

Syntactic Priming in Immediate Recall of Sentences

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In two previous papers (Lombardi & Potter, 1992; Potter & Lombardi, 1990) we reported evidence that immediate recall of a sentence requires regeneration from the message level, rather than from a verbatim representation. However, participants tended to reproduce the surface syntax even when there were two meaning-equivalent surface structures available (e.g., for dative verbs, “gave the letter to her mother,” “gave her mother the letter”). In three experiments we tested the hypothesis that this verbatim bias is the result of syntactic priming (Bock, 1986). In Experiment 1 single sentences were recalled; the prime sentence preceded the target dative sentence. In Experiments 2 and 3 two-clause sentences were recalled; the second clause served as a prime that had been perceived but not yet recalled when the first clause was produced, or vice versa. When the prime sentence or clause was a dative that mismatched the surface structure of the target there was an increase in changes to the alternate (primed) structure in recall of the target, compared with control primes. These results support the hypothesis that simply perceiving a sentence is enough to prime its surface syntactic structure, contributing to verbatim recall. © 1998 Academic Press

Whereas most people have difficulty immediately recalling more than six or seven unrelated words, they can easily recall a meaningful sentence of 14 or even 20 words. Psychologists have attributed this difference variously to chunking or to some special “verbatim memory” that preserves the surface sequence

of a sentence, perhaps in phonological form. A different hypothesis was proposed by Potter and Lombardi (1990): “[A] sentence is regenerated in immediate recall from a representation of its meaning, using recently activated words” (p. 633).

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Support for this hypothesis was obtained by Potter and Lombardi (1990) in experiments in which subjects read a sentence, engaged in a brief distractor task that incidentally activated a “lure” word, and then recalled the sentence. Under these conditions recall of the sentence was generally accurate except when the lure word was a plausible substitute for one in the sentence; then, the lure was intruded on a substantial percentage of trials. This supported the claim that there was no reliable surface representation of the sentence that preserved the sequence of words, but instead the sentence was understood and then regenerated,

using recently activated lexical items. This process would normally result in verbatim or near-verbatim recall.¹

A question remained: Is the surface syntax of a perceived sentence represented in memory? In a second paper, Lombardi and Potter (1992) proposed that "the surface syntax of the to-be-recalled sentence is not directly represented in memory, but is regenerated using normal mechanisms of sentence production. . . . [T]he selection of the verb determines the syntactic structure of the sentence." (p. 713)

To test this hypothesis using the lure-word method, Lombardi and Potter (1992) used pairs of verbs that were roughly synonymous but sometimes required different syntactic structures to express a given message. Dative alternators and their nonalternating synonyms provided such a case, as in (1) and (2):

(1) The rich widow is going to give a million dollars to the university.

(2) The rich widow is going to give the university a million dollars.

Donate can be substituted for *give* in (1) without other changes, but cannot be substituted grammatically in (2), unless other changes are made to the sentence. If a reader explicitly remembers the surface syntax when recalling (1) or (2), he or she should reject *donate* as a substitute for the verb in (2) but not (1).

Lombardi and Potter (1992) presented alternating datives such as "give" in to-be-recalled sentences. In two experiments nonalternating synonyms such as "donate" were activated incidentally, using the lure method of

Potter and Lombardi (1990). Although the number of intrusions of the lure verb was small (perhaps because the alternators tended to be shorter and higher in frequency than the nonalternating lures), there was no significant difference in intrusions between the two forms of the target sentence, suggesting that the incompatible surface structure of the target sentence did not constrain intrusions of a semantically appropriate verb. Moreover, subjects who did intrude a lure verb almost always made spontaneous changes in the recalled sentence that restored grammaticality, as the regeneration hypothesis predicts.

In two further experiments Lombardi and Potter (1992) used a more direct method to assess retention of the surface syntax of a just-read sentence. Subjects read a sentence such as (1) or (2) and then were presented with a new verb such as *donate*: they were instructed to say yes if the new verb could substitute for the sentence verb without any other changes in the sentence, and if so, they were to recall the sentence with the new verb but no other changes. Otherwise, they said no and recalled the sentence with the original verb. If no representation of the surface structure is available in immediate memory, then nonalternators such as *donate* should be accepted as substitutes in both (1) and (2), and in such cases (2) should be recalled with changes that would restore grammaticality. Both predictions were confirmed, supporting Lombardi and Potter's (1992) hypothesis that the surface syntax of the to-be-recalled sentence is not directly represented in memory, but is regenerated using normal mechanisms of sentence production, with the verb determining the structure.

Syntactic Priming in Immediate Recall

Lombardi and Potter (1992) recognized that there was a problem with the hypothesis as stated, however: When subjects recall a sentence with a verb such as a dative alternator that permits either of two surface forms, the regeneration hypothesis predicts that subjects will use either form, so that they will make many spontaneous changes. But in their study subjects rarely did make such changes unless

¹ In a recent study Lee and Williams (1997) replicated the main results of Potter and Lombardi (1990) but claimed that the lure effect was due to the conceptual relation between the lure word and the sentence, rather than to lexical priming per se. Although we have questions about the logic and the empirical justification for their claim, we do not pursue them here because the issue is only incidental to the present study. On the main issue, the regeneration of sentences from a conceptual representation, their results and conclusions agree with those of Potter and Lombardi (1990).

the subject substituted a verb that required a change. Why not, if they are regenerating rather than remembering the surface syntax? Lombardi and Potter (1992) had a possible answer: "When more than one structure is compatible with the conceptual representation and with the chosen verb, a structure that has been recently activated is likely to be reused" (p. 713). That is, parsing a stimulus sentence primes its surface structure, which is then used in recall.

