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Changes in Task-Extrinsic Context Do Not Affect the Persistence of Long-Term Cumulative Structural Priming

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Abstract

We present two experiments exploring the role of extrinsic memory factors (i.e., factors that are extrinsic to the primary task that is being performed) and intrinsic memory factors (i.e., factors that are intrinsic to the primary task being completed) in the persistence of cumulative structural priming effects. Participants completed a two-phase experiment, where the first phase established a bias toward producing either the double object or prepositional object construction, and the second phase assessed the effects of this bias. Extrinsic memory factors were manipulated by having participants complete the two phases of the study in the same or different locations (physical context change) or while watching the same or different videos (video context change). Participants completed the second phase of the study 10 min after the first phase of the study in Experiment 1, and after a delay of 1 week in Experiment 2. Results suggest that the observed structural priming effects were not affected by manipulations of extrinsic memory factors. These data suggest that explicit memory does not play a large role in the long-term persistence of cumulative structural priming effects.

A number of studies have demonstrated that adult language users can adapt their behavior to changes in their linguistic environment. Language comprehenders can adapt to changing phonological (e.g., Kraljic & Samuel, 2005; 2007) and syntactic (e.g., Kaschak & Glenberg, 2004; Wells, Christiansen, Race, Acheson, & MacDonald, 2009) patterns. Language producers demonstrate similar adaptations, acquiring new phonotactic constraints (e.g., Dell, Reed, Adams, & Meyer, 2000; Warker & Dell, 2006) and changing their syntactic choices based on changing patterns of experience with particular syntactic forms (e.g., Kaschak, 2007; Kaschak, Loney, & Borreggine, 2006). Language users' ability to adapt to their linguistic environment appears to be quite robust. Despite the range of these demonstrations, the nature of the learning and memory mechanisms that play a role in producing linguistic adaptations remains an open question (e.g., Hartsuiker, Bernolet, Schoonbaert, Speybroeck, & Vanderelst, 2008; Jaeger & Snider, under review; Kaschak & Borreggine, 2008; Kraljic & Samuel, 2011). We take a step toward addressing this issue by exploring the role that implicit and explicit memory processes play in the long-term persistence of structural priming effects.

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Structural priming refers to the tendency for speakers to repeat syntactic structures across utterances (Bock, 1986). A speaker who recently produced a double object construction (DO: Tim handed Karen the book) has an increased odds of producing another DO when describing the transfer of something between people (Meghan gave Michael the toy) as opposed to producing a prepositional object construction (PO: Meghan gave the toy to Michael) to describe the same event. Structural priming has been observed in spoken (Branigan, Pickering, & Cleland, 2000) and written (Cleland & Pickering, 2006) production, in language comprehension (e.g., Branigan, Pickering, & McLean, 2005), across a range of sentence types (e.g., Griffin & Weinstein-Tull, 2003; Hartsuiker & Kolk, 1998; Pickering & Branigan, 1998), and across several languages (e.g., Hartsuiker, Pickering, & Veltkamp, 2004). The presence or absence of structural priming effects in different contexts is of much interest to cognitive scientists, as the pattern of priming effects can be revealing about the representations that underlie language use (e.g., Branigan, Pickering, Liversedge, Stewart, & Urbach, 1995; Chang, Dell, & Bock, 2006; Pickering & Ferreira, 2008).

It is widely held that structural priming is the result of implicit learning within the systems responsible for language processing (e.g., Bock & Griffin, 2000; Chang et al., 2006). One way of envisioning such learning is via connectionist models whose learning algorithm is left “on” as the system continues to produce and/or comprehend language (e.g., Chang et al., 2006), adapting its behavior as the features of the linguistic input change (e.g., as the rates of use for a given syntactic structure change). A number of observations support the view that structural priming is a case of implicit learning. Ferreira, Bock, Wilson, and Cohen (2008) demonstrate that anterograde amnesiacs display structural priming, despite showing profound deficits in explicit memory. In addition, just as implicit learning has been shown to persist for long stretches of time (e.g., Allen & Reber, 1980), structural priming has also been shown to persist across time. Priming from an individual prime sentence to an individual target sentence can persist across at least ten intervening filler sentences (Bock & Griffin, 2000), and cumulative priming effects (i.e., structural priming accumulating across many trials in an experiment) have been shown to persist for at least 1 week (Kaschak, Kutta, & Coyle, 2012; Kaschak, Kutta, & Schatschneider, 2011b).

