 conversations constituted five pairs of conversations. The 2 conversations in each pair were kept as similar as possible, except that 1 conversation included a token of the needs construction, whereas the other did not (the conversation without the needs construction did not feature any examples of the standard construction). The 5 needs conversations plus the 5 filler conversations constituted the needs-training condition; the 5 control conversations plus the 5 filler conversations constituted the control training condition.

Procedure. Participants were informed that there would be a couple of components to their participation in the experiment. First, they were to listen to a set of conversations recorded for another experiment. They were instructed to sit quietly in a booth while listening. The conversations were presented over a small tape player. At the end of each conversation, the participant was told to rate the conversation on several dimensions: "How friendly was the conversation?" "How well do the conversants appear to know each other?" and "How realistic does the conversation sound?" The participants performed ratings for 10 conversations. Half the participants rated conversations that contained the needs construction, whereas the other half did not.

On the completion of the rating task, the experimenter collected the rating form and removed the tape player from the booth. The participants were then oriented toward the computer in the booth and instructed on how

[3] All materials for the experiments reported in this article are available upon request from Michael P. Kaschak.

to perform the reading task. The change between tasks took approximately 2–4 min.

The participants read the instructions for the reading task off the computer monitor. They were told that there would be two tasks to perform. First, they would read a series of texts sentence by sentence. A sentence would appear on the screen, and they were to read it as quickly and carefully as they could. As soon as they were sure that they understood the sentence, they were to press the space bar to advance to the next sentence. They were to proceed like this until the end of the passage. At the conclusion of each passage, a set of asterisks appeared on the screen to signal the participant to get ready for the second part of the trial, a probe-response task. The asterisks remained on the screen for 1 s, after which a probe word appeared. Participants were to indicate whether the word was related to the preceding passage or not. Half of the time, the correct response was *yes,* and half of the time the correct response was *no.* The probe task was included in the experiment to provide a motivation for the participants to read the passages carefully.

Participants read 48 texts (24 critical texts, 24 filler texts). Texts were randomized within blocks of eight trials. Of the eight trials, four were filler texts, two were critical texts that used the needs construction (one with a consistent follow-up, and one with an inconsistent follow-up), and two were critical texts that used the standard construction (one with a consistent follow-up, one with an inconsistent follow-up). Half the participants saw texts from Set A and half saw texts from Set B. The order of presentation of the texts was randomized for each participant.

Design and analysis. To control for sentence length, the reading time for both the critical sentences and follow-up sentences underwent separate regression analyses, with length entered as a predictor variable. The regression analyses were run on sentences from the critical trials only. The residuals from the regression analyses were entered into the data analyses reported below. For all experiments reported in this article, analyses conducted on the raw reading times produced essentially the same results.[4]

The regression-based procedure described above (and used for all experiments reported here) is a variant of the technique Ferreira and Clifton (1986) introduced to correct for length effects. There are two primary differences between their technique and ours. First, they included both filler and critical items in their regression analyses, whereas we included only critical items. Second, they calculated a separate regression analysis for each participant, whereas we performed one analysis across all participants. These changes were implemented in response to the unique features of our experimental designs. Because each sentence appeared in a needs and standard version in the experiment, sentence length (in Experiment 1) and word length (in Experiment 2) were generally balanced across conditions. However, because sentence presentation was randomized for each participant, there were cases in which the longer sentences or words were unevenly distributed across the cells of the design. Because we were interested only in adjusting for slight imbalances in the distribution of particular texts across the cells of the experiment, we included only critical items in the regression analysis. Our decision to perform the regression analysis across all participants (rather than for each individual participant) was motivated by the between-subjects components of our designs in Experiments 2–4. Given that some participants would be trained on a novel construction, whereas others would not see a novel construction, it was likely that the regression for those trained on the novel construction would result in residuals on a different scale than those not trained on the novel construction. This would make it difficult to make between-group comparisons. Thus, we ran the regression analysis on all participants to ensure that the residuals across groups would be on the same scale.

The analyses reported throughout the article include data from all sentences, whether or not the response to the probe word (see Experiment 1) or the comprehension question (Experiments 2–4) was correct. Significant effects are accompanied by partial omega squared (ω^2), a metric of effect size calculated per Keppel (1991). A value of .01 corresponds to a small effect, a value of .06 corresponds to a medium effect, and a value of .15 corresponds to a large effect (Cohen, 1977). All partial omega squared values were calculated on the basis of the analysis by subjects. As per the recommendation of Keppel (1991), simple main effects comparisons are computed in the following manner: Within-subjects tests are computed with a unique error term for each analysis, whereas between-subjects tests are computed on the basis of a pooled error term. For the between-subjects tests, calculated on the basis of a mixed-factorial design, we report pooled mean square error values and adjusted degrees of freedom (mean square errors and adjusted degrees of freedom were calculated using a Microsoft Excel workbook, downloaded from Baguley, 2003). Finally, to condense the reporting of statistical results throughout the article, we present only the results of analyses conducted, with subjects as a random factor (i.e., the traditional F1 analysis). The results of analyses conducted, with items as a random factor (i.e., the traditional F2 analysis), are essentially the same as the analyses reported here.[5]

The reading times for the critical sentences were analyzed using a 2 (sentence type: needs construction vs. standard construction) × 3 (time period: Trials 1–4, 4–8, and 9–12) within-subjects analysis of variance (ANOVA). The data from the follow-up sentences were analyzed using a 2 (sentence type: needs construction vs. standard construction) × 2 (follow-up type: consistent follow-up vs. inconsistent follow-up) × 3 (time period: Trials 1–4, 4–8, and 9–12) within-subjects ANOVA. The reading times for the first two critical sentence trials in the reading task were analyzed to observe transfer between the listening task and the reading task. These data were analyzed with a 2 (training condition: needs conversations vs. Control conversations) × 2 (sentence type: needs construction vs. standard construction) mixed-factor ANOVA, with training condition as the between-subjects factor. Because of the randomization scheme and the use of two sets of texts, there were a number of cases in which particular texts were not presented in a particular time period with a particular follow-up type (e.g., Text 28 may not have appeared with an inconsistent follow-up sentence during Trials 9–12). Because of the number of empty cells in the data, it was not practical to do full-text analyses for the follow-up sentences or the transfer data.

Performance on the probe-response items was uniformly high across conditions (means ranging from 92% to 96% correct), and there were no statistically significant effects involving accuracy. Consequently, these data are not discussed below.

Results

The results of Experiment 1 are presented in Table 1. Because the conversation training had little effect on the reading times of the critical and follow-up sentences beyond the first two trials, we collapsed the reported means and analyses across this variable in all cases except when we analyzed the first trials of the reading task. Results reported as significant are significant with the Type I error rate set at .05, unless otherwise noted.

Critical sentences. The important effect from the analysis of the critical sentences is a Sentence Type × Time Period interaction, $F(2, 98) = 9.31$, $MSE = 87{,}416$, $\omega^2 = .05$. Participants read the needs sentences more slowly than the standard sentences in Trials 1–4, $F(1, 49) = 25.75$, $MSE = 162{,}808$, $\omega^2 = .19$;, but this difference was attenuated in Trials 5–8, $F(1, 49) = 4.66$, $MSE = 84{,}878$, $\omega^2 = .04$, and Trials 9–12, $F(1, 49) = 3.69$, $MSE = 37{,}613$, $p = .061$. There was also a main effect of time, $F(2, 98) = 38.35$, $MSE = 160{,}856$, $\omega^2 = .19$, and sentence type, $F(1, 49) = 28.05$, $MSE = 110{,}467$, $\omega^2 = .08$.

[4] Raw reading times for all experiments available upon request from Michael P. Kaschak

[5] The results of analyses conducted are available upon request from Michael P. Kaschak.