But does such syntactic priming differ from an explicit representation of the surface structure of the sentence? Bock and her colleagues (Bock, 1986, 1989; Bock & Loebell, 1990) found that repeating a dative sentence aloud increases the tendency to use the same surface syntax when generating a subsequent, unrelated dative sentence to describe a picture. Because this priming occurs between sentences with distinct vocabulary and messages, they concluded that it reflects priming of a syntactic-generation module rather than being tied to memory of a particular sentence. (See also Branigan, 1995; Branigan, Pickering, Liversedge, Stewart, & Urbach, 1995, and Frazier, Taft, Roeper, Clifton, & Ehrlich, 1984.) Bock and Loebell (1990) also found that locative prepositional phrases primed dative sentences as much as did prepositional datives, suggesting that syntactic priming involves the mechanisms that create surface constituent structures regardless of differences between the prime and the target in thematic roles.²

Priming may be regarded as a type of memory, allowing a more precise statement of the syntactic priming hypothesis of Lombardi and Potter: There is no explicit memory for the surface syntactic structure of a perceived sen-

tence, although there is an implicit memory in the form of a trace of the most recently processed structure of a given type; this implicit memory is manifested as syntactic priming when the subject attempts to regenerate a sentence of that type from its meaning. Previous research indicates that the memory for a recently perceived or generated syntactic structure is modular, procedural, and implicit rather than explicit and declarative. As noted in the previous paragraph, the memory is modular in that it is specifically structural, not tied to the particular words or concepts used in the priming sentence. It is procedural and implicit in that the priming effect occurs without the subject's awareness or intention, when he or she perceives or generates a sentence with the same structure or with a choice among structures, one being that of the prime (e.g., Bock, 1986, 1987; Bock & Loebell, 1990).

In contrast, when a subject is asked to recall a sentence that has just been read or heard, as in the present study, an explicit memory is being tapped: The subject intentionally recreates the sentence as accurately as possible. Our previous work suggested that immediate recall (like longer-term recall) is initiated from the sentence's meaning, which is represented explicitly in memory. In regenerating the sentence, words that have been recently activated tend to be used to express the intended meaning. The hypothesis that we test in the present study is that syntactic priming is an additional factor contributing to "verbatim" recall. That is, both explicit memory for the meaning of the sentence and implicit syntactic priming play a role in recall, together with lexical priming. Thus, when there are two equivalent syntactic structures to express the same meaning (as in the case of dative sentences), syntactic priming from the to-be-recalled sentence will make it likely that the participant will generate the same structure processed at input.

In Bock's studies of syntactic priming (Bock, 1986; Bock & Loebell, 1990; Bock et al., 1996) and some of the studies of Branigan and her colleagues (1995; Branigan et al., 1995) the measure was the influence of the prime on generation of a new sentence,

² More recently, Bock and her colleagues (Bock, Dell, Griffin, Chang, & Ferreira, 1996) have argued that the mechanism may be implicit learning rather than the shorter-term activation that is usually assumed to underlie priming, since in the absence of competing structural input the effect persists unchanged over as many as ten intervening sentences. The rationale of the present studies would be the same whether the mechanism is activation or implicit learning, so for convenience we will continue to use the term "priming" to cover either possibility.

whereas in our studies subjects recalled sentences they had just read. If we are right in surmising that the same type of syntactic priming occurs whether subjects are generating an original sentence or are recalling a sentence, it should be possible to show priming from a different sentence than the one being recalled—assuming that in recall there will be competition between priming from the target sentence and from another sentence presented just before or after the target. The present study examined that possibility. In Experiment 1 the prime sentence was presented and recalled before the target sentence was presented and recalled. To assess the priming effect of reading a sentence but not (yet) recalling it, in Experiment 2 the prime sentence (now a clause) followed the target clause, so the prime had just been read but not yet recalled at the time the target clause (the first clause of the sentence) was recalled. Experiment 3 included Experiment 2's condition and added a condition in which the prime clause preceded the target clause in the sentence, so that the prime was recalled before the target clause.

EXPERIMENT 1

The purpose of Experiment 1 was to test the syntactic priming hypothesis in *immediate recall* of a sentence, as distinguished from previous evidence (Bock, 1986, 1989; Bock & Loebell, 1990; Bock, Loebell, & Morey, 1992; Branigan, 1995) for syntactic priming when *generating a new sentence*. Subjects read sentences using rapid serial visual presentation (RSVP) and recalled them after a brief intervening task. On critical trials a sentence with a dative-alternating verb, such as (3) or (4), was presented.

(3) The prompt secretary wrote her boss a message every week. (Double-object dative)

(4) The prompt secretary wrote a message to her boss every week. (Prepositional dative)

As shown in Table 1, the critical sentence was preceded by one of three types of priming sentences: A, a mismatching dative; B, a mismatching surface structure similar to a dative

TABLE 1

Design of Experiment 1 with Examples of Priming and Target Sentences

Double-object dative target

The prompt secretary wrote her boss a message every week.

Primes

A. Prepositional dative

The tycoon willed that mansion to his young nephew very grudgingly.

B. Locative

Lenore drove her new convertible to the beach early this afternoon.

C. Control

My favorite shirt glowed when the room was completely dark.

Prepositional dative target

The prompt secretary wrote a message to her boss every week.

Primes

A: Double-object dative

The tycoon willed his young nephew that mansion very grudgingly.

B: Double-NP nondative

A terrible accident almost cost the driver his life today.

C: Control

My favorite shirt glowed when the room was completely dark.