Although the view that structural priming reflects implicit learning in the language production system has received a good deal of support (e.g., Bock & Griffin, 2000; Chang et al., 2006; Ferreira et al., 2008; Kaschak, Kutta, & Jones, 2011a; Kaschak et al., 2011b), the possibility that explicit memory processes may shape structural priming has been discussed by several authors (e.g., Chang et al., 2006; Hartsuiker et al., 2008). Hartsuiker et al. (2008; Chang et al., 2006) raise the issue of explicit memory processes in structural priming when discussing the so-called lexical boost: priming between prime and target sentences is stronger when lexical items (particularly verbs) are repeated across sentences. One account of the lexical boost is that the repetition of lexical items increases the likelihood that participants will explicitly retrieve the preceding prime sentence when preparing to produce the target sentence, and this explicit retrieval increases the odds of the syntactic structure being repeated across utterances.

Kaschak et al. (2012) discuss the role of explicit memory in the context of the long-term persistence of cumulative structural priming effects. They performed experiments in two

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phases. In the Bias phase, participants were induced to produce either 100% DO constructions or 100% PO constructions. In the subsequent Priming phase, participants were free to produce either the DO or PO construction. Kaschak and colleagues (e.g., Kaschak, 2007; Kaschak et al., 2006) have shown that rates of DO and PO production in the Bias phase has an effect on the rates at which participants produce those constructions in the Priming phase; that is, structural priming effects accumulate across the course of the Bias phase (see also Hartsuiker & Westenberg, 2000).

Kaschak et al. (2012) present a series of experiments in which participants completed the Bias phase using either a written stem completion task (e.g., Pickering & Branigan, 1998) or a picture description task (e.g., Bock, 1986), and then completed the Priming phase using either the same task or a different task (e.g., using written stem completion throughout the experiment, or using written stem completion in the Bias phase, and picture descriptions in the Priming phase). In addition, the Bias and Priming phases either occurred back-to-back in a single experiment session (as in Kaschak, 2007), or were separated by a week (as in Kaschak et al., 2011b). Kaschak et al.'s (2012) results suggest that when the Bias and Priming phases occur in the same experiment session, cumulative priming effects that accrue during the Bias phase are seen in the Priming phase whether the same task is used in both phases of the experiment or not. When the Bias and Priming phases are separated by 1 week, a different pattern emerges: the cumulative priming effect is observed when the same task is used for the Bias and Priming phases, but not when the task switches across phases. The week-long persistence of the cumulative priming effect is in keeping with the idea that structural priming reflects implicit learning in the language production system (see also Kaschak et al., 2011b). The fact that the long-range persistence of cumulative priming is task-specific raises the question of whether the learning and memory mechanisms that are at work in these experiments are implicit, explicit, or some combination of both.

One problem that arises in assessing the role of explicit and implicit memory processes in priming experiments such as ours is that it is difficult to assess the possibility of explicit memory retrieval during the language production task without potentially disrupting the normal course of the language production process itself (e.g., asking participants to perform a recall task or recognition judgment while also performing the language production task). To avoid such problems, and to take a step toward identifying the role of explicit and implicit memory processes in the long-range persistence of structural priming, the current experiments employed context manipulations that memory researchers have used to distinguish tasks that have an explicit component from those that rely on implicit memory processes (e.g., McKone & French, 2001; Mulligan, 2011).

It is well known that memory performance is affected by contextual factors (e.g., Godden & Baddeley, 1975, 1980; Smith & Vela, 2001). Environmental context can affect the subsequent recall of information, as in Godden and Baddeley's (1975) famous work in which scuba divers learned a list of words on land or underwater and subsequently recalled more words when they were tested in the same location as they occupied during the learning phase of the study. Learning and memory performance is also known to be affected by lower-level contextual cues, such as the voice of the speaker presenting participants with a list of words (e.g., Goldinger, 1996) and the modality (e.g. spoken or written) through which words are presented to the learner (see Mulligan, 2004, for a review). Godden and Baddeley (1980; McKone & French, 2001) refer to these different types of contextual cues as extrinsic and intrinsic contextual factors. Extrinsic contextual factors are those features of the environment that are present but not necessary or relevant to the performance of the task at hand. Extrinsic factors include the general setting of the experiment (i.e., the environmental context), the color of the walls in the laboratory, the nature of one's seat at the computer at which the task is performed, and so on. Intrinsic contextual factors are contextual factors that are necessary to process in order to complete the task at hand (e.g., it is necessary to produce the font of written words in order to complete a task that involves visual presentation of verbal stimuli).