Table 1
Mean Residual Reading Times (in Milliseconds) and Standard Errors From Experiment 1

Construction	Trials 1–4 *M*	Trials 1–4 *SE*	Trials 5–8 *M*	Trials 5–8 *SE*	Trials 9–12 *M*	Trials 9–12 *SE*
Critical sentences						
Needs	478	120	−15	69	−168	54
Standard	68	65	−141	58	−242	47
Follow-up sentences						
Needs-consistent type	175	89	−74	77	−243	67
Needs-inconsistent type	502	127	116	124	−75	99
Standard-consistent type	−27	69	−170	87	−349	64
Standard-inconsistent type	265	122	27	93	−192	84

Follow-up sentences. The data from the critical sentences demonstrate that the participants were able to learn to comprehend the needs construction quickly (i.e., within 12 trials). As further evidence for the claim that participants were gaining facility in mapping between the needs construction form and its intended meaning, the data show that participants read the consistent follow-up sentences faster than the inconsistent follow-ups. This pattern was observed across all time points in the experiment for both the needs and standard critical sentences (see the middle section of Table 1). For the standard construction, the consistency effect was significant for all three time periods, $F(1, 49) = 8.53$, $MSE = 252{,}537$, $\omega^2 = .13$; $F(1, 49) = 4.74$, $MSE = 206{,}135$, $\omega^2 = .06$; $F(1, 49) = 6.76$, $MSE = 91{,}792$, $\omega^2 = .10$, respectively. For the needs construction, the consistency effect was significant in the first and third time periods, $F(1, 49) = 9.98$, $MSE = 267{,}661$, $\omega^2 = .15$; $F(1, 49) = 6.43$, $MSE = 109{,}730$, $\omega^2 = .09$; and nonsignificant for the second time period, $F(1, 49) = 2.87$, $MSE = 319{,}417$, $p = .097$, $\omega^2 = .03$.

More generally, reading of the follow-up sentences was faster after the standard construction, $F(1, 49) = 11.93$, $MSE = 251{,}024$, $\omega^2 = .01$, and became faster across time, $F(2, 98) = 34.28$, $MSE = 289{,}493$, $\omega^2 = .10$. There was also a main effect of follow-up type, with consistent follow-ups being read faster than inconsistent follow-ups, $F(1, 49) = 18.89$, $MSE = 393{,}191$, $\omega^2 = .03$. None of the interactions between sentence type, follow-up type, and time period were significant.

The data from the follow-up sentences counter the argument that the reading times for the needs and standard sentences converged at the end of the experiment not because the participants had learned anything, but because they had started to ignore the task (i.e., they were no longer reading for meaning). If the participants had started to ignore the task, one would expect that the reading times of the consistent and inconsistent follow-up sentences would have converged as well. This was not the case. Alternatively, it might be expected that the difference in reading times for the consistent and inconsistent follow-ups would have increased across the experiment. That is, as participants interpret the needs construction with more facility, the difference between the consistent and inconsistent follow-ups should become more marked. We did not observe this pattern in the data, probably because the participants arrived at the correct interpretation of the needs construction throughout the experiment, even though it took them longer to do so at the beginning of the experiment.

Reading time on Trials 1–2. We analyzed the first few trials of the reading task to determine whether hearing the needs construction in the conversation-rating task had any effect on the initial reading of the construction. The data are reported in the bottom section of Table 2, and they support the claim that hearing the needs construction facilitated reading comprehension. The analysis reveals a Sentence Type × Training Condition interaction, $F(1, 48) = 5.23$, $MSE = 293{,}132$, $\omega^2 = .04$. Although participants in both training conditions initially read the needs construction more slowly than the standard construction—$F(1, 24) = 20.24$, $MSE = 408{,}015$, $\omega^2 = .28$, for control training; $F(1, 24) = 7.08$, $MSE = 178{,}247$, $\omega^2 = .10$, for needs training—this difference was much smaller in the needs-training condition. In addition to the significant interaction, there was also a main effect of sentence type, $F(1, 48) = 27.25$, $MSE = 293{,}132$, $\omega^2 = .20$. The main effect of training was not significant, $F(1, 48) = 2.20$, $MSE = 1{,}086{,}886$, $p = .14$.

Discussion

There were two important results in this experiment. First, the reading time of the critical sentences demonstrates that participants can quickly learn to turn the needs construction into a meaning. Whereas the novel construction initially caused processing difficulty, the difficulty was largely attenuated within 12 exposures to the construction. This result is in keeping with both the constraint satisfaction and episodic-processing theories. Additionally, these data are among the first to show a learning effect of this kind in the context of a language comprehension task (cf. Bienvenue & Mauner, 2003).

The second finding of interest is the transfer effect observed on the first two trials of the reading task. The participants in the needs-training condition learned to comprehend a novel syntactic pattern in a somewhat representative task (i.e., listening to people have a conversation). These participants were able to learn to comprehend the new pattern from only a few exposures buried within about 10–12 min of conversation. Whereas the following experiments do not continue to explore this manipulation, the data suggest that more representative tasks such as these can be an interesting vehicle through which to explore learning effects in language processing.

Experiment 2

Experiment 1 showed that readers and listeners quickly learned to comprehend a new construction. Experiment 2 was designed to extend these results in two ways. First, to get a finer grained look at what happens as participants learn to comprehend the needs

Table 2
Mean Residual Reading Times (in Milliseconds) for Trials 1–2 of Experiment 1

Training	Sentence read: Needs *M*	Needs *SE*	Standard *M*	Standard *SE*
Needs	429	128	111	85
Control	986	268	173	122

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construction, this experiment introduced a different methodology: a word-by-word sentence reading task. Experiment 2 also expands on the previous experiment by testing a specific prediction made by the constraint satisfaction and episodic-processing theories (e.g., Kolers & Roediger, 1984; MacDonald et al., 1994; Whittlesea & Wright, 1997). After readers learn to comprehend a new construction based around a single verb, they should readily extend the construction to a new verb that is similar to the first (similarity being defined by the presence of overlapping semantic and syntactic features in the two verbs). This prediction was tested by first training readers on the needs construction and then asking them to read sentences that have the same syntactic structure, but use a new verb: *wants* (e.g., "The dog wants walked").

Experiment 2 was conducted in two phases. Phase 1 was the training phase during which readers were introduced to the needs construction. The introduction was achieved by asking the participants to read sentences such as Sentence 4:

4. The meal needs cooked given that dinner is in an hour.

Participants in the needs-training condition read 10 sentences of this sort in Phase 1. The remaining participants (in the control training condition) read the same 10 training sentences, but in the standard version (e.g., "The meal needs to be cooked given that dinner is in an hour"). This phase of the experiment was designed to replicate the learning effect found in Experiment 1: Participants should initially struggle to understand the needs construction, but this difficulty should be attenuated over repeated exposure to the structure.

Whereas the prediction from Experiment 1 was that participants would experience processing difficulty upon first encountering the needs construction, the word-by-word reading methodology allows for the generation of a more specific prediction. This prediction comes from the operation of constraint satisfaction models of sentence processing (e.g., MacDonald et al., 1994). When participants are unaware of the needs construction, they should initially interpret the opening sequence of words ("The meal needs cooked . . .") as the beginning of the modifier construction. When participants encounter the next word (*given*), they realize that the interpretation they selected is incorrect and revise their interpretation of the sentence to that of the needs construction. Thus, the initial processing difficulty, and the locus of the learning effect, should be focused around the word *given.*

Phase 2 of the experiment followed directly from the first. In this phase, participants no longer saw any examples of the needs construction. Instead, they started reading examples of the same construction using the verb *wants* (these are referred to as *wants sentences*):

5. The valiant hero wants recognized for his courageous actions.

If the predictions discussed in the introduction are correct, participants who were trained on the needs construction should read this sentence with relative ease.

Method

Participants. The participants were 40 introductory psychology students from the University of Wisconsin—Madison; they received extra credit in exchange for their participation. Half the participants were in the needs-training condition, and the other half were in the control training condition.

Materials. Fifty sentences were generated for this experiment. Ten sentences, such as Sentence 4, were generated for the Phase 1 training (needs and standard sentences were the same, except that the standard sentences had "to be" inserted after "needs"). Ten sentences, such as Sentence 5, were generated for Phase 2. The remaining 30 sentences were filler sentences of various sorts (e.g., "The sheep walked across the yard to exit through the gate"). In addition, a comprehension question was written for each sentence (e.g., "The meal needs cooked given that dinner is in half an hour" was followed by "Is dinner in an hour?"). The materials for this and subsequent experiments are presented in Appendix B.