(double NP or to-locative); or C, a control sentence. The prime sentence was conceptually unrelated to the target sentence, and the surface syntax of the VP mismatched or was neutral (control) with respect to the target sentence.

We predicted that if immediate recall of a sentence involves regeneration of the surface syntax using a syntactic module that can be primed by recent perception and recall of another sentence, then spontaneous change from a double-object to a prepositional dative or vice versa should be increased by a prime of that type (A versus C in Table 1). Furthermore, if Bock and Loebell (1990) are right in thinking that priming occurs equally from dative primes and from similar surface structures that are not datives, then we would expect more changes in Condition B than C, at least for the locative primes (whether the double NP primes actually have the same surface

structure as double-object datives is less clear).

Method

Participants. Twenty-four college student volunteers, all native speakers of English, were paid for their participation. They were divided into two groups of 12 each. Six additional participants (20%) were replaced because they failed to meet the criterion for the overall number of words reported correctly.

Materials and design. Table 1 illustrates the design and gives examples of the types of target sentences and primes used. As shown on Table 1, the critical dative sentence was preceded by one of three types of priming sentences: A, a mismatching dative; B, a mismatching surface structure similar to a dative (double NP or locative); or C, a control sentence. The two noun phrases of the verb phrase in the dative, locative, and double-noun-phrase sentences included one to three (average, two) words and never consisted of a pronoun or a proper name. The direct object and the recipient noun phrases had an equal number of words, on average. The prime sentence was conceptually unrelated to the target sentence.

Altogether there were 48 target sentences, averaging 11 words (range 10–13) in length, each with a dative-alternating verb. The prime sentences consisted of 16 dative sentences, 16 dative-like sentences (8 locative primes, 8 double-NP primes,³ and 16 control sentences. Each target sentence was presented equally often in each of the two dative forms (PP and NP) and with each of the three types of prime, within and across subjects. No sentence (prime, target, or filler) was seen more than once by a given subject. The surface syntax of the prime's VP always mismatched or was neutral (control) with respect to the target sen-

tence. Within that constraint and the constraint that the prime and target used different verbs (as well as different content words), the primes were assigned randomly to the target sentences.

Thus there were six conditions per target sentence (three for each of its two forms), counterbalanced across six versions of the experiment. Each subject saw only one version of each target sentence, and saw an equal number of sentences with each of the six prime-target combinations. Further examples of target sentences and primes are given in Appendix A.⁴ In group 1 a total of 192 filler sentences were included, with 3 to 5 (mean, 4) fillers between each critical prime-target sentence sequence; in group 2, with a total of 112 fillers, 2 or 3 (mean, 2.2) filler sentences separated the experimental sequences. That is, a prime was always immediately followed by a target sentence, but after each such pair there were at least 2, and up to 5, filler sentences before the next prime-target sequence. The filler sentences had no prepositional phrases or dative or double-NP verbs. From the subject's point of view, there was a continuous sequence of single, unrelated sentences to read and recall: the critical prime-target pairs were not marked off in any way.

Apparatus. The experiment was presented on an IBM AT with a fast-fade screen (B22) and a refresh rate of 60 hz.

Procedure. The words of the sentence were presented one word at a time in the center of the screen, a method termed RSVP for "rapid serial visual presentation." RSVP was used, as in Potter and Lombardi (1990) and Lombardi and Potter (1992), to control the rate of reading; our previous work had shown that sentences can be understood and repeated accurately—when no priming or other specific interfering conditions are included—at the rate of presentation we used in the present experiment. Although reading one word at a time without pre- or post-viewing of words may seem

³ The nondative double noun phrase primes used the following verb phrases (abbreviated): asked (NP questions), forgave (NP his sins), denied (NP their rights), envied (NP her good fortune), cost (NP his life), refused (NP his allowance), caused (NP gray hairs), afforded (NP many extras).

⁴ A full set of the materials used in this and the other experiments is available from the first author.

“unnatural,” it is in fact more similar to listening to speech than is conventional reading, which requires a motor act under the control of the reader to acquire successive words. The similarity to listening may account for the ease with subjects can read in this fashion.

The participant pressed the space bar to initiate a trial, which began with a row of five asterisks for 200 ms, a blank of 100 ms, and the words of the sentence for 100 ms each. Each word was centered on the screen. The last word of the sentence was followed by a string of pound signs for 100 ms, as a visual mask. A distractor task followed immediately, consisting of a row of five digits for 533 ms, a row of percentage signs for 100 ms (as a mask), and then a spelled digit for 500 ms. The subject's task was to decide whether or not the spelled digit had been among the five digits just presented, saying yes or no as appropriate, and then to recall the sentence aloud.

The experimenter noted the response to the digit probe task and recorded any errors in the subject's recall by “editing” a printed script of the sentences to conform with what the subject said when recalling each sentence. In previous work we had found that this method of noting recall errors was reliable. In group 1 the subject was instructed to wait until the experimenter had finished recording the response before initiating the next trial; in group 2, the subject was not told to wait, and the subject's response was tape-recorded for later checking in case the experimenter ran behind. Because of the larger number of filler sentences used with group 1 and the instruction to wait between trials, the experiment took about 70 minutes for group 1 and 50 minutes for group 2.

