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Is long-term structural priming affected by patterns of experience with individual verbs?

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Abstract

Several recent papers have reported long-term structural priming effects in experiments where previous patterns of experience with the double object and prepositional object constructions are shown to affect later patterns of language production for those constructions. The experiments reported in this paper address the extent to which these long-term priming effects are modulated by the participants' patterns of experience with particular verbs within the double object and prepositional object constructions. The results of three experiments show that patterns of experience with particular verbs using the double object or prepositional object constructions do not have much effect on the shape of the longterm structural priming effects reported elsewhere in the literature. These findings lend support to the claim that structural priming is the result of adaptations to the language production system that occur on an abstract, structural level of representation that is separate from representations regarding the behavior of particular lexical items in particular constructions [e.g., Chang, F., Dell, G. S., & Bock, K. (2006). Becoming syntactic. Psychological Review, 113, 234–272].

Keywords

Language production; Structural priming; Lexical effects

Structural priming refers to the tendency for speakers (or writers) to repeat syntactic structures across utterances (Bock, 1986). As one particularly well-studied example of this phenomenon, language producers who have recently produced (or comprehended) a double object construction ("Meghan gave her mom a kiss") are more likely to produce another double object construction to describe a transfer event ("Mike sent his boss a postcard") than to produce a prepositional object construction to describe the same event ("Mike sent a postcard to his boss"; see Bock, 1986; Bock & Griffin, 2000; Pickering & Branigan, 1998). Structural priming has been observed with a range of syntactic constructions (e.g., Corley & Scheepers, 2002; Griffin & Weinstein-Tull, 2003; Hartsuiker & Kolk, 1998; Hartsuiker & Westenberg, 2000), and has been observed both in lab tasks (e.g., Bock, 1986; Pickering & Branigan, 1998) and in samples of naturally occurring speech (e.g., Gries, 2005; Weiner & Labov, 1983). Although the repetition of lexical items (e.g., verbs) across utterances has been shown to affect the strength of the priming effects that are observed (e.g., Cleland &

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Pickering, 2003; Pickering & Branigan, 1998), the hallmark of structural priming effects is that they arise in the absence of such lexical repetition (Bock, 1986, 1989).

Structural priming is of interest to psycholinguists (and other cognitive scientists) for several reasons. First, the presence (or absence) of structural priming between different kinds of sentences provides insight into the nature of the representations that underlie language production (Branigan, Pickering, Liversedge, Stewart, & Urbach, 1995). Consider the following (non-exhaustive) set of issues that have been explored with structural priming experiments. Cleland and Pickering (2006) used a structural priming paradigm to demonstrate that written and spoken language production trade on the same underlying representations. Branigan, Pickering, McLean, and Stewart (2006) report a series of structural priming experiments suggesting that the language production system uses the same procedures to generate syntactic structures in different syntactic contexts (e.g., when the structure in question is produced as a main clause or as part of a subordinate clause). Bock et al. (in press) have demonstrated that the structural priming that occurs between language comprehension and language production follows essentially the same pattern as the structural priming that arises between two sentences that have been produced by the same individual (see Branigan, Pickering, & Cleland, 2000, for another demonstration of priming from comprehension to production). This finding suggests that language comprehension and language production involve the use of the same linguistic representations. Hartsuiker, Pickering, and Veltkamp (2004) used a structural priming study to show that the structural knowledge of Spanish and English found in Spanish–English bilinguals involves the use of shared (rather than separate) representational features across languages. Finally, and most germane to the focus of this paper, structural priming effects have been used to explore the interaction between lexical and syntactic knowledge during language production (e.g., Pickering & Branigan, 1998; Konopka & Bock, 2005).

Whereas most studies of structural priming have explored language production in adults, a number of researchers have employed priming paradigms in order to explore the development of syntactic knowledge in young children (e.g., Huttenlocher, Vasilyeva, & Shimpi, 2004; Savage, Lieven, Theakston, & Tomasello, 2003). Generally speaking, syntactic development in children progresses from a stage in which constructions are largely item-based (e.g., frames such as, “give X”) to an endpoint where knowledge of those constructions is abstracted away from the use of particular lexical items (see Tomasello, 2003, for a detailed review). The extent to which children show structural priming for a given construction (i.e., increased likelihood of using a construction after hearing or producing another token of the same construction) that is independent of any lexical priming is an indicator of the extent to which children have an abstract representation of that construction (see Tomasello, 2006, for a discussion). Beyond providing a tool through which to measure syntactic development, the mechanisms that give rise to structural priming may also be responsible for driving syntactic development itself (for a discussion of this point, see Bock & Griffin, 2000, among others). Similarly, Kaschak (2006; Kaschak & Glenberg, 2004) has argued that structural priming may underlie adults’ ability to adapt to a new construction in their native language, suggesting that the mechanisms that produce structural priming may function to promote learning and adaptation in the language processing system throughout the lifespan (cf., Bock & Griffin, 2000).

Even more broadly, studies of structural priming may be of import to research in other domains of linguistic study, such as the study of linguistic change (e.g., Bock & Kroch, 1989; Labov, 1994, 2001). Many syntactic changes involve shifts in the likelihood of using a particular structure: structure X becomes more common, driving structure Y into disuse. As the mechanisms that give rise to structural priming affect the choice of one syntactic structure over another, it may be the case that structural priming plays a role in pushing along the process of linguistic change. Several authors have raised this possibility (e.g., Bock & Kroch, 1989; Labov, 1994), and this may be an interesting direction in which research on structural priming can move.

Two theories of structural priming have been advanced. Chang, Dell, and Bock (2006) present an error-based learning account of structural priming. This account has been instantiated in a connectionist model that produces priming effects by leaving the learning mechanism of the model "on" throughout the sentence production task. Producing a token of one construction (double object) tunes the model weights such that the model will be more disposed to produce the same construction (double object) on a subsequent sentence than to produce an alternative construction (prepositional object) on a subsequent sentence. The structure of the Chang et al. (2006) model is such that its learning about particular constructions (double object or prepositional object) is kept separate from its knowledge about particular verbs that appear in those constructions (e.g., give or send). Thus, the model predicts that structural priming arises through changes to an abstract, structural representation of linguistic knowledge that should not be affected by patterns of experience with individual lexical items.

Pickering and Branigan (1998) present an alternative account of structural priming. This account is based on a model of lexical knowledge in which nodes representing particular lexical items (e.g., verbs) are linked to nodes representing rules governing the combination of words (e.g., the "noun phrase + noun phrase" rule licenses the production of the double object construction). When a verb is used in a particular syntactic structure, the link between the node that represents the verb ("give") and the node that represents the combinatorial rules governing that construction ("noun phrase + noun phrase") is activated, as is the node representing the combinatorial rule. The activation of both the link between the verb and the combinatorial rule and the node representing the combinatorial rule itself remains above baseline for several seconds, and this residual activation produces structural priming effects. Priming effects will be stronger when verbs are repeated across utterances, as in this case both the link between the verb and the combinatorial rule and the combinatorial rule node itself exhibit residual activation. When verbs are not repeated across utterances, the priming effect arises from the residual activation in the combinatorial rule node alone, and the comparatively lower level of residual activation produces a weaker tendency towards structural priming. Because syntactic priming is driven by the connection between particular lexical items (verbs) and particular syntactic rules, Pickering and Branigan's (1998) account suggests that the nature of structural priming effects should be affected by lexical factors (e.g., whether or not a verb [or, other word] is repeated between utterances; Cleland & Pickering, 2003; Pickering & Branigan, 1998).