Procedure. Participants were told that they were going to read a series of sentences word by word. They were told to read the sentences as quickly and carefully as they could. A trial began with a prompt to get ready for the sentence. The participant was to press the space bar of the computer keyboard to see the first word of the sentence. They were told to press the space bar to move to each subsequent word in the sentence. At the end of the sentence, the words "***GOT IT?***" were displayed on the screen. The participants were told to press the space bar again when they were sure they understood the sentence. Once they pressed the space bar, the comprehension question appeared on the screen. Participants responded by pressing keys labeled *Y* or *N* on the keyboard.

The order of presentation for sentences was randomized individually for each participant, with the constraint that needs sentences were only presented in the first 25 trials of the experiment (10 needs sentences and 15 filler sentences) and wants sentences were only presented in the last 25 trials of the experiment (10 wants sentences and 15 filler sentences). Presentation of items was randomized in blocks of five trials. Within each block, participants read 2 critical sentences (i.e., needs or wants sentences) and 3 filler sentences.

There were six dependent variables in this experiment. Reading times were recorded for each of the four words in the region of interest (" . . . needs cooked given that . . . "). These positions are referred to as Region 1, Region 2, Region 3, and Region 4 in the analyses and tables that summarize the data. The time required to press the space bar on the ***GOT IT?*** probe was also recorded. The final dependent variable was the participants' accuracy on the comprehension questions.

Design and analysis. To control for length effects, the reading times for words in each of the four positions in the region of interest were entered into separate regression analyses, using length as a predictor variable. Only words from the critical sentences were entered into the regression analysis. The residuals from the regression analyses were entered into the data analyses discussed below. Note that because of the methods used to compute residuals, reading times can be directly compared within each word position, but not across word positions.

Two primary analyses were conducted on the dependent variables. The first focused exclusively on the data from Phase 1. A 2 (training: needs vs. control) × 3 (time period: Trials 1–3, 4–7, and 8–10) mixed-factorial ANOVA was conducted, with training as a between-subjects variable. In comparing the reading of the needs and standard sentences, the words *to be* were excluded from the data from the standard sentences such that both sentences were analyzed on the words *needs, cooked, given,* and *that.* The second analyses involved the data from the end of Phase 1 (Trials 8–10) and from the first half of Phase 2 (Trials 1–5 from Phase 2). These analyses were aimed at observing differential transfer effects between the training conditions and the wants sentences. The data were analyzed using a 2 (training: needs vs. control) × 2 (time: end of Phase 1 vs. beginning of Phase 2) mixed-factor ANOVA, with training as a between-subjects variable.

The data and statistical analyses reported for this and subsequent experiments focus on the Phase 1 reading times in Regions 1–4 as well as the reading times from the same regions in the first half of Phase 2. The data from the second half of Phase 2, the *GOT IT?* probes, and the accuracy on the comprehension question are not reported in detail. The reading times from the second half of Phase 2 are not reported in detail for two reasons. First, the experiments are designed to determine how learning to comprehend the needs construction influences the reading of other kinds of sentences. These effects are best observed in the initial trials of Phase 2, in which the effects of learning the needs construction are not contaminated by any learning that goes on in the transfer phase of the experiment. Second, these data revealed no statistical effects of theoretical interest. The GOT IT? and accuracy data are not reported (except for the participants' overall accuracy for the experiment) because there were no statistically reliable effects of theoretical interest in any of the experiments. The results of the main statistical analyses are presented in the table that accompanies each experiment. Simple main effects tests are reported in the text.

Results

The mean reading times for the region of interest in Phase 1 and Phase 2 are presented in Table 3. The results of the two primary analyses described above are reported in Table 4. To keep the report of statistical results manageable, only those analyses whose results are of theoretical interest are presented in the text. Where relevant, the mean square errors and partial omega squared values for this and all subsequent experiments are reported in the tables that summarize the statistical results. Accuracy on the comprehension questions was 93.4%. Results reported as significant are significant with the Type I error rate set at .05, unless otherwise noted.

Phase 1. The data from Phase 1 replicate the learning effect of Experiment 1. This conclusion is supported by a significant Training × Time interaction, $F(2, 76) = 4.72$, in Region 3.[6] Participants in the needs-training condition read the critical sentences more slowly than participants in the control training condition in Trials 1–3, $F(1, 85) = 12.58$, $MSE = 26{,}324$, $\omega^2 = .12$, but this difference was not significant in Trials 4–7 or Trials 8–10 (Fs < 1).

Last trials of training to first half of Phase 2. We analyzed transfer effects between the training conditions in Phase1 and the reading of the wants sentences by comparing reading times in the last time period of Phase 1 (Trials 8–10) with those at the beginning of Phase 2 (Trials 1–5). The critical result was a significant Training × Time interaction in Region 3, $F(1, 38) = 17.82$, and Region 4, $F(1, 38) = 12.62$. Simple main effects showed that participants in the needs-training condition did not slow down substantially when they began to read the wants sentences (Regions 1–4: Fs < 1.38), whereas participants in the control training condition did slow down when first reading the wants sentences. We observed this effect in Region 2, $F(1, 19) = 5.84$, $MSE = 15{,}989$, $\omega^2 = .11$, Region 3, $F(1, 19) = 23.39$, $MSE = 44{,}684$, $\omega^2 = .35$, and Region 4, $F(1, 19) = 20.07$, $MSE = 10{,}018$, $\omega^2 = .32$. We conducted another set of simple main effects on Trials 1–5 in Phase 2. Participants in the needs-training condition read the wants sentences significantly faster than those in the control training condition in Region 3, $F(1, 69) = 26.70$, $MSE = 30{,}760$, $\omega^2 = .27$, and Region 4, $F(1, 61) = 5.29$, $MSE = 18{,}817$, $\omega^2 = .06$. Together, these analyses show that needs training had a facilitating effect on the processing of the wants sentences.

Discussion

There are two main findings in this experiment. First, the reading times in Phase 1 replicate the learning effect of Experiment 1 in a new paradigm. Participants initially had difficulty understanding the needs construction, but this difficulty largely vanished within the 10 training trials. This effect was observed in Region 3, as predicted by the constraint satisfaction theory. Second, the reading time of the wants sentences at the beginning of Phase 2 clearly shows that participants who learned to comprehend the needs construction were able to generalize this learning to processing the same construction with a new verb. This finding supports both the constraint satisfaction and episodic-processing theories.

Table 3
Mean Residual Reading Times (in Milliseconds) for Region of Interest in Experiment 2

Training and trial	Region 1	Region 2	Region 3	Region 4
Phase 1				
Needs training				
Trials 1–3	81	112	115	106
Trials 4–7	0	2	−28	−6
Trials 8–10	−18	−51	−82	−18
Control training				
Trials 1–3	37	58	−26	−26
Trials 4–7	−4	−32	−78	−26
Trials 8–10	−16	−84	−104	−74
Phase 2 (Trials 1–5)				
Needs	−6	5	−68	−32
Control	−22	11	218	68

Note. The region of interest for the needs sentences covered the words *needs cooked given that* (Regions 1, 2, 3, and 4, respectively). The region of interest for the wants sentences covered the words *wants recognized for his* (Regions 1, 2, 3, and 4, respectively).

[6] Evidence that adults have learned to comprehend the needs construction in this and the subsequent experiments comes primarily from the between-subjects comparison of the reading times of the needs and standard sentences. The critical feature of these comparisons is the observation that the differences in reading times for the needs and standard sentences is largely attenuated by the end of Phase 1 of the experiment. Further evidence for this claim comes from the observation of the reading times for the filler sentences in this experiment (Experiment 2). Participants in the control training condition read the filler sentences as quickly as the standard sentences in all time periods of the experiment. Participants in the needs-training condition initially read the needs sentences more slowly than the filler sentences (especially in Region 3), but this difference disappeared by the end of Phase 1. Furthermore, the reading times for the filler sentences were equivalent across both training conditions. Thus, the learning effect observed in Region 3 of the sentences is limited to the needs construction. Importantly, the pattern of reading times for the filler sentences did not differ across training conditions. This suggests that participants in the needs-training condition were not adopting an unusual reading strategy because they encountered a novel construction in their training. These observations from the filler sentences (equivalent reading times across training conditions, identical patterns of reading times across training conditions, and the initial difference between reading of the needs sentences and the filler sentences in Region 3 for participants in the needs-training condition) provide further (within-subject) behavioral evidence for the claim that participants in the needs-training condition were learning something specific in learning to comprehend the needs construction. This pattern of reading times was observed in Experiments 2–4.