Scoring. We set a criterion of 68% correct recall of the words in the experimental sentences (primes and targets), regardless of order. The 24 subjects who met the criterion recalled 81% of the words in the sentences correctly, range 68–96%. Trials were not included in the analysis unless (1) the verb phrase (VP) of the prime sentence was recalled with the

correct surface structure (84.5% of trials), and (2) the VP of the recalled target sentence could be classified unambiguously as a dative with a double-object or prepositional phrase structure (89.3% of the trials that passed the first criterion, i.e., 75.4% of all trials). Recall of the specific words of the prime and target sentences was not required for inclusion in the analysis. For each subject (and each item) in each of the six conditions, the percentage of target sentences in which the verb phrase was changed in recall to the other dative form (from double object to prepositional phrase, or vice versa) was calculated. This percentage was used in the main analyses. By-subject and by-item analyses were carried out. Because the materials were completely counterbalanced over the various conditions, subject and item analyses were expected to give much the same results, which they did.

Results

A preliminary analysis of variance was carried out on the percentage-of-change score just described, with type of target sentence (double object or prepositional phrase) and type of prime (dative, locative/double-NP, or control) as within-subject variables, and group as a between-subjects variable. Because neither the main effect of group, $F(1,22) = .73$, nor any interactions with group, F 's between .02 and 1.29, approached significance, only an analysis of the combined groups is reported. Figure 1 shows the percentage of verb phrases changed to the other form in recall, in each condition.

In recalling the dative target sentence, subjects changed the verb phrase to the alternative form on 30% of dative-prime trials (A), 20% of locative or nondative double-object trials (B), and 8% of control trials (C), $F_1(2,46) = 16.49$, $p < .001$; $F_2(2,94) = 27.41$, $p < .001$. There was also a large main effect of target-sentence form, with double-object target sentences changed to prepositional-phrase form on 29% of trials (white bars in Figure 1) but vice versa on 10% of trials (striped bars), $F_1(1,23) = 22.60$, $p < .001$; $F_2(1,47) = 26.90$, $p < .001$. As Figure 1 shows, these two effects

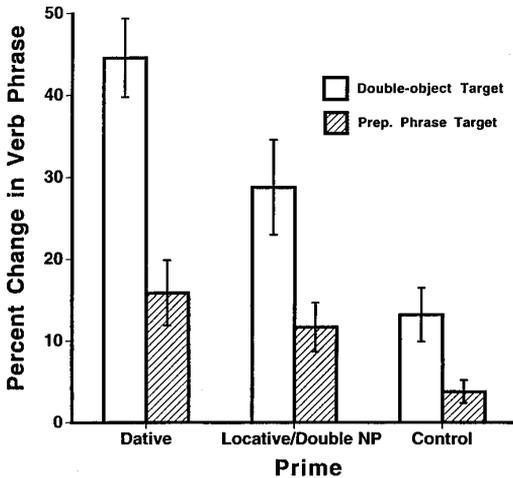


FIG. 1. Percent misrecall of the target sentence with a change in the form of the dative, following each type of prime (bars show standard errors) (Experiment 1).

interacted, $F_1(2,46) = 3.91, p < .05$; $F_2(2,94) = 7.90, p = .001$.

To explore the interaction further, separate analyses were carried out on the two forms of the target sentence. When the target sentence was in the double-object form, the percentage of changes to the prepositional-phrase form differed significantly for the three prime conditions, $F_1(2,46) = 12.84, p < .001$; $F_2(2,94) = 23.48, p < .001$. Newman-Keuls tests indicated that the control prime condition differed from the locative prime, $p < .05$, and from the prepositional dative prime, $p < .01$. The latter two priming conditions also differed from each other, $p < .05$. For target sentences in the prepositional-phrase form, there were fewer changes to the other, double-object form, although the overall effect of prime type was significant, $F_1(2,46) = 5.27, p < .01$; $F_2(2,94) = 4.82, p = .01$. A Newman-Keuls test found significant differences between the control condition and both the double-NP prime, $p < .05$, and the double-object dative prime, $p < .01$; the two latter conditions did not differ significantly.

Discussion

The results of Experiment 1 indicate that syntactic priming from an unrelated sentence

influences immediate recall of the following sentence. When the prime mismatches the target but suggests an alternative structure to express the message of the target sentence, that alternative structure is frequently produced in recall. The results support Bock's claim (1986; Bock & Loebell, 1990; Bock et al., 1992) that syntactic priming involves persisting activation of recently produced syntactic structures, independent of other levels of processing. Unlike a finding of Bock and Loebell (1990), the effect of a locative prime in Experiment 1 was not equal to that of a dative prime; a locative prime's effect was intermediate between dative and control primes, and significantly different from each. A possible reason for the difference between the present result and that of Bock and Loebell (1990) is that the locative and prepositional-dative priming sentences we used were entirely different from each other (see Table 1 and Appendix A), whereas Bock and Loebell used priming sentences that were identical except for the verb (e.g., ". . . gave/drove . . . to . . ."). Further consideration of this difference is postponed to the general discussion.

Experiment 1 showed that even a sentence that is recalled (almost) immediately is susceptible to syntactic priming from another sentence. This finding strengthens the Lombardi and Potter (1992) hypothesis that simply reading a sentence primes its own syntactic structure. This hypothesis accounts for the normally accurate regeneration of syntactic structure in immediate recall without assuming that the surface syntax is retained explicitly as part of the representation of the sentence in immediate memory. However, in Experiment 1 (and in Bock and her colleague's studies), subjects not only perceived the prime but also recalled it (or read it aloud), before reading and recalling the target sentence (or in Bock's case, generating the target sentence to describe a picture). Would simply perceiving a prime sentence (without recalling it or reading it aloud) be sufficient to prime recall of a target sentence? Experiment 2 tested that hypothesis.