A major distinction between the Chang et al. (2006) and Pickering and Branigan (1998) accounts is the role that lexical information plays in driving structural priming. At present, this issue is far from settled. Early studies of structural priming (Bock, 1986, 1989) demonstrated that such priming occurred in the absence of the repetition of lexical items across utterances, but more recent work (e.g., Cleland & Pickering, 2006; Pickering & Branigan, 1998) has shown that the repetition of verbs across utterances increases the amount of structural priming that is observed. Most studies in which this issue has been addressed have focused on the impact of a single preceding sentence (the "prime" sentence) on the production of a single subsequent sentence (the "target" sentence). As such, the data at hand do not do much to distinguish between Chang et al.'s (2006) account and Pickering and Branigan's (1998) account. Pickering and Branigan's model provides a clear rationale for why the repetition of lexical items should increase the strength of structural priming effects, but can also explain structural priming in the absence of repeated lexical items. For their part, Chang et al. (2006) have proposed that whereas the "basic" structural priming effect driven by a mechanism of implicit learning within the language production system that is not affected by lexical factors, it is possible for the repetition of lexical items to affect structural priming through other mechanisms. For example, the repetition of verbs between prime and target sentences increases the odds that the prime will be explicitly retrieved from memory when producing the target, leading to an increase in the tendency to repeat the structure of the prime sentence when producing the target sentence.

Although both theories can provide an explanation for the role of lexical information in the priming that arises between individual prime and target sentences, these theories make different predictions regarding the role of lexical information in long-term structural priming of the sort that has been studied by Kaschak and colleagues (Kaschak et al., 2006; Kaschak, in press). In a series of experiments, Kaschak and colleagues explored how a larger range of experience (ranging from 10 to 20 sentences) affects the production of individual target sentences. In the first part of these experiments, participants were induced to produce a certain proportion of double object and prepositional object constructions (with proportions ranging from 100/0 in favor of the double object to 100/0 in favor of the prepositional object). In the second part of the experiments, participants were given the freedom to produce either double object or prepositional object constructions. These studies demonstrate that the relative frequency with which the double object and prepositional object constructions are produced in the first phase of the experiment has a strong effect on the rate at which those constructions are produced in the second phase of the experiment. That is, there is a long-term structural priming effect that accumulates over many productions of the double object and prepositional object constructions (cf., Bock & Kroch, 1989; Hartsuiker & Kolk, 1998; Hartsuiker & Westenberg, 2000).

One question that can be asked within Kaschak and colleagues' paradigm is whether the long-term structural priming effects that they observe will be affected by structural factors alone (e.g., the relative frequency of double object and prepositional object constructions in the experiment), or if they will be affected by lexical factors (e.g., the frequency with which particular verbs are used in the double object and prepositional object constructions in the experiment). Because Chang et al.'s (2006) model separates learning about particular syntactic constructions from its learning about individual verbs, it predicts that the long-term

priming effects reported by Kaschak, Loney, and Borreggine (2006) should be unaffected by patterns of experience with particular lexical items in the experiment. On the other hand, because Pickering and Branigan's (1998) model uses the relationship between particular words and particular syntactic rules as its basis for producing structural priming effects, this model predicts that long-term priming effects should be affected by patterns of experience with particular lexical items in the experiment. This prediction follows straightforwardly from the structure of their theory, although there is an important caveat to consider. To date, Pickering and Branigan's (1998) account has not been extended to explain long-term priming effects (but see Pickering, Branigan, Cleland, & Stewart, 2000, for a discussion of this issue), and so it is possible (but perhaps unlikely) that an extension of this theory could be structured to minimize the role of lexical information in long-term priming.

EXPERIMENT 1

Experiment 1 had the same basic structure as the experiments presented in Kaschak et al. (2006). Participants engaged in the stem completion task developed by Pickering and Branigan (1998). In the first phase of the experiment (Bias phase), participants were asked to complete prime stems such as:

(1) **A.** Meghan gave her mom… (double object prime)

B. Meghan gave a kiss… (prepositional object prime)

Stems such as (1A) were designed to elicit double object constructions, and stems such as (1B) were designed to elicit prepositional object constructions. Kaschak et al. (2006) demonstrated that the use of stems such as these provides an effective means of controlling the proportion of double object and prepositional object constructions that participants produce in the Bias phase of the experiment. Participants in the Bias phase of the experiment produced either an equal split of double object and prepositional object constructions, all double object constructions, or all prepositional object constructions. In the second phase of the experiment (Priming phase), participants completed a series of prime–target pairs. The prime stem in each pair elicited either a double object or prepositional object construction (as in 1A or 1B). The target stem in each pair (e.g., "The teacher gave…") allowed participants to produce either a double object or prepositional object construction. The experiment featured four combinations of Bias phases and priming trials: (1) 50/50 split between the double object and prepositional object constructions in the Bias phase, double object priming trials, (2) 50/50 split in the Bias phase, prepositional object priming trials, (3) 100/0 split in favor of the double object in the Bias phase, prepositional object priming trials, and (4) 100/0 split in favor of the prepositional object in the Bias phase, double object priming trials. Conditions (1) and (2) are called the "Equal Exposure" conditions, and Conditions (3) and (4) are called the "Unequal Exposure" conditions. Replicating Kaschak et al. (2006), it is expected that structural priming (in the Priming phase of the experiment) will be strong in the Equal Exposure conditions, and will be weak (or absent) in the Unequal Exposure conditions.

In addition to the aforementioned variables, we also manipulated the relationship between the verbs in the Bias phase and the Priming phase. Half of the participants saw the same

verbs in the Bias phase and the Priming phase, and the other half saw one set of verbs in the Bias phase, and a different set of verbs in the Priming phase. If the long-term priming effects observed by Kaschak et al. (2006) are affected by patterns of experience with particular verbs in the double object and prepositional object constructions during the experiment, it is expected that the effects of Bias condition on performance in the Priming phase will be stronger when the same verbs are used throughout the experiment than when the verbs change between the Bias and Priming phases. This is because the patterns of experience established in the Bias phase will be localized to the connection between particular lexical items and particular constructions, and the connection between other lexical items and those same constructions will be relatively unaffected (or, less affected). On the other hand, if the long-term priming effects observed by Kaschak et al. (2006) are structural in nature, the effects of Bias condition on performance in the Priming phase will be unaffected by whether the verbs used in the Bias and Priming phases change or remain the same.

Participants

The participants were 96 introductory psychology students from Florida State University. They received course credit in exchange for their participation. As in Kaschak et al. (2006), participants were excluded from the analysis if their rates of production for double object and prepositional object constructions did not fall within an acceptable range for their Bias condition. In the Equal Exposure conditions, participants who were skewed more than 80/20 in favor of one construction were excluded from the analysis. For the Unequal Exposure conditions, participants who did not have at least an 80/20 skew in favor of the dominant construction were excluded. No participants were excluded from Experiment 1 on this basis.

Materials

The materials from Kaschak et al. (2006) were adapted for use in this study. For the Bias phase of the experiment, the twenty pairs of prime stems (one member of each pair eliciting double object completions, and the other eliciting prepositional object completions) from Kaschak et al., were turned into two sets of stems. For Set 1, 10 of the stem pairs used the verb give, and 10 of the stem pairs used the verb offer. For Set 2, 10 of the stem pairs used the verb send, and 10 of the stem pairs used the verb hand. Parallel sets of prime–target stems were created for the Priming phase of the experiment. For Set 1, 3 of the prime–target pairs used the verb give and three used the verb offer. For Set 2, 3 of the prime–target pairs used the verb send and three used the verb hand. All prime and target stems are presented in Appendix A. The experiment also used 130 filler stems that were designed to elicit a mix of transitive and intransitive constructions. None of the filler stems contained verbs that could be completed with a double object or prepositional object construction.

Procedure

Participants were randomly assigned to one of the four combinations of Bias and Prime conditions (Equal Exposure, double object prime; Equal Exposure, prepositional object prime; Unequal Exposure [double object], prepositional object prime; Unequal Exposure [prepositional object], double object prime). Half of the participants in each condition were assigned to receive the same verbs in the Bias phase and the Priming phase (Same Verb condition), and the other half received different verbs in the Bias and Priming phases

(Different Verb condition). Half of the participants in the Same Verb condition completed stems from Set 1 (using the verbs give and offer) and the other half completed stems from Set 2 (using the verbs send and hand). Half of the participants in the Different verb condition completed stems from Set 1 (give/offer) in the Bias phase and completed Set 2 stems (send/hand) in the Priming phase, and the other half saw the verb sets in the opposite order.