The distinction between implicit and explicit memory processes has occupied an important place in memory theory over the past several decades (e.g., McKone & French, 2001; Roediger & McDermott, 1993), and a number of studies have explored the extent to which implicit and explicit memory are sensitive to manipulations of intrinsic and extrinsic context (e.g., Jacoby, 1983; Mulligan, 2011; Parker, Dagnall, & Coyle, 2007). It is well established that explicit memory tasks are sensitive to both types of contextual manipulation, as in Godden and Baddeley's (1975) demonstration of environmental context effects in a recall task and Goldinger's (1996) demonstration of intrinsic context effects in a recognition task. Implicit memory tasks do not show sensitivity to changes in extrinsic memory factors (such as environmental context; Mulligan, 2011; McKone & French, 2001), though such tasks are sensitive to manipulations of intrinsic context (e.g., Marsolek, 1995; Tenpenny, 1995). It should be noted that whereas there are some demonstrations of extrinsic context effects on implicit memory performance (e.g., Parker, Gellatly, & Waterman, 1999), these are likely due to explicit memory factors contaminating performance on the implicit memory task (see Mulligan, 2011, for a discussion). Thus, it appears that sensitivity to different types of contextual manipulations provides an avenue for distinguishing tasks with an explicit memory component from tasks that rely on implicit memory with no (or very little) contribution from explicit memory processes.

Tasks that rely on contributions from explicit memory are sensitive to manipulations of both intrinsic and extrinsic context, but tasks that rely on implicit memory processes alone are sensitive to manipulations of intrinsic context and unaffected by manipulations of extrinsic context. Kaschak et al. (2012) demonstrate that intrinsic factors play a role in the long-term persistence of cumulative priming effects — cumulative priming persists across a week only when the intrinsic factors (i.e., the details of the experimental task) are reinstated at the second session. This is similar to Kolers (1976) finding that implicit learning effects persist across time more strongly when the intrinsic conditions of training and test (e.g., the nature of the stimulus materials) are matched, and as such suggests a role for implicit learning in long-term cumulative priming. Since the extrinsic context of both phases of the experiments was constant (i.e., participants completed both phases of the experiment in the same lab setting), Kaschak et al.'s (2012) results are not informative about whether extrinsic factors also affect the long-term persistence of cumulative priming. As such, Kaschak et al.'s (2012) data leave open the possibility that explicit memory factors may have also played a role in the persistence of the structural priming.

The current experiments employed the distinction between intrinsic and extrinsic context to assess the role of explicit memory in the long-term persistence of cumulative structural priming. We employed a written stem completion task for both the Bias and Priming phases of the studies, and therefore kept the task-relevant intrinsic factors constant across the experiment. At the same time, we manipulated two kinds of extrinsic context. First, participants completed the written stem completion task by typing their responses on a computer screen that displayed scenes from a particular setting (e.g., a sea cave). These scenes were extrinsic to the completion of the language production task and the participants were told to explicitly pay attention to the scenes while completing the sentences. Participants saw either the same scene during the Bias and Priming phases, or saw different scenes in the two phases of the experiment. Second, the physical location of the experiment was manipulated. Some participants completed both phases of the experiment within the same physical location (e.g., our research lab), and some participants completed the phases of the experiment in different locations (e.g., our research lab for the Bias phase, and a location elsewhere on campus for the Priming phase). The participants were not given any instructions to pay attention to the physical location. The manipulation of the two sources of extrinsic context and their instructions allowed us to the best opportunity to observe a contribution of extrinsic memory factors to implicit linguistic adaptations. If the strength of the cumulative structural priming effects observed within the same experiment session (Experiment 1; see also Kaschak, 2007) or in experiment sessions separated by 1 week (Experiment 2; see Kaschak et al., 2011b) is affected by manipulations of extrinsic context, it suggests a role for explicit memory processes in cumulative structural priming. If the manipulations of extrinsic context do not affect cumulative priming, it strengthens the case that such effects are driven by implicit learning.