EXPERIMENT 2

Method

To evaluate the effect of silently reading but not yet recalling a prime sentence, we initially planned to present the target sentence first, then the prime sentence, and then have the participant recall the two sentences in order. An advantage of this design is that the prime is read just before recalling the target, but is not itself recalled until after the target. However, in common with previous investigators (e.g., Glanzer & Nolan, 1986; Jarvella, 1979), we found in pilot work that subjects are very inaccurate in recalling two unrelated sentences, so that the experiment was failing to produce the generally verbatim immediate recall that we wanted to study (see Lombardi & Potter, 1992; Potter & Lombardi, 1990).

For that reason, we redesigned the experiment so that the two sentences were replaced by two coordinate clauses of a single sentence, written so that the first clause (the target) had a dative-alternator verb and the second clause was the prime. To increase the cohesiveness of the sentence, a referential link was established between the subjects of the two clauses, usually by omitting the second subject, but sometimes by pronominal reference, use of a possessive pronoun, or the like. In some cases the connection between the two clauses was not based on a common subject. An example of a sentence set is given in (5) and (6).

(5) Joe fed the baby pudding . . . (double-object dative target)

- A. and sold some diapers to the neighbor. (prepositional dative prime)
- B. and then dragged a highchair to the kitchen. (locative prime)
- C. and wondered when his wife would return. (control)

(6) Joe fed pudding to the baby . . . (prepositional dative target)

- A. and sold the neighbor some diapers. (double-object dative prime)
- B. because vegetables cost the hospital too much money. (double-NP prime)
- C. and wondered when his wife would return. (control)

Participants. Eighteen college student volunteers were paid for their participation. None had been in Experiment 1. Two additional participants (10%) were replaced because they did not meet the recall accuracy criterion.

Materials and design. The 48 critical trials consisted of a single two-clause sentence, 12–15 words in length. The first clause was the dative target, the second clause was the prime, so that subjects perceived the target, then the prime, and then recalled the target (and finally the prime). Thus, at the time the subject recalled the target clause, the prime had been perceived and encoded but not yet recalled. The two clauses were coherent at the discourse level, and the subject NP was usually the same (or co-referential), but no object referents were repeated between the two clauses. The two noun phrases of the verb phrase in the dative, locative, and double-noun-phrase clauses included one to three (average, two) words and never consisted of a pronoun or a proper name. The direct object and the beneficiary noun phrases had an equal number of words, on average. See (5) and (6) above and Appendix B for examples. Sixty two-clause filler sentences were written which included no datives, locatives, or prepositional phrases. At least one filler intervened between each critical sentence.

Procedure. Except as specified, the procedure was like that of Experiment 1. The rate of presentation was lower (167 ms/word rather than the 100 ms/word duration used in Experiment 1) because the sentences in Experiment 2 were somewhat longer than those in Experiment 1, and because the two-clause structure made the propositional load greater. Each sentence was followed by a mask of 12 pound signs. There was no secondary task; subjects immediately recalled the sentence aloud.

Scoring. A criterion of 70% correct recall of words of the experimental sentences was set. The 18 participants who met this criterion recalled a mean of 82% of the words of the sentences, range 74–92%. As in Experiment 1, for each subject (or each item) in each con-

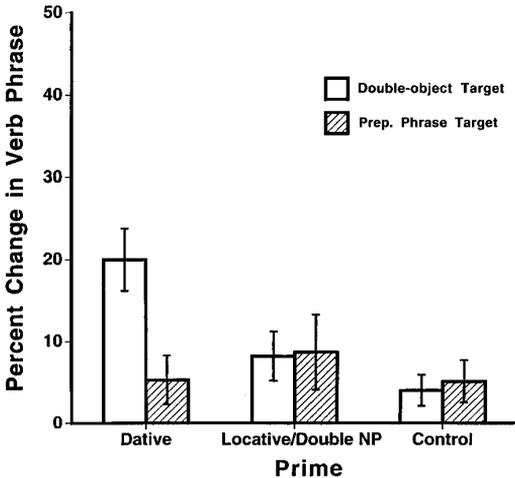


FIG. 2. Percent misrecall of the first clause (the target) with a change in the form of the dative, when the second-clause prime had been read but not yet recalled (bars show standard errors) (Experiment 2).

dition the score analyzed was the percentage of trials in which the form of the target dative was changed, out of all trials that could be scored unambiguously as one or the other form of the dative (85% of the trials). No requirement for correct recall of the prime was imposed, inasmuch as recall of the prime followed that of the target and thus would not have been independent of it. In the item analyses, cells in the design in which no recalled target clauses were scoreable as one or the other dative form (1.4% of the cells) were scored conservatively as 0% changed to the other form.

Results and Discussion

Figure 2 shows the main results. An analysis of variance was carried out on the percentage, for each subject in each of the 6 conditions, of trials in which the target dative clause was changed to the other form in recall (given that one of the two forms was recalled unambiguously, as stated above). The main effect of type of prime was significant, $F_1(2,34) = 3.84, p < .05$, $F_2(2,94) = 6.73, p < .01$. There was no main effect of target clause type, $F_1(1,17) = 1.86$, $F_2(1,47) = 2.04, p < .16$, but there was a significant interaction between

the two variables, $F_1(2,34) = 10.55, p < .001$, $F_2(2,94) = 4.97, p < .01$.

To examine this interaction further, separate analyses of the two forms of the target clause were carried out. The analysis of target clauses in the prepositional-phrase form showed no significant effect of prime type, $F_1(2,34) = 0.65$; $F_2(2,94) = 0.50$. For the target clauses in the double-object form there was a significant effect of prime type, $F_1(2,34) = 11.3, p < .001$; $F_2(2,94) = 9.25, p < .001$. A Newman-Keuls test on the by-subject analysis showed that the three means were each significantly different from the others at the .05 level or better. To sum up, dative primes of double-object target clauses had a significant priming effect of 20%, whereas priming in the other five conditions ranged from 4 to 9%. When subjects have not (yet) recalled the prime, but have only perceived it, there is still evidence for priming.