The critical stems were presented within the following constraints. In the Bias phase of the Equal Exposure conditions, prime stems alternated between the double object and prepositional object constructions. The alternation was set up so that the last stem of the Bias phase would use the construction opposite the one that was featured in the Priming phase (e.g., if the Priming phase had double object priming trials, the last stem in the Bias phase would elicit a prepositional object construction). Each verb appeared approximately 50% of the time in the double object construction and 50% of the time in the prepositional object construction. In the Bias phase of the Unequal Exposure conditions, participants completed stems that elicited only one construction (either the double object or prepositional object). In the Priming phase, participants completed priming trials for one construction (either the double object or prepositional object). Throughout the experiment, either 4 or 5 filler stems separated each critical prime stem (Bias phase) or critical prime–target pair (Priming phase). Within the preceding constraints, the order of critical stems and fillers was randomized for each participant.

The participants were told that they were going to see a series of sentence stems, and that they should complete each one so that they produced a grammatical English sentence. The sentence stem was presented near the top of the computer screen, and the text box in which the participants entered their completion was presented below the stem. Participants pressed the “return” button on the keyboard to enter their response. Participants could not go back to the previous trials.

Scoring

The stem completions were scored as follows. For prime stems, completions were scored as a double object if the completion was a noun phrase incorporating the patient of the verb. Completions were scored as a prepositional object if they began with a prepositional phrase using the word “to” that incorporated the beneficiary of the verb. For the target stems, completions were scored as a double object if they consisted of 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 prepositional object if they consisted of a noun phrase and a prepositional phrase using the word “to,” where the noun phrase denotes patient of the verb, and the prepositional phrase denotes the beneficiary of the verb. All other completions, including completions that contained a verb particle (e.g., “Meghan gave the toy back to her mom”) and completions that were non-reversible (e.g., a prepositional object completion that would not produce a grammatical double object completion: “The girl gave it to her mom”) were scored as “other.”

Design and analysis

The responses in the Bias phase were examined to ensure that each participant's performance fell within the target range of performance for that condition (as described earlier). The proportion of double object and prepositional object constructions produced by each participant was determined by dividing the number of responses of each type by the total number of double object and prepositional object responses produced in the Bias phase. This computation ignored trials on which participants produced "other" responses.

The target responses from the Priming phase of the experiment were analyzed as follows. For the critical target stems, the proportion of double object and prepositional object completions was computed by dividing the number of double object completions and the number of prepositional object completions by the total number of double object and prepositional object responses produced in the Priming phase. Although this method of calculating the proportions should produce complementary proportions of double object and prepositional object completions, in some conditions the proportions do not add to 1 because a small number of participants produced 0 double object or prepositional object completions.

The proportions of other, double object and prepositional object completions were analyzed by participants (analyses denoted F1) and items (analyses denoted F2). In keeping with Winer's (1971) recommendations for analyzing proportion data, we also analyzed the arcsine transformed proportion of other, double object, and prepositional object completions. These analyses produced results nearly identical to the analysis of the raw proportions, so we do not report them further in the paper. For the purposes of the analysis by items, we considered there to be 12 items (3 critical target stems for each of the 4 verbs in the experiment). The proportion of other, double object and prepositional object target completions were analyzed with a 2 (Training condition: Equal Exposure vs. Unequal Exposure) × 2 (Prime: Double Object vs. Prepositional Object) × 2 (Verb Condition: Same Verb vs. Different Verb) ANOVA. All factors were between participants and within items. Although the proportion of double object and prepositional object completions was not perfectly complementary (as noted above), the results of the analyses on the double object and prepositional object proportions produce essentially the same results. Consequently, only the results of the analysis of the proportion of double object target completions will be reported below. In the interest of completeness, the proportion of both double object and prepositional object completions will be presented in the figures.

In addition to the statistical tests described above, we provide partial omega squared (χ^2) values as an index of effect size (Keppel, 1991). These values are provided for effects that are statistically significant and non-significant effects of theoretical importance. The partial omega squared values were calculated based on the analyses conducted across participants. As per convention, partial omega squared values greater than .01 are considered small effects, values greater than .06 are considered medium effects, and values greater than .15 are considered large effects. We also present 95% confidence intervals surrounding the significant contrast effects (and non-significant results of theoretical significance) with the results of the statistical tests (per Masson & Loftus, 2003). Where we report the magnitude of certain effects below (e.g., the magnitude of main effect or interaction effects), we present the effects as absolute values (since the sign of the effect is arbitrary).

Results and discussion

The proportion of double object and prepositional object stem completions in the Bias phase of the experiment closely match the target proportions for each training condition (Equal Exposure: 54% double object completions, 46% prepositional object completions; Unequal Exposure: 99% of the completions were for the dominant structure (double object or prepositional object) in the Bias condition). The analysis of other responses produced in the Priming phase did not produce any significant effects [all F's < 4.01, $p > .07$]. The proportion of double object and prepositional object target stem completions produced in the Priming phase is presented in Fig. 1. Statistical analysis of the proportion of double object target completions revealed a main effect of Prime [$F1(1, 88) = 19.27$, $p < .001$; $F2(1, 11) = 24.35$, $p = .002$; $minF(1, 63) = 10.75$, $p = .002$; $\omega^2 = .16$]. Overall, participants who were given double object primes produced more double object target completions ($M = .59$) than participants who were given prepositional object primes ($M = .30$). The confidence interval for this difference of .29 is .14. There was also an interaction of Training and Prime [$F1(1, 88) = 11.89$, $p = .001$; $F2(1, 11) = 13.38$, $p = .006$; $minF(1, 52) = 6.30$, $p = .015$; $\omega^2 = .10$]. The magnitude of this interaction effect is .48, with a confidence interval of .28. Critically, the Verb Condition × Training × Prime interaction was not significant [$F1$, $F2$, and $minF < 1$; $\omega^2 < .001$]. The magnitude of this interaction effect is .046, with a confidence interval of .45. None of the other effects were significant (all p's > .20).

To follow up the significant Training · Prime interaction noted above, we split the three-factor design along the Training factor and examined the effects of Verb condition and Prime within the Equal exposure and Unequal exposure training conditions. We elected to do these analyses (rather than simply examining the effect of Prime type across Training conditions) in an effort to show that the Verb condition factor did not affect performance in either Training condition when considered alone. In the Equal exposure training condition, there was a main effect of Prime [$F1(1, 44) = 37.43$, $p < .001$; $F2(1, 11) = 31.30$, $p < .001$; $minF(1, 59) = 14.05$, $p < .001$; $\omega^2 = .43$], with participants producing more double object completions after double object primes ($M = .68$) than after prepositional object primes ($M = .14$). The confidence interval for this difference of .54 is .18. There was no effect of Verb condition [$F1$, $F2$, and $minF < 1$; $\omega^2 < .001$], and no Verb condition · Prime interaction [$F1(1, 44) = 1.02$, $p = .32$; $F2$ and $minF < 1$; $\omega^2 < .001$]. In the Unequal exposure training condition, there were no significant effects [all F's < 1.17, all ω^2 values < .009]. Thus, there was a robust structural priming effect in the Equal exposure condition, but not in the Unequal exposure condition (replicating Kaschak et al., 2006). There were no effects involving the Verb condition factor in either training condition.

The results of Experiment 1 suggest that whereas the relative frequency with which the double object and prepositional object constructions are presented in the Bias phase affects the magnitude of the structural priming effects that are observed later in the experiment, this pattern was relatively unaffected by whether the verbs in the Bias and Priming phases of the experiment were the same or not. This outcome is consistent with the claim that long-term structural priming effects should not be greatly affected by patterns of experience with particular verbs within the experiment (e.g., Chang et al., 2006).

As one final note about this experiment, an anonymous reviewer pointed out that the effect size reported for the main effect of Prime condition in the Equal exposure condition is quite large ($\omega^2 = .43$) relative to other priming effects reported in the literature. It is worth noting that priming effects of this magnitude have been reported elsewhere in the literature. As one example, for Cleland and Pickering's (2006) Experiment 1 analysis (presented in their Table 2), we computed a ω^2 value of .71. A similarly large χ^2 was found for the Prime effect in their combined analysis of Experiments 1 and 3. Overall, it appears that the written production paradigm produces somewhat larger effects than the effects found in experiments involving spoken language production. This may be a function of the fact that the similarities between the prime and target sentences are more explicit in stem completion tasks, and this increases the magnitude of the structural priming effects.