EXPERIMENTS 1 AND 2

Our experiments were conducted in two phases: the Bias phase, where participants were induced to produce 100% DO constructions or 100% PO constructions, and the Priming phase, where participants were free to produce either construction. The experiments employed a written stem completion task (Pickering & Branigan, 1998). During the Bias phase, participants completed stems that induced the production of the DO construction (Meghan gave Michael _______) or the PO construction (Meghan gave the toy _______). During the Priming phase, participants completed stems that allowed the production of either construction (The soldier gave _______).

Participants were exposed to two sources of extrinsic information. The first source of extrinsic contextual information was the physical setting of the laboratory. As in past studies, all participants began their participation (Bias phase) in our research laboratory. Half of the participants completed their participation (Priming phase) in the laboratory, and the other half completed their participation in a different physical setting (a location elsewhere on campus). The second source of extrinsic context was the video scene presented in the background while participants were performing the stem completion task on the computer. The sentence stems were superimposed on top of this video. Smith and Mazano (2010) demonstrate that video-context paradigms have reliable effects on memory performance. Half of the participants saw the same video in the Bias and Priming phases, and the other half saw different videos in the two phases of the experiment. Physical location and video environments were manipulated factorially, so that all combinations of physical location (same vs. different) and video environment (same vs. different) appeared in our design.

The design of Experiments 1 and 2 was identical, except that in Experiment 1 the Bias and Priming phases were separated by 10 min (the time needed to change physical locations), and in Experiment 2 the phases were separated by 1 week. If cumulative structural priming effects are sensitive to explicit memory factors, we expect that the manipulations of physical and video context should affect the magnitude of the cumulative priming effects. In addition, it has been shown that the importance of the match between encoding and retrieval for memory performance increases as the length of time between encoding and retrieval increases (e.g., Read & Craik, 1995). Thus, it is possible that the effects of physical and video context will be larger in Experiment 2, when a full week intervenes between the Bias and Priming phases of the study.

METHOD

Participants

Eighty undergraduate psychology students participated in Experiment 1, and a different sample of eighty students participated in Experiment 2. To maintain the integrity of our Bias manipulation, we excluded any participants who did not produce the target structure for their Bias condition at least 80% of the time during the Bias phase (e.g., a participant biased toward the DO would have to produce a DO on 80% of the Bias phase trials on which either a DO or PO was produced). All of the participants in each of the experiments produced 100% of the biased construction in the Bias phase so no one was excluded on this basis.

Materials

The Bias phase of the experiment used 12 pairs of prime stems, where one member of the pair elicited the DO construction (The captain handed the old sailor _______) and the other member elicited the PO construction (The captain handed the travel log _______). The priming phase used 6 target stems that could be completed as either a DO or PO construction (The student handed _______). The materials are presented in Appendix A. The experiment also used 60 filler stems that could not be easily completed as a DO or PO construction. Thirty-six of the filler stems appeared in the Bias phase, and the remainder appeared in the Priming phase.

Two videos were used for the backgrounds in the experiment. Both were taken from a high definition nature show on the Discovery Channel. The first video is a footage from the Yosemite National Park, and contains 11 scene changes. The second video is a footage from a sea cave in Maine and contains 9 scene changes. These videos were chosen because they are quite distinct from one another, and thus can create separate video contexts.

Procedure

The experiment had a 2 (Bias condition: DO bias vs. PO bias)×2 (Physical reinstatement: lab setting reinstated for Priming phase vs. change in location)×2 (Video reinstatement: video context reinstated for Priming phase vs. change in video) between-participants design. Participants were randomly assigned to one of the cells in this design, with the constraint that an equal number of participants appear in each cell. The presentation order of the videos (sea cave, and Yosemite) was counterbalanced such that half of the participants saw the sea cave during the Bias phase, and half saw Yosemite. Half of the participants saw the same video again during the Priming phase, and half saw a new video.