EXPERIMENT 3

Experiment 3 was designed to replicate Experiment 2 and to include the reverse condition, in which the prime clause precedes the target clause and is recalled before it. We mixed these two conditions in a single experiment both to assess the relative importance of simply reading, or reading and recalling, the prime, and to make the experimental manipulation less obvious. In most respects the method was like that of Experiment 2.

Method

Participants. There were 24 participants from the same MIT pool as that in the previous experiments. Four subjects (14%) were replaced because they did not meet the recall accuracy criterion. No subject had participated in either of the previous experiments.

Design and materials. Experiment 3 was like Experiment 2 except that on half the trials in a given version of the experiment the two clauses were reversed so that the prime was both perceived and recalled before the target clause.

The materials used in Experiment 2 were modified so that the clauses could be re-

versed (keeping the subject noun in the first clause, in most cases) without violating grammaticality or plausibility, or changing meaning. Minor changes were made, as necessary, to maintain the coherence and plausibility of the sentence when the clauses switched, but in most cases the verb phrases in the two target clauses (target-first and target-second) were identical. As in Experiment 2, there were 60 two-clause filler sentences that were unrelated in structure to the experimental sentences. Two sets of experimental sentences are given in Appendix C.

Procedure. The procedure was the same as that of Experiment 2: sentences were presented using RSVP at 167 ms per word, followed by a mask of pound signs, and were recalled aloud immediately.

Scoring. As in Experiment 2, the recall accuracy criterion was set at 70% correct recall of words of the experimental sentences. The 24 subjects meeting that criterion recalled a mean of 82% of the words of the experimental sentences, range 71–95%. The same criteria for inclusion of individual trials in the analysis were applied as in Experiment 2: only responses in which the target clause could be scored as a prepositional or a double-object dative were included in the analysis (83% of responses). When the target came first, 14.9% of the trials were excluded for this reason; when the target clause came second, 19.4%. In the item analyses, cells in the design in which no recalled target clauses were scoreable as one or the other dative form (5.7% of the 576 cells) were scored as having 0% changes. The percentage-of-syntactic-change measure was the same as that used in Experiments 1 and 2. As in Experiment 2, in the main analysis there was no requirement that the prime clause be recalled in the correct form.

Results and Discussion

The results for the main analyses are shown in Figs. 3a (target first) and 3b (target second). In an analysis of variance with target position (first or second clause), prime type, and target dative form as variables, the type of prime was the only significant main effect, with 20% changes when the prime was a dative, 11%

when it was a locative or nondative double-object, and 7% when it was an unrelated control clause, $F_1(2,46) = 8.95, p = .001, F_2(2,94) = 6.48, p < .01$.

The prime type \times target form interaction was significant in the subject analysis and approached significance in the item analysis, with a larger priming effect from dative (and locative) primes when the target clause was in the double-object form than when it was in the prepositional form, $F_1(2,46) = 3.68, p < .05, F_2(2,94) = 2.40, p < .10$. The target form \times target position interaction was significant: when the target was the first clause, a double-object target was more likely to change to a prepositional form than vice versa, whereas the reverse was true when the target clause came second, $F_1(1,23) = 8.39, p < .01; F_2(1,47) = 10.21, p < .01$. Notably, the target position \times prime type interaction was not significant, both F 's < 1.0 . That is, the overall priming effect did not differ, whether the prime clause was recalled before the target clause, or was perceived but not yet recalled before the target clause. However, the triple interaction of prime type, target-clause form, and target position approached significance in the subject analysis and was significant in the item analysis, $F_1(2,46) = 2.82, p = .07; F_2(2,94) = 4.86, p = .01$.

A planned analysis of the target-first (prime-second) condition alone (which replicates Experiment 2) again showed a significant main effect of prime type, with 17% changes after a dative prime, 11% after a locative or (non-dative) double-object prime, and 5% after a control prime, $F_1(2,46) = 5.42, p < .01, F_2(2,94) = 4.59, p < .05$, and an interaction with target-clause type, $F_1(2,46) = 7.40, p < .01; F_2(2,94) = 6.44, p < .01$. As Figure 3 shows, there was a strong priming effect of 27% for the double-object dative target clause only; the effects in the other five conditions ranged from 3 to 11%. Thus, when the priming clause came second and had not yet been recalled when the target clause was recalled, there was nonetheless substantial priming, with a pattern very similar to that in Experiment 2.