EXPERIMENT 2

Experiment 2 was designed to explicitly contrast the relative frequency with which the double object and prepositional object constructions were produced in the experiment with the relative frequency with which particular verbs appeared in the double object or prepositional object constructions in the experiment. In the Bias phase, all participants produced an equal number of double object and prepositional object constructions. The prime stems in this phase used two verbs (e.g., give and lend). In the Balanced training condition, participants produced an equal number of double object and prepositional object constructions for each verb. Thus, the overall split between the double object and prepositional object constructions was 50/50, and the split between the constructions for each verb was 50/50. In the Skewed training condition, participants produced only double object constructions for one verb (e.g., give) and only prepositional object constructions for the other verb (e.g., lend). Thus, the overall split between the double object and prepositional object constructions was 50/50, but the split between constructions for each verb was 100/0 in favor of either the double object or prepositional object. In the Priming phase of the experiment, participants completed six priming trials using one of the two verbs (e.g., give). We refer to this verb as the target verb for that training condition. As in Experiment 1, when the experience for one verb is skewed towards one construction (double object), the priming trials for that verb will use the alternate construction (prepositional object).

If long-term structural priming effects are sensitive to the relative frequency with which particular verbs appear in the double object and prepositional object constructions within the experiment, structural priming should be stronger in the Balanced training condition than in the Skewed training condition. In the Balanced condition, experience with the target verb is balanced between the double object and prepositional object constructions, and this pattern of experience should not affect the structural priming effects that are expected to occur (as in Kaschak et al., 2006, and Experiment 1). In the Skewed condition, experience with the target verb is biased towards one construction (double object), and this should attenuate the priming observed for the other construction (prepositional object) when that verb is used. On the other hand, if the long-term structural priming effects seen in these studies are the result of changes to the language production system on an abstract, structural level that is

independent of lexical representations, the strength of structural priming should be essentially the same in the Balanced and Skewed conditions.

Methods

Participants—The participants were 208 introductory psychology students from Florida State University (52 tested on each target verb). They received course credit in exchange for their participation. All participants met the performance criterion for the Bias phase of the experiment outlined in the Methods section of Experiment 1 (i.e., the overall proportion of double object and prepositional object completions could not be skewed stronger than 80/20 towards one construction). In addition, we required that participants' rate of production for the double object and prepositional object constructions for each verb fall within an acceptable range of performance. For the Balanced condition, participants' rate of production for the double object and prepositional object constructions could not be skewed stronger than 80/20 towards one construction for each individual verb. For the Skewed condition, participants' rate of production for the double object and prepositional object constructions could not be skewed less than 80/20 in favor of the intended construction for each individual verb. All participants met this additional set of performance requirements.

Materials

The materials from Experiment 1 were adapted for use in this study. Four sets of materials (including 20 prime stems for the Bias phase and 6 prime–target pairs for the Priming phase) were constructed. For Set 1, 10 prime stems used the verb give and 10 prime stems used the verb lend. The 6 prime–target pairs used the verb give. For Set 2, the same 20 prime stems from Set 1 were used, and the 6 prime–target pairs used the verb lend. For Set 3, 10 prime stems used the verb send, and 10 prime stems used the verb hand. The 6 prime–target pairs used the verb hand. For Set 4, 10 prime stems used the verb send and 10 prime stems used the verb hand. The 6 prime–target pairs used the verb send. The verb used for the prime trials was considered the target verb for each set. The 4 sets of items are shown in Appendix B. The filler items from Experiment 1 were used in this experiment.

Procedure

Participants were randomly assigned to one of four Bias/Prime conditions [Balanced training, double object prime; Balanced training, prepositional object prime; Skewed training, double object prime; Skewed training, prepositional object prime]. In addition, they were randomly assigned to receive one of the four sets of items described above. The assignment was done within the constraint that an equal number of participants in each Bias/Prime condition saw each of the 4 sets of items.

The critical sentence stems were presented as follows. In the Balanced training conditions, the stems alternated between verbs (e.g., give, lend, give…). The nature of the prime stem (double object or prepositional object) followed an ABBA pattern (e.g., double object-prepositional object-double object) to ensure that each verb appeared equally often in each construction. Trials were ordered so that the non-target verb in each set was presented on the last prime stem of the Bias phase. The prime stems also alternated between verbs in the Skewed training condition, but here each verb appeared with only one construction (double

object or prepositional object). For the Skewed training condition, the priming trials always used the opposite construction as that used for the target verb in the Bias phase. For example, if give was skewed towards the double object in the Bias phase, participants would see give in the prepositional object construction during the Priming phase. Throughout the experiment, either 4 or 5 filler stems separated each critical stem. Within the preceding constraints, the order of critical stems and fillers was randomized for each participant. The instructions and experimental task were the same as in Experiment 1.

Scoring

Prime and target stems were scored as in Experiment 1.

Design and analysis

The data were analyzed as in Experiment 1. The proportion of other, double object and prepositional object responses were analyzed with a 2 (Training: Balanced vs. Skewed) · 2 (Prime: double object vs. prepositional object) ANOVA. Both factors were between-participants and within-items. We considered there to be 24 items (6 target stems for each of the 4 verbs) for the items analysis.

Results and discussion

The data from the Bias phase of the experiment show that we were able to manipulate the relative frequency with which the target verb was produced in the double object and prepositional object constructions while keeping the overall proportion of double object and prepositional object constructions produced at around a 50/50 split. In the Balanced training condition, stems involving the target verb were completed as a double object 52% of the time, and were completed as a prepositional object 48% of the time. Overall in the Balanced training condition, participants produced 51% double object stem completions and 49% prepositional object stem completions. In the Skewed training condition, stems involving the target verb were completed as the intended construction (double object or prepositional object) 99% of the time, and were completed as the opposite construction 1% of the time. Overall in the Skewed training condition, participants produced 52% double object stem completions and 48% prepositional object stem completions. Analysis of the proportion of other responses produced in the Priming phase did not produce any significant effects [all F's < 1.92, $p > .17$].

The proportion of double object and prepositional object target stem completions produced in the Priming phase is presented in Fig. 2. Analysis of the proportion of double object target completions revealed a main effect of Prime [$F1(1, 204) = 18.39$, $p < .001$; $F2(1, 23) = 27.84$, $p < .001$; $minF(1, 149) = 11.07$, $p = .001$; $\omega^2 = .077$]. Participants who saw double object primes produced more double object completions ($M = .44$) than participants who saw prepositional object primes ($M = .24$). The confidence interval for this difference of .20 is .09. There was no effect of Training condition [$F1$, $F2$, and $minF < 1$; $\omega^2 < .001$] and no Prime · Training condition interaction [$F1(1, 204) = 1.87$, $p = .17$; $F2(1, 23) = 2.34$, $p = .14$; $minF(1, 116) = 1.03$, $p = .31$; $\omega^2 = .004$]. The magnitude of the Prime × Training interaction was .13, with a confidence interval of .19.

Although the Prime × Training interaction was not significant, the data do show that the structural priming effects in the Balanced condition (.27) are stronger than the priming effects in the Skewed condition (.14). A closer look at the data revealed that the trend towards weaker priming effects in the Skewed condition is almost entirely due to the participants' performance on the verb lend. As seen in Table 1, whereas priming effects are equally strong in the Balanced and Skewed conditions for the verbs give, hand, and send, the priming effects for lend are much stronger in the Balanced condition than in the Skewed condition. The Prime · Training interaction is significant for lend [$F1(1, 48) = 5.53$, $p = .023$; $F2(1, 5) = 11.26$, $p = .02$; $minF(1, 49) = 3.71$, $p = .06$; $\omega^2 = .08$], but not for any of the other verbs [all F's < 3.20, $p > .13$]. The magnitude of the Prime · Training interaction for lend is .42, with a confidence interval of .36.