All participants completed the Bias phase of the experiment alone in a room in our laboratory. This was the initial physical context. Participants were instructed to watch the scenery on the computer screen. They were also told that they would see a series of sentence stems appear on the screen. Participants were instructed to complete each stem so that it made a grammatical sentence. Each stem was presented for 9 s, so that participants could type in their responses without feeling rushed. All items in the Bias and Priming phases were put into a random order, and each participant saw the items in the same random order. Participants in the DO bias condition completed 12 DO-inducing prime stems, and participants in the PO bias condition completed 12 PO-inducing prime stems. Throughout both the Bias and Priming phases, 3 or 4 filler items separated each critical prime or target stem.

After completing the Bias phase, all participants in Experiment 1 had a 10 min delay before the Priming phase. During this delay, participants were escorted on a walk around campus. Following McKone and French (2001), we told participants that the goal of the study was to investigate the effects of non-strenuous exercise on task performance. After the walk, half of the participants returned to the lab setting and half were led to a classroom building across campus from the lab. The participants then completed the Priming phase of the study. They received 6 target stems during this phase of the study. These were separated by 3 or 4 filler stems.

The procedure of Experiment 2 was identical to that of Experiment 1, except that at the end of the Bias phase participants were asked to return a week later. Half of the participants were asked to return to the lab, and the other half were given a location across campus at which to meet the experimenter.

Scoring

The scoring for written stem completions was as follows. For prime stems (e.g., Karen gave Susan…), completions were scored as a DO if the completion was a noun phrase incorporating the patient of the verb. Completions were scored as a PO if they began with a prepositional phrase using the word “to” that incorporated the beneficiary of the verb. For target stems (e.g., The captain sent…), completions were scored as a DO if they contained two noun phrases, the first denoting the beneficiary of the verb, and the second denoting the patient of the verb. Completions were scored as a PO if they consisted of a noun phrase denoting the patient of the verb and a prepositional phrase using the word “to” that denoted the beneficiary of the verb. All other completions, including completions containing a verb particle (Susan gave the toy back to Karen) and completions that were non-reversible (e.g., a PO completion that would not produce a grammatical DO completion: The girl gave it to her mom), were scored as "other."

Analysis

The responses from the Bias phase were examined to ensure that each participant reflected the intended bias toward the DO or PO construction. The proportion of the target construction (DO for the DO bias condition, PO for the PO bias condition) produced by participants was calculated by dividing the proportion of DO or PO responses by the total number of responses on which a DO or PO construction was used. This calculation ignored trials where participants produced an "other" response.

The trials from the Priming phase were analyzed as follows. We first excluded trials on which an "other" response was made (Experiment 1: 15% in the DO bias condition, 13% in the PO bias condition; Experiment 2: 15% in DO bias condition, 13% in PO bias condition). Choice of DO or PO construction was the binary dependent measure for our experiments (DO coded as 1, PO coded as 0). Mixed logit analysis was conducted to predict the log odds of producing a DO target completion. The data from Experiments 1 and 2 were analyzed separately. Models included participants and items as crossed random factors. Intercepts could vary across participants and items. We began by running a model including Bias condition (DO bias=1, PO bias=0), Physical reinstatement (Context reinstated=1, Context changed=0), Virtual reinstatement (Context reinstated=1, Context changed=0), and the interactions of these factors. We included all variables in the model (rather than taking a model comparison approach to fitting the best model) because all factors were of theoretical interest. Subsequent to this, we ran another model that included the full complement of random slopes across participants and items. The inclusion of these random slopes did not improve model fit, and they are not reported in the results below. Because the interactions between our predictors did not improve model fit, we excluded these factors from the final analysis. The final model thus included Bias condition, Physical reinstatement, and Virtual reinstatement. All variables were centered before being entered into the analysis. Analysis was done with the HLM statistical package (Raudenbush, Bryk, Cheong, & Congdon, 2004). Because they are of little theoretical interest, we present the estimates for the random effects in the mixed logit models in Appendix B.

RESULTS AND DISCUSSION

Experiment 1

Mixed logit results are presented in Table 1. We observed a cumulative priming effect, as evidenced by the effect of Bias condition (pb.001). As seen in many previous studies (e.g., Kaschak, 2007), participants in the DO bias condition were more likely to produce a DO target completion than were participants in the PO bias condition. The effects of Physical reinstatement and Virtual reinstatement were not significant (p's>.21). Thus, it appears that the cumulative priming effect was not affected by the manipulation of extrinsic context factors.