Table 4
Statistical Analysis From Experiment 2

	Time			Training			Time × Training		
Region of interest	*F*	*MSE*	ω^2	*F*	*MSE*	ω^2	*F*	*MSE*	ω^2
Phase 1[a]									
Region 1	14.83*	4,465	.13	<1	33,367	—	1.36	4,465	—
Region 2	18.56*	12,960	.22	<1	62,783	—	<1	12,960	—
Region 3	17.51*	15,521	.21	4.46*	47,929	.02	4.72*	15,521	.06
Region 4	15.37*	9,410	.19	2.62	28,494	—	<1	9,410	—
Comparison of last block of Phase 1 with first half of Phase 2[b]									
Region 1	<1	4,970	—	<1	19,683	—	<1	4,970	—
Region 2	5.98*	19,638	.06	<1	54,066	—	<1	19,638	—
Region 3	21.42*	26,692	.20	5.34*	65,589	.05	17.82*	26,692	.17
Region 4	8.51*	9,607	.09	<1	28,028	—	12.62*	9,607	.13

Note. In both sets of analyses, training is a between-subjects factor, and time is within subjects. Dashes indicate that the partial omega squared value is not reported because the *F* value is not significant.
[a] For Time and Time × Training, $df = 2, 76$; for Training, $df = 1, 38$. [b] For all factors, $df = 1, 38$.
* $p < .05$.

Experiment 3

Experiments 1 and 2 demonstrated that readers and listeners quickly learn to comprehend a novel syntactic construction and that they are willing to extend the new construction to at least one other verb. In Experiment 3, our focus shifts to a new question: How does exposure to the needs construction affect the processing of structures with which the participants are already familiar? More specifically, this experiment addressed how exposure to the needs construction affects the processing of the modifier construction.

To determine what effect the needs construction has on the reading of the modifier construction, we conducted an experiment similar to Experiment 2. Phase 1 of the experiment was the training phase in which participants were trained either on the needs construction or on the standard construction. In Phase 2 of the experiment, participants continued to read the needs construction (in the needs-training condition) or the standard construction (in the control training condition) and also began to read the modifier construction. The control training condition was intended as a baseline condition to observe reading of the modifier construction in participants who are unaware of the needs construction.

In the introduction to Experiment 2, we noted that participants in the needs-training condition would experience processing difficulty on the word *given* (Region 3) in the initial stages of Phase 1. This is because the opening sequence of the training sentences, "The meal needs cooked . . . ," is ambiguous between a needs construction interpretation and a modifier interpretation, and readers would not expect the needs continuation because it was unknown to them. The effect that exposure to the needs construction has on the processing of the modifier construction depends on how the comprehension system deals with this ambiguity. The constraint satisfaction account described by MacDonald et al. (1994) suggests that the incorrect modifier reading of the needs sentences in Phase 1 of the experiment is temporarily inhibited when the reader realizes that this interpretation is incorrect. Training on the needs construction should therefore either interfere with the processing of the modifier construction or have no effect on the processing of the modifier construction (depending on the specifics of the constraint satisfaction system such as the duration of the inhibition). As discussed earlier, the episodic-processing account makes the opposite prediction: Training on the needs construction should facilitate processing of the modifier construction.

Method

Participants. The participants were 42 introductory psychology students from the University of Wisconsin—Madison; they received extra credit in exchange for their participation. There were 21 participants in each training condition.

Materials. Sixty-five sentences were generated for this experiment. The 10 needs sentences (and their respective standard versions) from Experiment 2 were used as the training items in this study. Sixteen additional sentences were generated for Phase 2. These sentences were written such that they had the same beginning ("The meal needs cooked. . . . ") but continued differently to create one needs sentence and one modifier sentence from each sentence stem (the standard sentences were created by adding a "to be" phrase to the needs sentences). The 30 filler items from Experiment 2 were used in this experiment; 9 more filler sentences were added to fill out the design of the experiment. As in Experiment 2, a comprehension question was generated for each sentence (see Appendix B).

Procedure. The procedure was essentially the same as for Experiment 2. The only change was that in the second phase of the experiment, participants in the needs-training condition read both needs sentences and modifier sentences, whereas participants in the control training condition read standard and modifier sentences.

Design and analysis. The reading times were corrected for length in the same manner as in Experiment 2.

There were two main analyses in this experiment. The first involved the data from Phase 1. A 2 (training: needs vs. control) × 3 (time: Trials 1–3, Trials 4–7, Trials 8–10) mixed-factor ANOVA (training is between subjects) was done on the reading times from Phase 1 to observe the learning effect seen in the previous experiments. The second analysis compared the reading times of all of the sentences in the first half of Phase 2. A 2 (sentence type: needs/standard vs. modifier) × 2 (training: needs vs. control) mixed-factor ANOVA (training is between subjects) was performed on these reading times. This analysis was intended to test whether the Phase 1-training conditions had a differential effect on the reading of the modifier construction

Results

The mean residual reading time for Regions 1–4 are presented in Table 5. The results of the two primary analyses described above are reported in Tables 6 and 7. The results reported in the text below focus on the analyses of most theoretical importance. Average accuracy on the comprehension questions was 93.6%. Results reported as significant are significant with the Type I error rate set at .05, unless otherwise noted.

Phase 1. The data from Phase 1 replicate Experiment 2. There was a significant Training × Time interaction in Region 3, $F(2, 80) = 5.74$. Participants in the needs-training condition read the critical sentences more slowly than participants in the control training condition in Trials 1–3, $F(1, 98) = 12.65$, $MSE = 105{,}623$, $\omega^2 = .12$, but this difference was attenuated in Trials 4–7 ($F < 1$) and Trials 8–10 ($F < 1$). As before, these data suggest that readers in the needs-training condition are initially misinterpreting the needs sentences as examples of the modifier construction.

Phase 2 (Trials 1–4): All sentence reading times. The critical result from the reading times in the first half of Phase 2 was a Sentence Type × Training interaction in Region 3, $F(1, 40) = 16.36$. Simple main effects revealed that whereas participant read the needs and standard sentences with equal facility ($F < 1$), participants in the needs-training condition read the modifier construction more quickly than participants in the control training condition, $F(1, 58) = 18.36$, $MSE = 28{,}848$, $\omega^2 = .22$. Further simple main effects analyzing the data from Regions 1–4 show that the facilitation effect on the modifier construction was limited to the modifier sentences themselves and was not due to more general differences in reading between participants in the two training conditions. Comparing the reading time of the needs and standard sentences revealed no statistically reliable differences (Fs < 2.51, $p > .12$), suggesting that readers in both training conditions were processing sentences at approximately the same speed. Thus, the difference in reading seen in Region 3 is isolated to the modifier sentences.

The general facilitation of processing for the modifier construction in the needs-training condition does not mean that the modifier sentences were processed with complete ease. Simple main effects comparing the reading of needs sentences with modifier sentences (in the needs-training condition) showed that readers were slower reading the modifier construction in Region 4, $F(1, 20) = 4.42$, $MSE = 27{,}530$, $\omega^2 = .08$. Simple main effects comparing the reading of the standard and modifier sentences (in the control training condition) showed that readers were slower reading the modifier construction in Region 3, $F(1, 20) = 22.21$, $MSE = 23{,}455$, $\omega^2 = .34$, and Region 4, $F(1, 20) = 7.11$, $MSE = 12{,}375$, $\omega^2 = .13$.