Why might lend be acting differently than the other verbs in our experiment? It is unlikely that the anomalous result with lend is due to the fact lend is a low frequency verb (in both American and British English), as hand is similarly low in frequency (Francis & Kucera, 1982; Leech, Rayson, & Wilson, 2001). It is also unlikely that the data were caused by lend having an irregular past tense, as give and send also have irregular past tenses. Finally, it seemed unlikely to us that the semantics of lend would cause this verb to behave differently than the others. After checking with several native speakers of the same dialect of American English as most of our participants, we discovered that although lent (the form of lend used in this experiment) is comprehensible to speakers of this dialect, it is a dispreferred form; our informants reported that whereas they use lend in the present tense, they do not use lent for the past tense (where they prefer to use loaned). The comparative oddity of the form lent may have made the stems involving this verb stand out from the other stems in the experiment, making previous tokens of having completed a stem involving lent particularly memorable to the participants. As discussed by Chang et al. (2006), lexical effects on structural priming may be observed in cases such as this, where explicit retrieval of previous tokens of having produced a sentence with a given verb affects the production of the target sentences. We address this hypothesis in Experiment 3.

EXPERIMENT 3

Experiment 3 was designed both to generalize the effects of Experiment 2 to a new verb and to address the hypothesis that the reason why lend showed a strong lexically-based effect on long-term structural priming (whereas the other verbs in the Experiment 2 did not) is because the form of lend used in the experiment (lent) was somewhat odd to our participants. To do this, we replicated Experiment 2 using the verbs give and loan, with loan as the target verb in the experiment. We collected data using loan not only because this verb is similar in frequency and meaning to lend, but also because it is the past tense form of loan/lend that our participants use. As such, we expect that the form loaned would not stand out in the experiment, and would therefore show a pattern of data similar to give, hand, and send (i.e., no Prime × Training interaction). On the other hand, if there is something about the semantics of lend and loan (or, something else unique about these verbs relative to the other verbs in our experiment), we expect that loan will show a pattern of data similar to lend (i.e., a Prime × Training interaction).

Method

Participants—The participants were 52 introductory psychology students from Florida State University. They received course credit in exchange for their participation. Participants met the same performance criterion in the Bias phase of the experiment as participants in Experiment 2.

Materials

The experiment used the materials from Set 2 of Experiment 2, with the exception that the verb lent was replaced with the verb loaned. The items are presented in Appendix B.

Procedure

The procedure was identical to Experiment 2.

Scoring

The data were scored as in Experiment 2.

Design and analysis

The data were analyzed as in Experiment 2. The proportion of other, double object, and prepositional object target completions was analyzed using a 2 (Prime: double object vs. prepositional object) × 2 (Training: Balanced vs. Skewed) ANOVA with Prime and Training as between-participants factors. Both factors were within items.

Results and discussion

Performance in the Bias phase of the experiment was similar to that in Experiment 2. In the Balanced training condition, stems involving the target verb were completed as a double object 52% of the time, and were completed as a prepositional object 48% of the time. Overall in the Balanced training condition, participants produced 54% double object stem completions and 46% prepositional object stem completions. In the Skewed training condition, stems involving the target verb were completed as the intended construction (double object or prepositional object) 99% of the time, and were completed as the opposite construction 1% of the time. Overall in the Skewed training condition, participants produced 53% double object stem completions and 47% prepositional object stem completions. Analysis of the proportion of other responses produced in the Priming phase did not produce any significant effects [all F's < 1.02, $p > .30$].

The proportion of DO target completions for this experiment is presented at the bottom of Table 1 (as the verb loan). Statistical analysis revealed a main effect of Prime [$F1(1, 48) = 9.73$, $p = .003$; $F2(1, 5) = 57.29$, $p = .001$; $minF(1, 306) = 8.32$, $p = .004$; $\omega^2 = .17$], such that participants were more likely to produce a double object completion following a double object prime ($M = .49$) than following a prepositional object prime ($M = .19$). This difference of .30 has a confidence interval of .20. The main effect of training was significant by items [$F1(1, 48) = 3.09$, $p = .085$; $F2(1, 5) = 16.57$, $p = .01$; $minF(1, 208) = 2.60$, $p = .11$; $\omega^2 = .07$]. There was no a Prime × Training interaction [$F1 < 1$; $F2(1, 5) = 2.12$, $p = .21$;

minF < 1; ω^2 = .001]. The magnitude of the Prime · Training interaction was .05, with a confidence interval of .40.

The combined outcome of Experiments 2 and 3 supports the claim that patterns of experience with particular verbs in particular constructions do not exert a strong effect on long-term structural priming. Priming for a particular construction (double object) was equally strong whether the verb used on the priming trials had previously been encountered in both the double object and prepositional object constructions or had only been encountered in the opposite construction (prepositional object). When the overall relative frequency of the double object and prepositional object constructions in the experiment is put in conflict with the relative frequency of the double object and prepositional object constructions for particular verbs, the data show that the overall relative frequency of the constructions in the experiment affects the pattern of target completions, but the relative frequency of the constructions for particular verbs does not. These data provide support for Chang et al.'s (2006) contention that learning about patterns of usage for particular constructions is independent of learning about the behavior of particular lexical items in those constructions. The one case in which this larger pattern appears not to hold (i.e., the verb lend) is also consistent with Chang et al.'s (2006) analysis. Whereas structural priming effects reflect adaptations on a structural level of representation, Chang et al. (2006) note that lexical effects on structural priming may occur in cases where the prime sentences can be explicitly retrieved from memory. Previous studies have demonstrated this by presenting prime and target sentences in succession during the experiment (e.g., Pickering & Branigan, 1998), such that the prime would be available for memory retrieval while producing the target sentence. The current experiment suggests that memory-based effects of this sort can operate over a broader range of time under certain circumstances (e.g., when the sentences produced using a given verb are highly memorable because the verb being used is unusual in some way).

ANALYSIS OF FIRST TRIAL OF PRIMING PHASE

Experiments 1–3 show that long-term structural priming effects are not greatly affected by patterns of experience with particular verbs within the experiment. Although the results are straightforward, an anonymous reviewer pointed out that the design of our studies might be sub-optimal for the observation of lexical influences on long-term structural priming. The strength of priming between prime and target sentences in the Priming phase, as well as the repeated use of a single construction in this phase, may override whatever lexical effects on priming accrued during the Bias phase. If this is the case, it might be possible to observe lexical effects on longterm structural priming early in the Priming phase. To explore this possibility, we examined our participants' responses on the first trial of the Priming phase.

We looked at the first trial of the Priming phase of Experiments 1 and 2 (we included the data from Experiment 3 in the analysis of Experiment 2). As in the main analysis of the experiments, we were interested in those trials on which the prime stem was completed as a double object or prepositional object construction, and on which the target stem was completed as a double object or prepositional object construction. In other words, we ignored trials on which participants produced another response for either the prime or target

stem. With the remaining trials, we collapsed across the Prime factor that was a part of the original experiments and simply asked how often the participant produced the same syntactic structure on the prime stem and the target stem. [Note: none of the trials involved in these analyses had participants completing the prime stems with a construction other than the one that was intended (i.e., producing a prepositional object completion for a double object stem)]. The raw counts of trials on which participants produced matching and mismatching target completions (along with the accompanying proportions) are presented in Table 2.

In Experiment 1, the proportion of matching and mismatching completions shows a hint of a lexically-based effect: in the Unequal exposure condition, participants are more likely to match in the Same verb condition than in the Different verb condition. However, Chi-squared analyses on the raw counts from Experiment 1 show that the tendency towards a lexically-based effect was not significant in either the Equal exposure [$X^2(1) = .008$, $p = .92$] or the Unequal exposure conditions [$X^2(1) = 1.02$, $p = .31$]. In Experiment 2, the proportions indicate that participants were more likely to produce a matching target completion in the Balanced condition than in the Skewed condition, but this pattern was not significant [$X^2(1) = 2.15$, $p = .14$]. Thus, there are hints of a weak lexical effect on structural priming (the weaker priming effect on the Different verb trials in the Unequal exposure condition of Experiment 1; the weaker priming effect in the Skewed condition in Experiment 2), but these effects did not reach statistical significance.