Experiment 2

Mixed logit results are presented in Table 2. As in Experiment 1, there was a strong effect of Bias condition (pb.001). This replicates the findings of Kaschak et al. (2011b), showing that cumulative priming effects can persist for a week. The effects of Physical reinstatement and Virtual reinstatement were not significant (p's>.95).

Combined analysis

Because the critical results of Experiments 1 and 2 were null effects of Physical and Virtual reinstatement, we decided to perform one further analysis combining the results of both studies (see Table 3). We included Bias condition, Physical reinstatement, Virtual reinstatement, and Delay (10 min vs. 1 week) as predictors in the analysis. Even with the increased power produced by pooling all 160 participants into a single analysis, only Bias condition was a significant predictor of the log odds of producing a DO target completion (pb.001). None of the other effects were significant (p's>.32).

As a final point of interest, it is worth noting that the cumulative priming effects observed when the physical and virtual context are both reinstated is numerically weaker than in all of the other reinstatement conditions. We do not wish to over-interpret this pattern due to the fact that the trend is not statistically reliable (note the absence of effects for Physical and Virtual reinstatement, and the lack of interactions with these factors). Nevertheless, it is worth pointing out that this pattern is the opposite of what one would expect if there was even a weak effect of extrinsic context in these studies. Overall, then, our data suggest that extrinsic context factors do not have a large influence on cumulative structural priming effects.

GENERAL DISCUSSION

We undertook this study to explore the memory mechanisms that play a role in shaping cumulative structural priming effects. Whereas many extant findings point to a role for implicit learning in producing cumulative priming effects (e.g., Ferreira et al., 2008; Kaschak et al., 2011b; Kaschak et al., 2011a), other authors have raised the possibility that explicit memory processes might play a role in structural priming above and beyond the contributions of implicit learning and memory (e.g., Hartsuiker et al., 2008; Kaschak & Borreggine, 2008; Kaschak et al., 2012). McKone and French (2001; Mulligan, 2011) demonstrated that explicit memory effects are affected by manipulations of factors extrinsic to the completion of the experimental task at hand, but implicit memory effects are only affected by manipulations that are intrinsic to the experimental task. Kaschak et al. (2012) demonstrated that intrinsic factors play a role in the long-term persistence of cumulative priming effects. The question of interest is whether extrinsic factors would also affect cumulative priming.

The results of our study are clear. Manipulations of physical and virtual contexts did not strongly affect the cumulative structural priming effects observed in these experiments. This was true in Experiment 1, where a period of 10 min separated the Bias and Priming phases. It was also true in Experiment 2, where the Bias and Priming phases were separated by 1 week. These data support the contention that explicit memory processes do not play a major role in the long-term persistence of cumulative structural priming effects. These data also support the claim that structural priming is the result of implicit or procedural learning within the language production system (e.g., Chang et al., 2006; Ferreira et al., 2008; Jaeger & Snider, under review; Kaschak et al., 2011a). Implicit learning can be long lasting (e.g., Allen & Reber, 1980; Kolers, 1976), and the results of Kaschak et al. (2011b), Kaschak et al. (2012), and the current Experiment 2 demonstrate that structural priming is also long lasting. Similarly, just as implicit learning performance can be sensitive to the match between the conditions of learning and later tests of the learning (e.g., Kolers, 1976), Kaschak et al. (2012) show that the long-term persistence of structural priming is also task sensitive.

Whereas the present results argue that explicit memory processes play little role in long-term structural priming, these results should not be taken as conclusive evidence that explicit memory processes play no role in structural priming. Hartsuiker et al. (2008) suggest that a combination of implicit and explicit memory processes may be necessary to capture both the general structural priming effect that can be observed, and the lexical boost that occurs when lexical items are repeated across prime and target utterances. Chang et al. (2006) make a similar argument. Reitter, Keller, and Moore (2011) have also advanced the claim that explicit memory processes are necessary to model the full range of structural priming effects. Closer to the present results, Kaschak and Borreggine (2008) suggest that there are circumstances under which cumulative priming effects may be affected by explicit memory processes (e.g., if the priming effects are induced using verbs or sentences that are unusual or unfamiliar to the participant). Although the work cited in this paragraph leaves open the possibility that explicit memory processes play a role in structural priming, it is important to note that these studies generally do not directly manipulate or test factors known to affect explicit memory retrieval. That is, the role of explicit memory in structural priming has been discussed more frequently than it has been directly assessed.