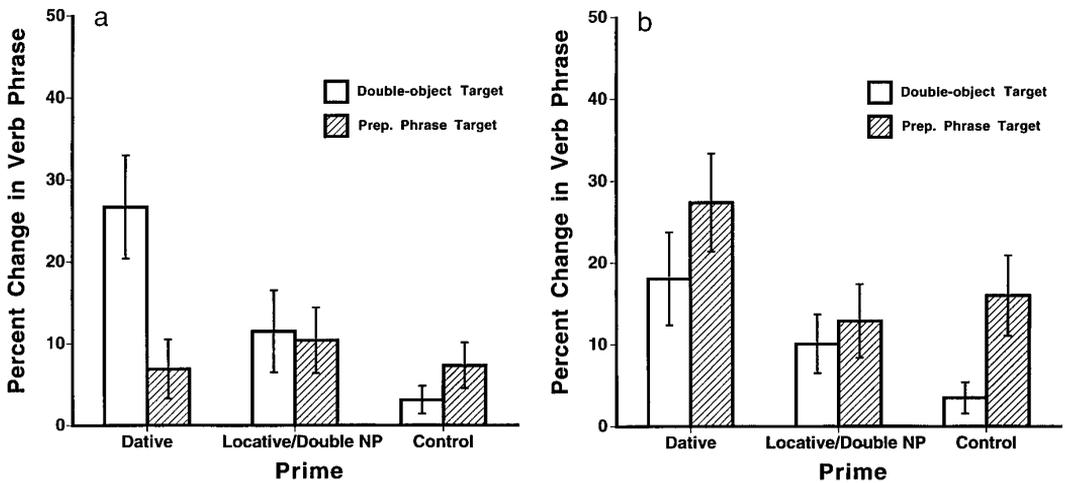


FIG. 3. Percent misrecall of the target clause with a change in the form of the dative (a) when the target clause was the first clause in the sentence, so that the prime had been read but not yet recalled and (b) when the target clause was the second clause in the sentence, so that the prime had been read and recalled before the target (bars show standard errors) (Experiment 3).

As expected and as shown in Figure 3b, there was also priming of the target clause when the target came second and was therefore recalled after recalling the prime clause. An analysis of the target-second condition showed a significant effect of prime type, with 23% changes after a dative prime, 11% after a locative or (non-dative) double-object prime, and 10% after a control prime, $F_1(2,46) = 4.44$, $p < .02$, $F_2(2,94) = 3.07$, $p = .051$. There was also a significant effect of target clause type (marginal in the item analysis), $F_1(1,23) = 5.51$, $p < .03$, $F_2(2, 94) = 3.39$, $p < .08$, with *more* changes in the prepositional target clauses (19%) than in the double-object targets (11%). There was no interaction between these variables, suggesting that the propensity to change prepositional datives to the double-object form was a result of the target's being the second clause, not a result of priming. That is, in recall of the second of two clauses participants showed a preference for the double-object form of the dative, independent of priming from the first clause. The overall preference for the double-object form, seen in the difference between switches to the prepositional and to the double-object dative, was strongest in the control condition, as Fig-

ure 3b shows. Note that because all variables were within-subjects, the same subjects who changed first clauses preferentially to the prepositional form changed second clauses more often to the double-object form.

Separate analyses were carried out in which a further criterion for inclusion was that the prime be recalled in the correct syntactic form. An additional 19% of the trials were excluded by this criterion. The analyses gave results similar to the main analyses (although they were not as reliable) and they will not be reported in detail.

One other question about the two-clause sentences used in Experiments 2 and 3 is whether there is a preference for producing parallel clauses in a sentence, and whether that preference, rather than syntactic priming, accounts for the priming effects we obtained. It should be noted that priming effects were greater in Experiment 1 (with separate sentences) than in Experiments 2 and 3 (with two-clause sentences), contrary to the parallel-preference explanation. Also, there was no evidence for greater priming when the target clause came second, in Experiment 3: that is the condition in which one would expect a parallel-clause bias to be most evident. More-

over, Branigan (1995) found syntactic priming from one sentence to another whether they were separate or conjoined. Because Bock and her colleagues have demonstrated syntactic priming in conditions that would not be expected to involve "parallel structures" and because we obtained priming in Experiment 1 with separate sentences, the more parsimonious conclusion is that the supposed preference for parallel structure is a result rather than a cause of syntactic priming.⁵

Conclusions from Experiment 3. The target-first condition in Experiment 3 replicated the results of Experiment 2, with significant priming from a perceived but not yet recalled clause. This finding supports the hypothesis that the surface syntax of a perceived sentence primes its own recall, explaining the observation of Lombardi and Potter (1992) that surface syntax is normally preserved in immediate recall even when other surface forms are available to express the same idea.

In the prime-first condition of Experiment 3, in which the prime was recalled before the target clause, there was also significant priming, as expected from the results of Experiment 1 and earlier studies. Although there were more syntactic changes in recall of the target, overall, when the target clause came second, there was not a significant interaction between target position and type of prime. Thus, there was no reliable difference in the size of the priming effect, whether the prime was read but not yet recalled, or had been both read and recalled before the target clause was recalled.

GENERAL DISCUSSION

In three experiments subjects recalled sentences they had just read. In Experiment 1, subjects were more likely to change a dative sentence to the alternative possible surface structure when that structure had been primed

by reading and repeating a previous dative sentence, than when the structure of the prime sentence was unrelated to that of the target. Nondative prime sentences with a surface structure similar to one form of the dative had an intermediate effect on recall of target sentences. These primes were locative sentences that had the same surface structure as a prepositional dative and double-np complement sentences that were superficially similar to a double-object dative.

In Experiments 2 and 3, subjects recalled two-clause sentences in which one clause was the target dative and the other was the prime. When the prime clause followed the target, the prime had been perceived but not yet recalled at the time the target clause was recalled. Both experiments showed significant syntactic priming in this condition, indicating that priming can occur when the prime has been perceived but not yet produced by the subject. When the priming clause came first in the sentence and therefore was recalled before the target clause (in one condition in Experiment 3) there was again evidence of priming, although this situation was more complex because recall of the prime was itself subject to priming from the target clause. The size of the priming effect did not interact with the position of the target clause relative to the prime.