GENERAL DISCUSSION

The data presented here make the case that long-term structural priming effects of the sort observed by Kaschak et al. (2006) represent adaptations in the language production system that take place on an abstract, structural level of representation that is separate from the representations that track the behavior of particular lexical items (in this case, verbs). Experiment 1 demonstrates this point by showing that the effects of patterns of experience in the Bias phase on the target completions in the Priming phase are not greatly affected by whether the verbs remain the same between the Bias and Priming phases or not. Experiments 2 and 3 strengthen this claim by showing that when the overall relative frequency of double object and prepositional object constructions in the experiment is put in conflict with the relative frequency of double object and prepositional object constructions for a given verb, the overall relative frequencies affect subsequent patterns of language production, but the relative frequencies for a given verb have relatively little effect on subsequent patterns of language production. The conclusion that longterm structural priming is not greatly affected by lexical factors is further supported by a study reported in Konopka and Bock (2005). In this experiment, participants reconstructed prime and target sentences from memory, where the primes and targets were either presented successively, or with one, two, or three filler items intervening between the prime and target. When the prime and target sentences were presented in succession, participants were more likely to produce the same structure on the prime and target sentence when they used the same verb than when they used a different verb (replicating previous studies); however, when the prime and target sentences were separated by one or more filler sentences (i.e., long-term structural priming), priming was the same whether the prime and target used the same verb or not.

Before moving on to a discussion of the broader implications of our results, it is important to note that all of the experiments presented here (and in Kaschak et al., 2006; and Kaschak, in press) involve the use of written language production (more specifically, typed language production). Previous research has demonstrated that the modality of sentence production has an effect on the patterns of structural priming that are observed. For example, experiments using spoken language production have demonstrated long-lasting structural priming between prime and target sentences (e.g., priming persists even when up to 10 filler sentences intervene between the prime and target; Bock & Griffin, 2000), but experiments using written language production have not (e.g., priming from a prime to a target is disrupted when even one filler intervenes between the sentences; Branigan, Pickering, & Cleland, 1999). Given such modality-based differences in structural priming, it should not be taken for granted that the effects reported here would be unchanged by switching the task to spoken language production. This issue will need to be addressed in future studies.

Our findings have implications for theories of structural priming. The data are consistent with the model of structural priming described by Chang et al. (2006). This model acquires syntactic knowledge and produces priming effects via an error-based (connectionist) learning mechanism. This mechanism has two features that allow it to account for our findings. First, the model continues to adapt as it continues to produce sentences. This is necessary for capturing the adaptation effects reported here and elsewhere (Kaschak et al., 2006; Kaschak, in press). Second, the model separates its learning about syntactic forms from its learning about particular lexical items. This provides a rationale for explaining why participants are sensitive to patterns of experience with the double object and prepositional object constructions, but not to patterns of experience with particular verbs in those constructions. Our data are less consistent with the lexically-based account of structural priming advanced by Pickering and Branigan (1998). Because any adaptations within the system would need to be represented in the links between particular lexical items and particular combinatorial nodes, current versions of the account would have a difficult time explaining the dissociation between patterns of experience with constructions and patterns of experience with particular verbs within those constructions. However, as Pickering and Branigan's (1998) account has yet to be explicitly extended to cases of long-term structural priming, it remains to be seen exactly how their formalisms behave in situations such as those presented in our experiments.

The claim that long-term structural priming effects reflect adaptations in language production on an abstract, structural level of representation is echoed by the longterm adaptation effects in sentence comprehension reported by Kaschak and Glenberg (2004; Kaschak. 2006). Kaschak and Glenberg (2004) repeatedly exposed participants to a novel syntactic construction: the Needs construction (e.g., The floor needs cleaned). After several exposures to the Needs construction, participants not only came to comprehend the construction with relative ease, but they also readily extended it to new verbs (wants) and new syntactic contexts (e.g., when the construction was presented in pseudo cleft forms; Kaschak, 2006). These results show that adaptations in language comprehension can occur on an abstract, structural level of representation (i.e., a level of representation abstracted away from particular lexical items and particular syntactic contexts). That abstract, structural adaptations can be observed in tasks involving both language comprehension and language

production supports the general idea that language users have knowledge about particular syntactic constructions that is independent of their knowledge of particular lexical items, and that this knowledge plays a role in language processing (e.g., Goldberg, 1995; Kaschak & Glenberg, 2000; but see Branigan, Pickering, & McLean, 2005, among others, for evidence that structural priming in language comprehension may not be entirely independent of lexical influences).

As noted in the introduction, there appears to be a disconnect between short-term and long-term structural priming, wherein the former is influenced by the repetition of lexical items but the latter is not. Chang et al. (2006) reconcile this difference between short-term and long-term priming by proposing the contribution of two kinds of mechanisms to structural priming. The basic structural priming effect (both short- and longterm priming effects) is produced by implicit learning within the language production system (Bock & Griffin, 2000; Chang et al., 2006). The basic priming effect may be augmented by explicit memory for the immediately preceding prime sentence, where the presence of shared lexical items between the prime and target sentence facilitates explicit retrieval of the prime sentence. Retrieval of the prime sentence increases the likelihood of the same structure being used to produce the target sentence (as in Pickering & Branigan, 1998). Thus, experiments involving short-term structural priming may show lexical effects; experiments involving long-term priming (such as those reported here and in Konopka & Bock, 2005) will not show lexical effects.

Chang et al.'s (2006) approach provides a rationale for explaining the time-based presence of lexical effects in structural priming, but it is worth noting that the overall conclusion about short-term and long-term priming may be qualified by the lend data from our Experiment 2. Although our assumptions about the increased memorability of sentences involving the verb form lent have not been tested directly here or elsewhere (but see Ferreira & Bock, in press, for a discussion of earlier results showing that long-term memory for sentences does not necessarily lead to stronger structural priming effects; cf., Ferreira, Bock, Wilson, & Cohen, 2005; Bock, Loebell, & Morey, 1992), the data do at least suggest the possibility that there are circumstances under which the explicit retrieval of sentences produced earlier in the experiment can affect sentence production over relatively long ranges of experience, provided the earlier sentences are particularly memorable (such as when they use an unusual verb). To the extent that our hypothesis holds true, it would suggest that the role of implicit and explicit memory retrieval in language production can be explored on dimensions other than the short-term/long-term split that Chang et al. (2006) describe in the context of their model.

Although most of our efforts in this General Discussion have been aimed at arguing that long-term structural priming effects are not greatly affected by patterns of experience with particular lexical items and discussing the theories that provide a rationale for this claim, we acknowledge that there is a larger issue surrounding the relationship between lexical and syntactic knowledge that needs addressed: if the mechanisms that produce long-term structural priming (and long-term learning and adaptations in the language production system) are not affected by the behavior of individual lexical items, how is it that lexical effects are observed in cases where long-term experience with language must be playing a role in one's linguistic behavior? For example, Gries (2005) reports that verbs that are used

in the double object and prepositional object constructions (give, send, etc.) often have a clear bias towards being used in one construction or the other. Similarly, an examination of Table 1 from this paper (and Kaschak's, in press, Table 2) shows that whereas each individual verb exhibits some degree of structural priming in these experiments, they also exhibit a tendency to skew towards one construction or another. These biases most likely arise over long-term experience using those verbs in those particular constructions. The problem becomes deeper if one presumes that language comprehension and language production make use of the same representations, as several studies have reported lexical effects on syntactic processing (e.g., Trueswell, Tanenhaus, & Kello, 1993), and several theories of sentence comprehension give an important role to lexical information (e.g., MacDonald, Pearlmutter, & Seidenberg, 1994; Jurafsky, 1996). By all accounts, the relevant probabilistic information about the use of particular lexical items in particular constructions must have accrued over long spans of linguistic experience.

We do not pretend to have a definitive resolution to this issue, and it is our sense that finding such a resolution will likely require a good deal of empirical and/or theoretical development. Nonetheless, we will use the rest of this paper to discuss two possible resolutions that may be empirically tractable. The first resolution is to claim that there actually are lexical effects on long-term structural priming, but they have not been seen in experiments either because the effects are too weak to be easily detected or the design of the experiments are not optimal for capturing the effects. This alternative is always available in cases such as ours, where the conclusion of main interest rests on a null effect. In support of this claim, it is interesting to note that the non-significant "verb" effects reported throughout this paper were virtually always in the direction predicted by the lexically-based account advanced by Pickering and Branigan (1998; see Tables 1 and 2). Future studies should be aimed at determining if these trends really do reflect weak verb-based effects on long-term structural priming.