We propose that explicit memory processes may play a role in structural priming, but it is unlikely to be a broad, general role. It is more likely that explicit memory processes will affect structural priming under very specific circumstances, such as when the sentence that is being produced reminds you of a specific utterance that you produced some time in the past. Hintzman (2011) notes that such “involuntary remindings” of past experiences are a pervasive element of our experience. Likewise, it is our intuition that such explicit reminders or cues occur when we are producing language. Whether (and how) these reminders play a role in shaping one's choice of syntactic structure remains to be seen.

It might be argued that our specific manipulations of extrinsic context (e.g., change in physical location) were less than optimal in looking for the role of explicit memory in structural priming due to the fact that the effects of such contextual factors are somewhat removed from the scope of extant theoretical accounts of these phenomena (e.g., Chang et al., 2006; Reitter et al., 2011), and somewhat removed from the scope of what is typically thought to be important in considering the language production process. Although manipulations of extrinsic context of the sort we used here fall outside the scope of models of language production, they are nevertheless well-replicated methods of affecting explicit memory performance. As such, they afforded us with a useful tool for beginning the task of assessing the role of explicit memory in structural priming. Examinations of the extent to which learning and memory performance transfers across tasks and manipulations of context have proven to be extremely useful for developing theoretical accounts of memory processes and the role that such processes play both in the execution of different tasks and in the transfer of learning across tasks (e.g., Crowder, 1993; Kolers & Roediger, 1984; Mulligan, 2011). It is our sense that such manipulations can play a similar role in the study of language processing.

As a final comment, we remain open to the possibility that extrinsic factors that are more related to the language production act, such as the identity of the speaker with whom you are interacting, may affect one's structural choices and therefore provide a vehicle for observing an influence of explicit memory on structural priming (e.g., Branigan, Pickering, McLean, & Cleland, 2007; Branigan, Pickering, Pearson, McLean, & Brown, 2011; Coyle & Kaschak, 2012). This is an intriguing possibility, and one that we believe is well worth exploring. A caveat to using speaker identity and other related extrinsic context manipulations for this purpose, however, is that it may turn out that the identity of one's conversational partner affects different layers of the production process (e.g., one's communicative goals, and how these shape subsequent language production choices), and is in fact more intrinsic to the production act than might be presumed.

We examined whether the manipulation of extrinsic memory factors would affect the shape of cumulative structural priming effects that persist over short and long delay periods. Our results suggest that these factors do not strongly affect cumulative priming. These findings also strengthen the argument that cumulative priming effects reflect implicit learning within the language production system, and that explicit memory factors play a limited role in the persistence of structural priming.

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Appendix A

Prime and target stems used in Experiments 1 and 2.

Prime stems (DO eliciting version presented first)

1. The captain handed the old sailor/The captain handed the travel log.
2. The millionaire loaned the struggling artist/The millionaire loaned the valuable painting.
3. The builder sent his new client/The builder sent the blueprints.
4. The mother gave the hungry toddler/The mother gave the expensive toy.
5. The woman sent the couple/The woman sent the claim.
6. The lecturer loaned the student/The lecturer loaned the book.
7. The grandmother handed the little girl/The grandmother handed the big present.
8. The secretary gave the manager/The secretary gave the invoice.
9. The eager boyfriend sent his girlfriend/The eager boyfriend sent the box of flowers.
10. The swimmer handed the diver/The swimmer handed the towel.
11. The travel agent loaned the young fan/The travel agent loaned the last ticket.
12. The happy child gave her father/The happy child gave the coloring book.

Target stems

1. The student handed
2. The businessman sent
3. The owner gave
4. The janitor gave
5. The worker loaned
6. The fireman handed

Appendix B

The estimates for the random effects of participants and items are presented below.