Discussion

The important finding from this experiment is that readers who were trained on the needs construction read the modifier construction faster than participants who trained on the standard construction. These results support the predictions of the episodic-processing account, and they contradict both predictions from the constraint satisfaction theory. More broadly, these data suggest that the initial misinterpretation of the needs construction during training is more than a simple detour in the learning process. Rather than being inhibited or discarded, the modifier interpretation appears to be a part of the memory traces generated while learning the needs construction. When the reader encounters the modifier construction in Phase 2 of the experiment, these early traces of the modifier construction work to facilitate processing of the structure when it first appears. That is, the traces of the modifier interpretation activated when the participant reads "The meal needs cooked . . . " speeds reading of the construction relative to its reading in the control condition (in which readers have not previously considered a modifier interpretation of the training sentences). This finding is consonant with the results reported in Christianson et al. (2001), who showed that the initial misinterpretation of garden path sentences can linger even after a reinterpretation of the sentence has been made. The data reported here extend these results, showing that not only does the misinterpretation linger but also that it can remain in memory long enough to affect the processing of subsequent sentences.

Table 5
Mean Residual Reading Times (in Milliseconds) for Region of Interest in Experiment 3

Training and trial	Region 1	2	3	4
Phase 1				
Needs training				
Trials 1–3	51	123	402	132
Trials 4–7	18	26	58	11
Trials 8–10	−18	12	−78	−22
Control training				
Trials 1–3	139	172	−45	75
Trials 4–7	69	100	−17	17
Trials 8–10	27	27	−59	−42
Phase 2 (Trials 1–4)				
Needs training				
Needs	−42	−48	−17	−31
Modifier	−11	−36	−55	73
Control training				
Standard	6	1	−53	−12
Modifier	8	49	169	79

Note. The region of interest for the needs sentences in Phase 1 and Phase 2 covered the words *needs cooked given that* (Regions 1, 2, 3, and 4, respectively). The region of interest for the modifier sentences (Phase 2) covered the words *needs cooked vegetables given* (Regions 1, 2, 3, and 4, respectively).

Experiment 4

The results of Experiment 3 provide general support for episodic-processing theories of memory: Training on the needs construction facilitates reading of the modifier construction relative to the reading of modifier sentences following training on the standard construction. The episodic-processing theory claims that the facilitation effect is the result of a specific set of events as readers learn to comprehend the needs construction. First, it is proposed that upon encountering ". . . needs cooked . . . ," readers

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Table 6
Statistical Analysis From Phase 1 of Experiment 3

	Time			Training			Time × Training		
Region of interest	*F*	*MSE*	ω^2	*F*	*MSE*	ω^2	*F*	*MSE*	ω^2
Region 1	15.77*	5,499	.19	3.05	38,198	—	1.00	5,499	—
Region 2	11.51*	15,522	.14	<1	84,451	—	<1	15,522	—
Region 3	13.48*	69,902	.17	3.37	177,065	—	5.74*	69,902	.07
Region 4	17.29*	11,552	.21	<1	38,055	—	<1	11,552	—

Note. Training is a between-subjects factor, and time is within subjects. For time and Time × Training, df = 2, 80; for training, df = 1, 40. Dashes indicate that the partial omega squared value is not reported because the *F* value is not significant.
* $p < .05$.

mistakenly select the modifier interpretation of the sentence. Evidence for this misinterpretation was observed in Phase 1 of Experiments 2 and 3. Readers experienced the greatest processing difficulty (and showed the greatest learning gains) in Region 3, exactly as one would expect if participants had initially selected the modifier interpretation of the sentence.

The second component of the episodic-processing account is that these misinterpretations become part of one's memory for the needs construction (see Christianson et al., 2001, for another demonstration of this phenomenon). When the reader encounters another needs sentence, the incoming sentence retrieves stored processing episodes for turning the construction into a meaning. In Phase 2 of Experiment 3, when the participants read "The meal needs cooked . . . ," they retrieve the needs-processing episodes, which contain traces of having initially selected the modifier interpretation. These active traces of the modifier interpretation facilitate processing of the sentence when it turns out to be an example of the modifier sentence (rather than a needs sentence). Reading the modifier construction is slower in the control training condition because the participants do not have these previous selections of the modifier interpretation to draw on in interpreting the sentence.

The episodic-processing approach is based on the idea that traces of the processing done on a stimulus become a part of the memory for that stimulus. This leads to a straightforward prediction regarding the relationship between the needs construction and the modifier construction: If the processing of the needs construction is altered such that readers do not first select the modifier interpretation (i.e., the experimental context is biased such that the needs interpretation of the training sentences is much more likely than the modifier interpretation), then the facilitation effect should disappear. Experiment 4 was designed to test this prediction.

There were five conditions in this experiment. Two of these replicate previous experiments. Participants were trained on the needs construction in Phase 1 and then read either the modifier construction (noninstructed needs–modifier condition) or the wants sentences (noninstructed needs–wants condition) in Phase 2. Participants were expected to behave as they did in previous experiments, showing little processing difficulty in moving from the needs construction to modifier or wants constructions.

Two further instructed conditions were designed to test the prediction that changing the processing of the needs construction will remove the facilitation effect on the modifier construction. In both of these conditions, participants received additional instructions before beginning the reading task. The participants were told that they were going to read a type of sentence with which they were unfamiliar. The participants were given a short example of the needs construction (e.g., "The floor needs cleaned"), and told that it meant something akin to the standard construction (e.g., "The floor needs to be cleaned"). Next, the participants were told that they were going to be reading examples of the needs construction that were longer than the initial example. They were then given an example of this longer construction (e.g., "The floor needs cleaned before tomorrow morning"). This was designed to introduce participants to the kind of sentence that they were going to read in the experiment in such a way that the likelihood they would initially select the incorrect modifier interpretation of these

Table 7
Comparison of Reading Times in the First Half of Phase 2 in Experiment 3

	Sentence type			Training			Sentence Type × Training		
Region of interest	*F*	*MSE*	ω^2	*F*	*MSE*	ω^2	*F*	*MSE*	ω^2
Region 1	<1	2,286	—	1.70	17,064	—	1.61	2,286	—
Region 2	3.83	2,340	—	1.47	35,269	—	<1	2,340	—
Region 3	12.24*	10,803	.12	1.69	46,892	—	16.36*	10,803	.15
Region 4	11.14*	8,860	.11	<1	31,185	—	<1	8,860	—

Note. Training is a between-subjects factor, and time is within subjects. For all factors, df = 1, 40. Dashes indicate that the partial omega squared value is not reported because the *F* value is not significant.
* $p < .05$.

Fn7 sentences would be reduced.[7] After this training, the participants engaged in the standard Phase 1 training, followed by Phase 2 reading that involves either the modifier (instructed needs, modifier condition) or the wants (instructed needs, wants condition) sentences.

The episodic-processing account makes several predictions regarding these four conditions. First, the initial instruction on the needs construction should create a context in which it is unlikely that readers will initially select the modifier interpretation when they process the needs construction. The learning effect typically observed in Region 3 during reading in Phase 1 should be attenuated by this initial training. Second, because the modifier interpretation was not selected during the processing of the sentence, participants who receive the additional instruction will not have traces of having selected the modifier construction in their memory of the needs construction. Thus, the instruction should remove the facilitation effect on the modifier construction. That is, participants given the instruction should read the modifier construction more slowly in Region 3 than participants who were not given the initial instruction (just as participants in the control training conditions did). Third, the effect of the instruction on Phase 2 reading should be limited to the modifier construction. The needs-processing traces stored during training condition should still facilitate processing of the wants sentences.

Even if the predicted pattern of results is obtained, there is an important difference between the instructed- and noninstructed-training conditions that could cloud the interpretation of the results. Participants in the instructed condition encounter 8 needs constructions during the instruction period then read 10 more needs sentences in Phase 1. This is a total of 18 needs sentences read before encountering the modifier and wants sentences in Phase 2. Participants in the noninstructed condition only read 10 needs sentences before Phase 2. This makes it unclear whether it is the instructions (and consequent lack of consideration of the modifier interpretation) that remove the facilitation effect on the modifier or the extra exposure (and, perhaps, additional strengthened priming of the specific needs interpretation) that is doing so. To test among these possibilities, a fifth condition was added to the experiment. Participants in this condition read 18 needs constructions in Phase 1 of the experiment and then read the modifier construction in Phase 2 (noninstructed needs 18–modifier condition).

Method

Participants. The participants were 105 introductory psychology students from the University of Wisconsin—Madison. Participants were given extra credit in exchange for their participation. There were 21 participants in each of the five experimental conditions.