An alternative (but related) resolution to the issue of why long-term structural priming seems not to be affected by patterns of experience with particular lexical items when syntactic processing in other contexts (such as sentence comprehension) is affected by long-term patterns of experience with lexical items might be that the utility of such lexical information differs across experimental tasks. Thus, the processing mechanisms responsible for sentence comprehension and sentence production are sensitive to probabilistic information about both the frequency of use for particular syntactic constructions and the frequency of use of lexical items in those constructions, but the extent to which a given type of information is used in a given language processing task depends on the nature of the task itself. A typical sentence processing experiment presents participants with two "critical" sentence structures that represent preferred and dispreferred options when processing a temporarily ambiguous sentence (e.g., the main clause and reduced relative structures that have been featured in many sentence processing experiments; see MacDonald et al., 1994, for a detailed discussion). Because participants are equally likely to see both the preferred and dispreferred structure in the experiment, structural information may not be a particularly useful cue to use in selecting a potential sentence interpretation when one reaches the point of ambiguity in the sentence. However, in the context of the experiment, lexical information (e.g., how often is this verb used as a main verb as opposed to being used in a reduced

relative clause?) is comparatively more useful in predicting the ultimate structure of the ambiguous sentence. Thus, lexical effects on syntactic processing are observed. In contrast, it may be that in long-term structural priming experiments such as the ones reported here, structural information is more relevant for task performance. When preparing to generate another sentence conveying a "transfer" meaning, participants may find it more useful to ask, "what structures have I used to convey this general meaning within the experiment?" than to ask, "how have I used this particular verb within the experiment?" Thus, no (or, very weak) lexical effects on long-term structural priming are observed. We acknowledge that the resolution sketched here is highly speculative. Nonetheless, it is our hope that this formulation (and others) will spur further research into this important theoretical issue.

CONCLUSION

This paper has explored the extent to which longterm structural priming is affected by the behavior of particular lexical items within the experiment. Our data suggest that long-term structural priming is not greatly affected by the behavior of particular lexical items within the experiment, a finding that is consistent with some theories of structural priming (Chang et al., 2006) and potentially inconsistent with others (Pickering & Branigan, 1998). By providing support for Chang et al.'s (2006) claim that one's learning about constructions is independent of one's learning about particular verbs, we have taken a step towards clarifying the nature of the representations that underlie language production.

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Appendix A

Prime and target stems from Experiment 1. For each pair of prime stems, the double object-eliciting stem is presented first, and the prepositional object-eliciting stem is presented second. For the Bias phase prime stems, the verbs give and offer are used for the Set 1 materials (these are presented below). The Set 2 materials are created by replacing the verb give with hand, and replacing the verb offer with send. For the Priming phase prime and target stems, the verbs give and offer are used for the Set 1 materials (these are presented below). The Set 2 materials are created by replacing the verb give with send and replacing the verb offer with the verb hands.

Bias phase

1. The captain gave the old sailor/The captain gave the spare life jacket
2. The millionaire gave the struggling artist/The millionaire gave the valuable painting
3. The researcher gave the experienced surgeon/The researcher gave the detailed results
4. The mother gave the hungry toddler/The mother gave the expensive toy
5. The travel agent gave the young fan/The travel agent gave the last ticket
6. The grandmother gave the little girl/The grandmother gave the big present
7. The secretary gave the manager/The secretary gave the invoice

8. The swimmer gave the diver/The swimmer gave the towel
9. The woman gave the insurance company/The woman gave the claim
10. The lecturer gave the professor/The lecturer gave the instructions
11. The eager boyfriend offered his girlfriend/The eager boyfriend offered the box of flowers
12. The unhappy customer offered the business owner/The unhappy customer offered a solution
13. The happy child offered her father/The happy child offered the coloring book
14. The young couple offered the IRS investigator/The young couple offered their mortgage payment
15. The ship's captain offered the admiral/The ship's captain offered her travel log
16. The photographer offered the editor/The photographer offered the finished proofs
17. The mean neighbor offered the woman next door/The mean neighbor offered a nasty note
18. The good looking bartender offered the girls at the bar/ The good looking bartender offered free drinks
19. The builder offered his new client/The builder offered the blueprints
20. The architect offered the president of the company/The architect offered the model of the building

Priming phase (double object and prepositional object primes on top, target stem on bottom)

1. The fashion designer gave the famous journalist/The fashion designer gave the pink jacket

   The diver gave
2. The woman gave the new neighbor/The woman gave the rusty bike

   The librarian gave
3. The disgruntled employee gave the manager/The disgruntled employee gave the long letter

   The famous novelist gave
4. The teacher offered the student/The teacher offered the certificate

   The consultant offered
5. The bartender offered the customer/The bartender offered the cocktail

   The mailman offered

6. The spy offered the double agent/The spy offered the submarine blueprints

   The kidnapper offered

Appendix B

Prime and target stems from Experiments 2 and 3. For prime stems, the double object-eliciting prime is listed first, and the prepositional object-eliciting prime is listed second. The prime and target stems that are listed below are the stems from Experiment 2°s Set 1 (target verb: give). Set 2 (target verb: lend) is created by replacing the verb give with the verb lend in the prime and target stems in the Priming phase. Set 3 (target verb: hand) is created by replacing the verb give with the verb hand in both the Bias and Priming phases, and by replacing the verb lend with send in the Bias phase. Set 4 (target verb: send) is identical to Set 3, except that the verb send replaces the verb hand in the Priming phase. The prime and target stems used in Experiment 3 are identical to Set 2, except that the verb lend is replaced by the verb loan.

Bias phase

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7. The secretary gave the manager/The secretary gave the invoice
8. The swimmer gave the diver/The swimmer gave the towel
9. The woman gave the insurance company/The woman gave the claim
10. The lecturer gave the professor/The lecturer gave the instructions
11. The eager boyfriend lent his girlfriend/The eager boyfriend lent the box of flowers
12. The unhappy customer lent the business owner/The unhappy customer lent a solution
13. The happy child lent her father/The happy child lent the coloring book
14. The young couple lent the IRS investigator/The young couple lent their mortgage payment
15. The ship’s captain lent the admiral/The ship’s captain lent her travel log
16. The photographer lent the editor/The photographer lent the finished proofs

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18. The good looking bartender lent the girls at the bar/The good looking bartender lent free drinks
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Priming phase

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4. The teacher gave the student/The teacher gave the certificate

   The consultant gave
5. The bartender gave the customer/The bartender gave the cocktail

   The mailman gave
6. The spy gave the double agent/The spy gave the submarine blueprints