The random effects of participants and items were highly significant in all analyses. This indicates that there was significant variability in the rates of DO production across participants and items. That there should be significant variability in the rates of DO production associated with particular items is not surprising, as different verbs have different degrees of bias toward the DO or PO construction, and these biases are reflected in the overall rates of DO production for stems involving that verb (see, for example, Kaschak, 2007, Experiment 2). Variability in rates of DO production across participants has also been observed in other studies (see, for example, Appendix B of Kaschak et al., 2011b). Participant-based variability in base rates of DO production has not been explored in much detail in the literature, but the results of Kaschak et al. (2011a) suggest that individual differences in implicit learning may be related to these differences. As noted in the earlier Analysis section of the paper, random slopes across items did not significantly improve the fit of our mixed logit models. This suggests that the effects observed in these experiments were stable across individual items.

	Std. dev.	Variance component	*df*	χ^2	*p*-value
Experiment 1					
Participants	1.51	2.27	76	183.44	<.001
Items	.80	.64	2	31.18	<.001
Experiment 2					
Participants	1.06	1.13	76	142.96	<.001
Items	1.13	1.28	2	57.60	<.001
Combined analysis					
Participants	1.34	1.79	156	334.27	<.001
Items	1.02	1.04	2	83.56	<.001

Table 1

Mixed logit results for Experiment 1.

Mixed logit model						
Predictor	**Coefficient**	**SE**	**t-value**	**df**	***p*-value**	**Odds ratio**
Intercept	0.171	0.399	0.43	346	0.667	1.19
Bias condition	2.33	0.46	5.09	346	<.001	10.32
Physical condition	−0.564	0.46	−1.24	346	0.217	0.57
Virtual condition	0.504	0.46	1.10	346	0.271	1.65

Raw and estimated proportions of DO completions for Experiment 1.

		Raw means		
Physical	Virtual	DO bias	PO bias	Difference between DO bias – PO bias
Diff	Diff	.885	.330	.55
Diff	Same	.808	.330	.478
Same	Diff	.625	.267	.358
Same	Same	.690	.392	.298

		Estimated means		
Physical	Virtual	DO bias	PO bias	Difference between DO bias – PO bias
Diff	Diff	.797	.276	.521
Diff	Same	.867	.387	.48
Same	Diff	.691	.178	.513
Same	Same	.787	.263	.524

Table 2

Mixed logit results for Experiment 2.

Mixed logit model

Predictor	**Coefficient**	**SE**	**t-value**	**df**	***p*-value**	**Odds ratio**
Intercept	0.377	0.50	0.76	346	0.450	1.46
Bias condition	1.48	0.36	4.06	346	<.001	4.38
Physical condition	−0.0089	0.36	−0.025	346	0.980	.991
Virtual condition	0.029	0.36	0.083	346	0.934	1.03

Raw and estimated proportions of DO completions for Experiment 2.

		Raw means		
Physical	Virtual	DO bias	PO bias	Difference between DO bias – PO bias
Diff	Diff	.745	.453	.292
Diff	Same	.757	.427	.33
Same	Diff	.760	.400	.36
Same	Same	.663	.583	.08

		Estimated means		
Physical	Virtual	DO bias	PO bias	Difference between DO bias – PO bias
Diff	Diff	.751	.408	.343
Diff	Same	.757	.415	.342
Same	Diff	.760	.406	.344
Same	Same	.755	.413	.342

Table 3

Combined analysis of Experiments 1 and 2.

Mixed logit model

Predictor	**Coefficient**	**SE**	**t-value**	**df**	***p*-value**	**Odds ratio**
Intercept	0.279	0.44	0.631	695	0.528	1.32
Bias condition	1.89	0.30	6.39	695	<.001	6.65
Physical condition	−0.268	0.29	−0.915	695	0.361	.765
Virtual condition	0.291	0.29	0.993	695	0.322	1.34

Raw and estimated proportions for the combined analysis of DO completions in Experiments 1 and 2.

		Raw means		
Physical	Virtual	DO bias	PO bias	Difference between DO bias – PO bias
Diff	Diff	.815	.392	.423
Diff	Same	.783	.379	.404
Same	Diff	.693	.334	.359
Same	Same	.677	.488	.189

		Estimated means		
Physical	Virtual	DO bias	PO bias	Difference between DO bias – PO bias
Diff	Diff	.771	.336	.435
Diff	Same	.818	.404	.414
Same	Diff	.720	.279	.441
Same	Same	.775	.341	.434