Materials. The 10 needs sentences read in all training conditions were the same training sentences used in Experiments 2 and 3. In addition, the 10 wants sentences used in Experiment 2 were used in this experiment. For this experiment, eight additional needs sentences were constructed for the initial instructions (and for the additional reading in the noninstructed needs 18–modifier condition). An additional 10 new modifier sentences were constructed for Phase 2. The new sentences were used in this experiment to show that the facilitation effect observed in Experiment 3 generalizes to a different set of sentences. Twelve additional filler sentences were generated to fill out the trials in the noninstructed Needs 18–modifier condition (see Appendix B for materials).

Procedure. In the noninstructed conditions, the procedure was identical to that used in Experiment 2. Participants read 10 needs sentences in Phase 1 and then read either 10 modifier sentences or 10 wants sentences in Phase 2. In the noninstructed needs 18–modifier condition, the procedure was essentially the same, save that participants read 18 needs sentences in Phase 1.

In the instructed conditions, participants were given initial instruction on the needs construction. Participants were told that they were going to read a type of sentence with which they were not familiar. They were given an example of this sentence type: "The floor needs cleaned." The participants were told that this sentence meant the same thing as "The floor needs to be cleaned." Next, participants were told that they would read longer versions of the same sentence type, such as "The room needs lighted so we can read our books." The participants then read another seven examples of this sort aloud. After this initial instruction, participants engaged in the reading task as in the noninstructed conditions.

Design and analysis. The reading data were corrected for length in the same manner as in Experiment 2.

The data analysis strategy for Experiment 4 is similar to that used in previous experiments. The first set of analyses examined data from Phase 1. These data were analyzed with a Training (instructed vs. noninstructed) × Time (Trials 1–3, Trials 4–7, Trials 8–10) ANOVA, with training as a between-subjects factor. Because participants in the noninstructed Needs 18–modifier condition received 18 needs trials in Phase 1, the data from Trials 1–3, Trials 4–7, and Trials 16–18 were used in this analysis. The second set of analyses compares reading from the last trials of Phase 1 (Trials 8–10 or Trials 16–18, depending on the condition) with the first trials of Phase 2 (Trials 1–5). Separate analyses were done on the data from participants who read the modifier construction in Phase 2 and on the data from participants who read the wants sentences in Phase 2. These data were analyzed with a Training (instructed vs. noninstructed) × Time (end of Phase 1 vs. beginning of Phase 2) mixed-factor ANOVA, with training as a between-subjects factor.

Results

The mean residual reading times from this experiment are presented in Tables 8 and 9. The results of the two primary T8-9 analyses described above are reported in Table 10. The results T10 reported in the text below focus on the analyses of most theoretical importance. Average accuracy on the comprehension questions was 94%. Results reported as significant are significant with the Type I error rate set at .05, unless otherwise noted.

Phase 1. The critical result from Phase 1 was the Training × Time interaction observed in Region 3, $F(2, 206) = 4.22$. Participants in the instructed-training conditions initially read Region 3 faster than participants in the noninstructed-training conditions in Trials 1–3, $F(1, 194) = 4.49$, $MSE = 81{,}825$, $\omega^2 = .02$, but this difference was not significant at any other point in Phase 1 (Fs < 1).[8] The initial difference in reading time suggests that the instruc- Fn8 tions were successful in making it unlikely that readers would

[7] In saying that participants are unlikely to select the *modifier* interpretation, we do not mean to imply that our instructions have prevented readers from activating this interpretation altogether (see Footnote 2).

[8] The claim that participants in the instructed-training conditions were not selecting the *modifier* interpretation of the needs sentences in Phase 1 is also supported when one compares the pattern of reading times in Experiment 4 with the pattern observed in Phase 1 of the other experiments conducted in this paradigm (Experiments 2 and 3, plus four other experiments not reported here). For the six other experiments conducted using this training paradigm, the difference in reading time between Trials 1–3 and Trials 8–10 was computed for both the needs sentences and the standard sentences. Considering these differences as the beginning of a sampling distribution of learning effects observed in needs training or control training, confidence intervals were constructed for each training condition. Across the five experiments, the

Table 8
Mean Residual Reading Times (in Milliseconds) for Region of Interest in Phase 1 of Experiment 4

	Region			
Training and trial	1	2	3	4
Reading times by instruction condition (collapsing across Phase 2 reading condition)				
Instructed training				
Trials 1–3	87	166	84	88
Trials 4–7	44	39	9	24
Trials 8–10	26	40	−27	−12
Noninstructed training				
Trials 1–3	38	70	205	74
Trials 4–7	−2	0	9	−8
Trials 8–10	−39	−60	−54	−75
Reading times split according to Phase 2 reading condition				
Instructed training—Modifier Phase 2				
Trials 1–3	108	203	103	122
Trials 4–7	82	80	−1	62
Trials 8–10	40	78	−20	21
Noninstructed training—Modifier Phase 2				
Trials 1–3	26	44	263	60
Trials 4–7	−44	−53	−41	−44
Trials 8–10	−62	−88	−26	−80
Instructed training—Wants Phase 2				
Trials 1–3	66	129	65	55
Trials 4–7	5	−2	19	−14
Trials 8–10	12	1	−34	−46
Noninstructed training—Wants Phase 2				
Trials 1–3	33	80	177	60
Trials 4–7	7	23	21	−1
Trials 8–10	−46	−44	−64	−42
Noninstructed training, 18 needs sentences—Modifier Phase 2				
Trials 1–3	49	85	173	103
Trials 4–7	31	29	46	20
Trials 16–18	−8	−48	−74	−104

Note. The region of interest covered the words *needs cooked given that* (Regions 1, 2, 3, and 4, respectively).

select the modifier interpretation of the needs sentences in this
Fn9 phase of the experiment.[9]

Last trials of Phase 1 to first trials of Phase 2 (modifier conditions). The important result from this analysis was a Time × Training interaction in Region 3, $F(2, 60) = 3.43$. Simple main effects revealed that participants in the instructed-training condition slowed down in moving from the needs sentences to the modifier sentences, $F(1, 20) = 4.21$, $MSE = 45{,}549$, $p = .053$, $\omega^2 = .07$, whereas participants in the noninstructed conditions sped up slightly (but not significantly) in moving from the needs sentences to the modifier sentences, replicating Experiment 3 (Fs < 1). Another set of simple main effects revealed that participants in the instructed condition read the modifier sentences more slowly than participants in the noninstructed conditions in Regions 1, 2, and 4 as well (Fs > 5.47, ω^2s $> .02$).

average learning effect in the needs-training condition was 320.2 ms (95% confidence interval: 159.5 ≤ learning effect ≤ 480.9). In the same experiments, the average learning effect in the control training condition was 105.8 ms (95% confidence interval: 73.17 ≤ learning effect ≤ 138.43). The learning effect in the instructed conditions in Experiment 4 was 111 ms, and the learning effect in the noninstructed conditions was 205 ms. The effect in the instructed condition clearly falls into the interval for the control training conditions, whereas the effect in the noninstructed condition clearly falls into the interval for the needs-training conditions. This implies that reading in the instructed conditions was akin to reading in the control training conditions of the other experiments, in which no garden path effects were observed.

[9] It might be argued that the reading times in the instructed conditions do not reflect normal language processing because we had, in some sense, told the participants what to do in the experiment. To counter this argument, we ran a control study. Instead of providing the participants with explicit instruction on the needs construction, we asked them to read a series of passages containing the construction (surrounded by filler passages), as in Experiment 1. The reading of whole sentences such as "The floor needs cleaned" was intended to introduce the participants to the needs construction in such a way that the modifier construction did not come into play. After finishing this reading task, the participants were told that they were going to engage in another unrelated experiment. This experiment was identical to the Phase 1 training used in Experiments 2–4. The reading times from this task were virtually identical to the reading times from the instructed conditions in Experiment 4. This suggests that the pattern of data in the instructed conditions was the result of a particular kind of previous experience with the needs construction (i.e., one in which the *modifier* interpretation was not initially selected) rather than experimenter-generated expectations.