   The kidnapper gave

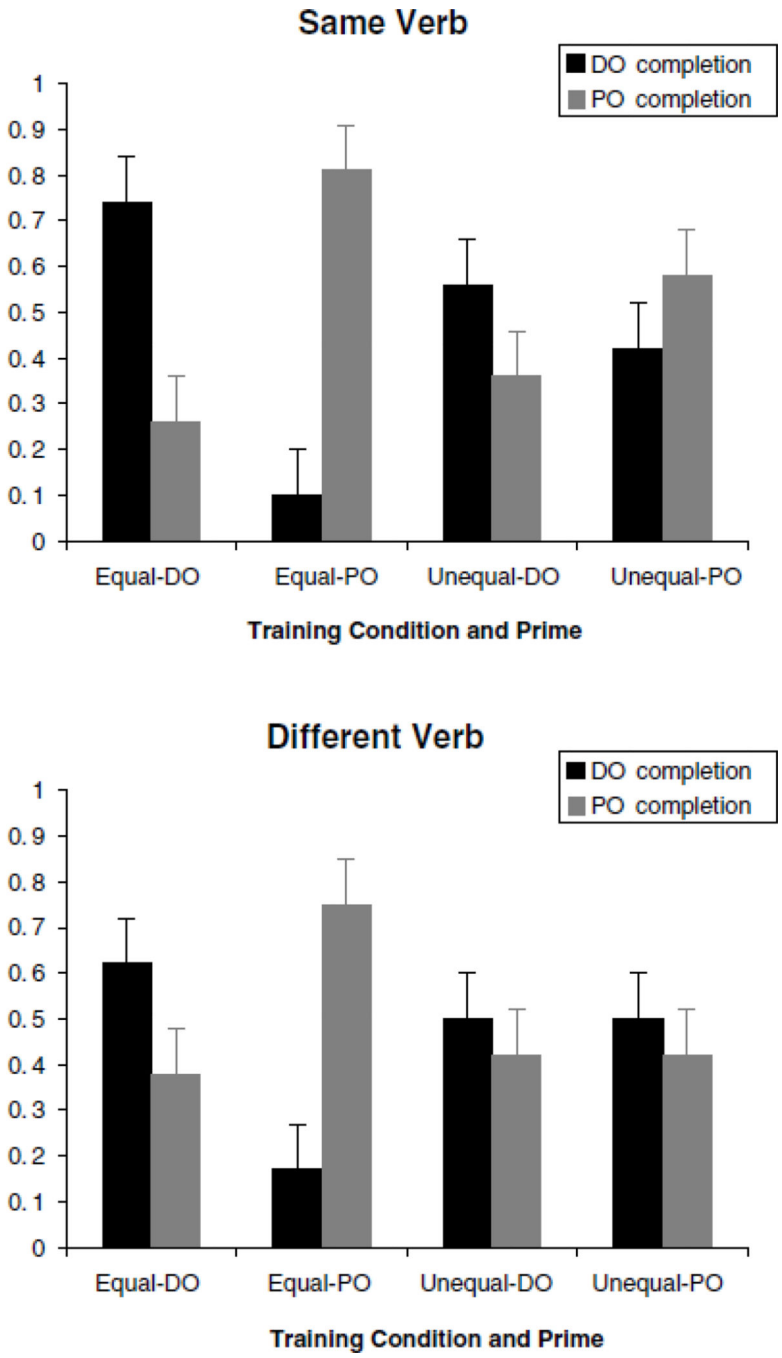

Fig. 1.

Proportion of double object (DO) and prepositional object (PO) target completions in Experiment 1 (with Standard Errors). Equal-double object = Equal exposure, double object primes; Equal-prepositional object = Equal exposure, prepositional object primes; Unequal double object = Unequal exposure, double object primes; Unequal prepositional object = Unequal exposure, prepositional object primes.

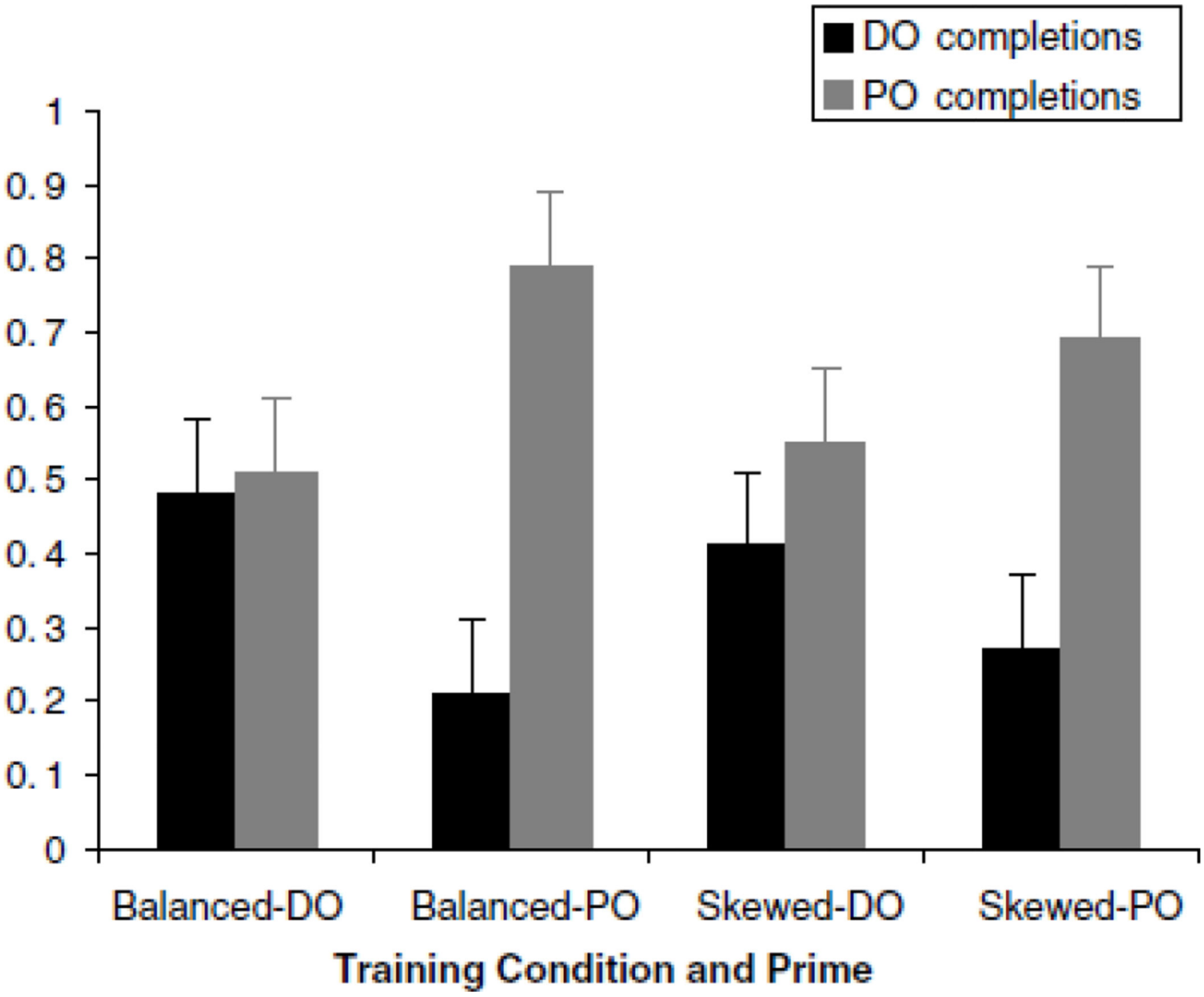

Fig. 2.

Proportion of double object (DO) and prepositional object (PO) target completions in Experiment 2 (with Standard Errors). Balanced double object, Balanced training, double object primes; Balanced prepositional object, Balanced training, prepositional object primes; Skewed double object, Skewed training, double object primes; Skewed prepositional object, Skewed training, prepositional object primes.

Table 1

Proportion of double object Target Completions by Training Condition, Prime Condition, and Individual Verbs in Experiment 2

Prime	Training condition					
	Balanced			Skewed		
	DO	PO	Difference	DO	PO	Difference
Give	.61	.39	.22	.55	.36	.19
Hand	.57	.20	.37	.62	.32	.30
Lend	.51	.16	.35	.13	.20	−.07
Send	.22	.09	.13	.33	.22	.11
Loan	.59	.26	.33	.39	.11	.28

Note: The difference is computed as the proportion of double object target completions produced after double object primes—the proportion of double object target completions produced after prepositional object primes. The magnitude of the Prime × Training interaction is the difference for the Balanced condition—the difference for the Skewed condition (Give = .03; Hand = .07; Lend = .42; Send = .02; Loan = .05). DO, double object; PO, prepositional object.

Table 2

Raw count of matching and mismatching target completions on the first trial of the priming phase in Experiments 1 and 2 (corresponding proportions are listed in parentheses)

Verb	Equal exposure		Unequal exposure	
	Same	**Different**	**Same**	**Different**
Experiment 1				
Matching	13(.76)	9(.75)	9(.75)	6(.55)
Mismatching	4(.24)	3(.25)	3(.25)	5(.45)
	Balanced training		Skewed training	
Experiment 2				
Matching	64(.63)		52(.53)	
Mismatching	38(.37)		47(.47)	