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Table 9
Mean Residual Reading Times (in Milliseconds) for Region of Interest in Phase 2 of Experiment 4 (Trials 1–5)

Training	Region 1	Region 2	Region 3	Region 4
Modifier				
Instructed training	70	58	116	114
Noninstructed training	−42	−78	−91	−13
Noninstructed, 18 needs training	−38	−60	−103	−30
Wants				
Instructed training	−17	−25	−47	−20
Noninstructed training	10	−21	−8	−53

Note. The region of interest for the modifier sentences covered the words *needs cooked vegetables given* (Regions 1, 2, 3, and 4, respectively). The region of interest for the wants sentences covered the words *wants recognized for his* (Regions 1, 2, 3, and 4, respectively).

Last trials of Phase 1 to first trials of Phase 2 (wants conditions). There were no significant effects in this analysis. Simple main effects showed that the readers did not slow down in moving from the needs sentences to the wants sentences ($F\text{s} < 2.30$, $p > .145$), and that reading of the wants sentences themselves did not differ across training conditions ($F\text{s} < 1$).

Discussion

There are four important results in this experiment. First, in Phase 1, participants in the instructed conditions initially experienced less processing difficulty than participants in the noninstructed conditions in Region 3. This suggests that the readers in the instructed-training conditions were not selecting the modifier interpretation of the needs sentences during training. Second, readers in the instructed-training condition slowed down when they first read the modifier sentences, whereas readers in the noninstructed-training condition sped up slightly when they first read the modifier sentences. Third, participants in the instructed and noninstructed-training conditions behaved identically in their reading of the wants sentences. Fourth, it was shown that the lack of a facilitation effect on the modifier construction in the instructed-training condition was not simply because of extra exposure to the needs construction. This conclusion is supported by the facilitation effect on the modifier sentences seen in the noninstructed needs 18–modifier condition, in which the participants showed the facilitation effect despite encountering the same number of needs sentences as in the instructed-training condition. These observations provide clear support for the episodic-processing account.

General Discussion

We began this project with two goals. First, we wanted to characterize the processing events that occur as adults gain facility in comprehending a novel construction in their native language. The results of our experiments suggest that adults can quickly learn to comprehend a new construction, that the new construction is readily generalized to verbs other than those seen during initial training, and that exposure to the new construction affects the way that more familiar constructions are processed. Our second goal was to assess the extent to which extant psycholinguistic theories could capture readers' behavior in these experiments. We focused

Table 10
Statistical Analysis From Experiment 4

Phase and/or region of interest	Time			Training			Time × Training		
	F	*MSE*	ω^2	*F*	*MSE*	ω^2	*F*	*MSE*	ω^2
Phase 1[a] (collapsed across Phase 2 reading conditions)									
Region 1	19.05*	6,992	—	2.97	71,563	—	<1	6,992	—
Region 2	30.86*	14,929	.16	3.48	134,417	—	1.96	14,929	—
Region 3	30.20*	37,348	.16	<1	169,138	—	4.22*	37,348	.02
Region 4	48.52*	9,238	.23	1.58	63,682	—	1.63	9,238	—
Comparison of last block of Phase 1 (Trials 8–10) to first half of Phase 2 (Trials 1–5)									
Modifier Phase 2[b]									
Region 1	<1	8,496	—	2.70	47,823	—	1.29	8,496	—
Region 2	<1	9,749	—	3.72*	72,464	.04	<1	9,749	—
Region 3	<1	34,881	—	2.08	103,747	—	3.43*	34,881	.04
Region 4	34.28*	5,524	.21	4.53*	48,367	.05	<1	5,524	—
Wants Phase 2[c]									
Region 1	<1	11,251	—	<1	60,660	—	3.33	11,251	—
Region 2	<1	6,973	—	<1	76,864	—	1.84	6,973	—
Region 3	<1	25,487	—	<1	86,141	—	<1	25,487	—
Region 4	<1	4,284	—	<1	36,862	—	1.66	4,284	—

Note. In all analyses, training is a between-subjects factor, and time is within subjects. Partial omega squared values are reported for each significant effect. Dashes indicate that the partial omega squared value is not reported because the *F* value is not significant.
[a] For time and Time × Training, $df = 2, 206$; for Training, $df = 1, 103$. [b] For time, $df = 1, 60$; for training and Time × Training, $df = 2, 60$. [c] For all factors, $df = 1, 40$.
* $p < .05$.

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on the constraint satisfaction approach to sentence comprehension because its duality as a model of language processing and language learning made it the most appropriate of all existing theories to be applied to the learning of a new construction. Whereas the constraint satisfaction approach aptly characterized the pattern of reading times seen in Phase 1 of Experiments 2–4, it did not make the correct prediction for how exposure to the needs construction affects processing of the modifier construction. An episodic-processing approach to memory straightforwardly predicts the facilitated reading of the modifier construction after training on the needs construction.

Together with Christianson et al.'s (2001) study of garden path sentences, the results of Experiments 3 and 4 challenge the widely held view that the less preferred interpretation of an ambiguous sentence is discarded during the comprehension process (e.g., Frazier & Clifton, 1996; MacDonald et al., 1994). Because this view features prominently in virtually every extant theory of sentence processing, these results suggest that most sentence processing theories are either incorrect or incomplete. At the same time, our data point to one direction in which theories of sentence processing might be developed, namely by incorporating elements of the episodic-processing approach to memory into their architecture. It is interesting to note that the episodic-processing account sketched in the introduction to this article is essentially a merger of the episodic-processing account and the constraint satisfaction account. The "processing work" that formed the memory trace for episodes of comprehending the needs construction is exactly the kind of processing that is done by a constraint satisfaction model. Although it may be too early to develop a detailed episodic-processing theory of language processing (i.e., one that makes commitments to particular kinds of syntactic knowledge), one route toward developing such a theory might be to expand on this type of architecture. That is, the dynamic trajectory of events that unfold as a sentence is comprehended leaves a memory trace in the language-processing system, and these episodic traces are retrieved to support comprehension of subsequent sentences. An account of this sort would be sensitive to both global probabilistic information (abstracted across many individual episodes of sentence processing) and more specific elements of one's linguistic experience (as in these experiments).

Although the episodic-processing effect observed in Experiments 3 and 4 are not predicted by extant theories of sentence processing, they are not unanticipated in the literature. For example, episodic-processing effects in speech processing have been reported by Nygaard and Pisoni (1998). Participants were trained on the voices of unfamiliar speakers, who produced either individual words or sentences. These participants outperformed untrained participants on transfer tasks only when the transfer task required processing that matched the processing done during training (e.g., when training and transfer involved the processing of isolated words). Furthermore, Goldinger (1998) has discussed how an episodic memory system can account for a range of findings in the literature on lexical processing. More recently, Hughes and Whittlesea (2003) have reported episodic-processing effects in a semantic-priming task. Our data provide an extension of these results, demonstrating that episodic-processing effects can also be observed in online sentence-processing tasks.

Our data are also consistent with work on structural priming (e.g., Bock, 1986; Bock & Griffin, 2000; Chang, Dell, Bock, & Griffin, 2000). Structural priming has been studied most extensively in language production (e.g., Bock, 1986; Pickering & Branigan, 1998; Weiner & Labov, 1983), where the phenomenon of interest is that speakers are more likely to produce a sentence having a particular structure given recent exposure to another sentence of the same structure (e.g., one is more likely to produce a passive sentence given recent exposure to another passive sentence). Structural priming has been studied less frequently in language comprehension, for which it has been shown that sentences are processed with greater ease when they have been preceded by another sentence of the same syntactic structure 1(cf. Bienvenue & Mauner, 2003; Branigan, Pickering, Liversedge, Stewart, & Urbach, 1995). Our participants' increased facility in comprehending the needs construction given repeated exposure to examples of the construction can be seen as another demonstration of structural priming in language processing. The proposal that the mechanisms responsible for structural priming (such as the learning mechanisms specified by Chang et al., 2000) may underlie our participants' increasing facility in understanding the needs construction, which is in accord with work in child language acquisition. For example, Brooks and Tomasello (1999) demonstrated that structural priming plays a role in children's acquisition of syntactic constructions. Thus, our data support the possibility that a mechanism that functions in child language acquisition may also play a role in adults' continued ability to learn new constructions in their native language (cf. Seidenberg & MacDonald, 1999).

Nevertheless, there are important limitations to these data. First, our studies concerned adults' learning to comprehend a single construction. To gain a broader picture of adults' ability to handle novel syntactic constructions, similar studies should be done with a range of novel constructions and a range of transfer conditions. Such studies will be necessary to find the limits on adults' capacity to learn new constructions and to further address the issue of what exactly it is that participants have learned in the experiments. For example, did the participants learn something new and general about English, or was their learning specific to this experimental context (i.e., akin to learning to comprehend someone's idiolect)? Without a definitive answer to this question, the most conservative conclusion that can be drawn from these data is that repeated exposure to a novel construction can lead to more facile comprehension of that construction and can have an influence on the processing of other kinds of sentences, provided those other sentences are encountered in a context in which traces of having encountered the novel construction will be retrieved.

Another limitation to this work is that the data do not allow us to discern whether the participants learned to comprehend the needs construction via "normal" comprehension processes or whether they were engaging a more conscious or strategic form of processing to handle the construction. On the one hand, it is not clear that it is necessary to invoke any special processing strategies to account for the pattern of reading times observed in these experiments. Whereas a constraint satisfaction model would initially struggle with the novel needs construction, given the similarity of this construction to the standard construction, it is likely that the comprehension system could arrive at the correct interpretation for the sentence without requiring any additional assumptions. On the other hand, the facilitated reading of the modifier construction observed in Experiment 3 is straightforwardly predicted by the episodic-processing account we sketched. Finally, whereas the effect of the instruction manipulation in Experiment 4 appears to be indicative of a special processing strategy, this need not be the case. We can view the instructions as a form of contextual information that weights the competition between the needs and modifier interpretations of the training sentences in Phase 1 toward the needs interpretation, therefore explaining the effect entirely within the context of existing approaches to sentence processing.

Although it may not be necessary to invoke unusual, strategic processing strategies to explain our data, the data do not conclusively rule out the possibility that participants in the needs-training condition were using such strategies. Even if this is the case, we do not feel that it trivializes the results of our experiments. There are many situations in which language comprehenders are faced with input that is novel or otherwise nonoptimal for the operation of the language-processing system, such as when one listens to a speaker whose accent or use of particular syntactic constructions is unfamiliar. It may be the case that successful comprehension in some or all of these contexts requires the use of unusual strategies to accommodate the atypical linguistic input. The increasing facility that one has in processing the atypical input might therefore reflect either faster access to these strategies, adjustment in the normal mechanisms of language processing, or some combination of both. Broader conclusions about what happens as individuals acquire a new syntactic construction (in the sense of learning to comprehend and produce the construction) must be delayed pending more extensive studies of the learning process.

These experiments take a first step toward understanding how adults learn to comprehend novel constructions. Of course, our results only scratch the surface of a series of critical theoretical questions about the interaction between learning, memory, language acquisition, and language processing. Although much work remains to be done to understand these interactions, this work will be rewarded by a deeper understanding of one of the most complex skills that humans master.

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Appendix A

Example Passage From Experiment 1

Introduction

Blair looked bored as she sat on a lawn chair in her yard. It was another summer day with nothing to do. Just then, her mom walked by. Noticing Blair's boredom, she remarked,

Critical sentence

"The grass needs cut." (Needs construction)
"The grass needs to be cut." (Standard construction)

Follow-up sentence

The grass had been growing quickly all summer, and was high yet again. (consistent)

The grass had burned out earlier in the summer, and hadn't grown at all since then. (inconsistent)

Conclusion

Blair rolled her eyes at her mother's suggestion.

Probe word

yard

Appendix B

Sentences From Experiments 2–4

(Note that for all training sentences, the Needs versions are presented. The Standard version of the sentence can be generated by adding "to be" after "needs.")

Needs Training Sentences (Phase 1, Experiments 2–4)

1. The wood floor needs cleaned before our parents get here.
2. The white walls need painted to keep the tenants happy.
3. The old chair needs fixed so the guests can sit on it.
4. The computer program needs debugged before I hand it in.
5. Florida oranges need peeled before they can be eaten.
6. The large pumpkin needs carved before it can be put on display.
7. Small potatoes need boiled before they can be used in the soup.
8. The term paper needs revised before tomorrow morning.
9. The blank CD needs burned so I can give it to you.
10. The green light bulb needs changed since it just burned out.

Additional Training Sentences (Phase 1, Experiment 4)

11. The room needs lighted so we can read our books.
12. The television needs repaired before we can watch it again.
13. The piano needs tuned so the musicians can play.
14. The fire needs stoked to keep it from burning out.
15. The patio needs decorated for the party.
16. The film needs copyrighted before it can be released.
17. The shirt needs ironed so I can wear it tonight.
18. The lock needs checked so we can be sure the apartment is secure.

Wants Sentences (Phase 2, Experiments 2 and 4)

1. The shaggy dog wants walked before it is time to go to the movies.
2. The kitten on the couch wants scratched before she eats dinner.
3. The rich customer wants served before everyone else in the restaurant.
4. The valiant hero wants recognized for his courageous actions.
5. The brightly colored parrot wants fed because she has been hungry for days.
6. The injured soccer player wants treated by the team doctor.
7. The brilliant scientist wants photographed for the school paper.
8. The chef wants praised for her extraordinary recipe for chicken soup.
9. The cute baby wants held because he is feeling uneasy.
10. The general wants honored for his wartime heroics in years past.

Needs/Modifier Sentences (Phase 2, Experiment 3)

1. The ceramic tile needs washed before it is put on the wall./The ceramic tile needs washed stickers to be put on it.
2. The oak cabinet needs dusted when you clean the living room./The oak cabinet needs dusted candles to be placed on its shelf.
3. The legal file needs completed since the case is closed./The legal file needs completed documents before it can be closed.
4. The plastic bench needs folded to be put away./The plastic bench needs folded paper to be put on it.
5. The apple pie needs baked very soon so we can serve it./The apple pie needs baked walnuts to be placed on its crust.
6. The soccer ball needs inflated while we wait for the game./The soccer ball needs inflated holders to keep it in place.
7. The new screws need tightened so the shelf does not collapse./The new screws need tightened bolts to keep them in place.
8. The meal needs cooked given that dinner is in an hour./The meal needs cooked vegetables to make it complete.
9. The red wine needs refrigerated after it is opened./The red wine needs refrigerated grapes to complement it.
10. Tim's feet need measured so we can buy him shoes./Tim's feet need measured fabric to wrap them up.
11. The beautiful picture needs trimmed to fit in the frame./The beautiful picture needs trimmed paper to hold it in the frame.
12. The pork chops need glazed before they are baked./The pork chops need glazed pineapples to be cooked with them.
13. The car needs recycled when it is put in the scrap yard./The car needs recycled air inside to make the ride comfortable.
14. The large oven needs scrubbed to remove all of the grease./The large oven needs scrubbed pans to be put back inside.
15. The back lawn needs cut because the grass is so high./The back lawn needs cut flowers to be sprinkled on it.
16. The washing machine needs rebuilt after you take it apart./The washing machine needs rebuilt gears to be installed.

Modifier Sentences (Phase 2, Experiment 4)

1. The ceramic tile needs washed stickers to be put on it for the big party.
2. The oak cabinet needs dusted candles to be put on its shelf.
3. The literary magazine needs edited poems before it can be printed.
4. The plastic bench needs folded paper to cover it.
5. The apple pie needs baked walnuts sprinkled on top of its crust.
6. The new screws need tightened bolts to keep them in place.
7. The meal needs cooked vegetables so the guests will be happy.
8. The beautiful picture needs trimmed paper to hold it in the frame.
9. The curtain needs torn patches to be ironed on for the show.
10. The car needs washed hubcaps so it will look totally clean.

Received August 1, 2003
Revision received March 9, 2004
Accepted March 17, 2004 ■

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EQ1: Ed—175 correct as set? ms unclear.

EQ2: Ed—OK for training in footnote [b] to start with a lowercase t as edited, or, cap T as in footnote [a] preferred for consistency?