The Potter-Lombardi Regeneration Hypothesis

The overall view of immediate sentence recall that we have proposed (Lombardi & Potter, 1992; Potter & Lombardi, 1990) replaces the idea of a special verbatim memory of the perceived sentence with three distinct memory mechanisms: one, the conceptual representation of the sentence's meaning, which can be expressed by regenerating the sentence using normal sentence-production mechanisms; two, activated traces of the lexical items of the perceived sentence, which have a high likelihood of being chosen when generating the sentence; and three, syntactic priming from having processed the stimulus sentence, which in-

⁵ We suspect, however, that there will be a stronger preference for producing parallel structures when two sentences or clauses are conceptually parallel or when the verbs are the same, permitting ellipsis, but neither was the case in the present study.

creases the likelihood of correctly recalling the syntactic structure of the sentence.⁶ The first two mechanisms were supported by previous work (Potter & Lombardi, 1990). Lombardi and Potter (1992) provided evidence that readers are not aware of the surface structure of a sentence they have just read; instead, they (re)generate the surface structure in recall in accordance with the verb they select.

But, other things being equal, subjects in the Lombardi-Potter (1992) study had a strong tendency to reproduce the surface structure they had just read, even when there was another structure available (as in the case of dative alternation). Did this mean that readers and listeners, contrary to our hypothesis, remember explicitly that "John gave the book to Mary" rather than that "John gave Mary the book"? Or, as we hypothesized, was implicit syntactic priming responsible for the propensity to select the right structure in recall? The present study tested the latter hypothesis by using a second sentence or clause as a syntactic prime of a to-be-recalled target sentence or clause. The evidence we obtained for syntactic priming in this case supports the hypothesis that self-priming plays a role in the accuracy of immediate recall of a sentence. Crucially, we obtained substantial syntactic priming even when the prime had not yet been recalled (Experiment 3's target-first condition), the condition most similar to the hypothesized self-priming situation. In all the priming experiments reported here the prime was in competition with self-priming from the target sentence or clause, so the effects would be expected to be weaker than when a sentence primes itself without interference from an immediately preceding or intervening sentence or clause with a competing structure.

Because both lexical activation and syntac-

tic priming would be expected to be subject to rapid decay or interference, this model accounts for the rapid loss of "verbatim" memory for sentences (e.g., Jarvella, 1971, 1979; Jarvella, Snodgrass, & Adler, 1978; Sachs, 1974). The much slower loss of the conceptual content of the sentence is presumably due to the greater distinctiveness of the information as well as to the fact that a reader or listener's goal is normally to extract and encode meaning, discarding the lexical and syntactic forms that convey the meaning.

Priming versus Interference in Memory

Like other forms of memory and learning, implicit priming can produce either positive or negative effects. In the case of syntactic priming of production, as in the studies of Bock cited earlier, the prime has a biasing effect on production of a new sentence; this bias cannot be classified as either positive or negative. In the case of reading time of a new sentence or clause, as in experiments of Frazier et al. (1984) and experiments cited by Branigan et al. (1995), syntactic priming has a positive effect when the prime supports the correct reading of a locally ambiguous target, and a negative effect when it supports the incorrect reading. In the case of priming the recall of a target sentence or clause, in the present experiments the prime always mismatched the target, or was a neutral control. In these conditions the mismatching primes had a negative effect on recall accuracy of the target, compared with the neutral condition.

The presence of systematic interference (or facilitation) indicates that a trace of the prime interacted with encoding or retrieval of the target. The fact that this interaction between the two verb phrases occurred in the present study despite a complete lack of overlap in lexical items and concepts indicates that the effect was confined to the syntactic surface structures of the verb phrases, abstracted away from propositional content. Our earlier study (Lombardi & Potter, 1992) showed that readers have little explicit knowledge of the surface structure of a sentence they have just read. Sachs (1974), however, found that read-

⁶ Another memory mechanism that may also contribute, but that we have not studied, is phonological information, as proposed by Baddeley in his articulatory loop hypothesis (1986); this mechanism, by itself, cannot account for verbatim recall of sentences longer than six or seven words, but might contribute to recall of the most recent words of a sentence.

ers could recognize word order changes that did not affect meaning, if tested immediately after reading a given sentence, although recognition was poor after one intervening sentence. It is not possible to determine whether this ability to recognize the change (which involved a change in word order or the deletion or insertion of one or more words) reflected memory for surface syntax as such, or simply memory for word order or changes in lexical content. In any case, recognition memory might not be reflected in recall. In studies by Jarvella (1971, 1979) and particularly in a study by Jarvella et al. (1978) in which subjects recalled recent spoken clauses or sentences, the accuracy of recall dropped rapidly as intervening material was presented. On balance, it is likely that the present syntactic priming effect is implicit, rather than the consequence of an explicit memory of the prime syntax that has interfered with an explicit memory of the target syntax.

Asymmetry between the Two Forms of the Dative

In the present experiments priming generally affected only the double-object target sentences (causing them to change to the prepositional form). (A similar asymmetry is reported in the sentence-completion priming study of Branigan, 1995, Chapter 6, Experiment 1.) A number of factors affect preference for one or the other form: the particular dative verb, the animacy of the recipient or goal, the definiteness of the noun phrases and their given-new status, their concreteness or imageability, and their heaviness, to name a few (Bock, 1977; Bock et al., 1992; Bock & Warren, 1985; Gropen, Pinker, Hollander, Goldberg, & Wilson, 1989; Pinker, 1989). We controlled for the last factor, (relative) heaviness, by matching the two NPs (theme and goal) for average length in words, across the materials in each experiment. Beyond that, we attempted to write the sentences so that either form sounded natural and neither was strongly preferred. Interestingly, in the prime-first condition in Experiment 3 in which the dative target clause was the second clause of the sentence,

there was a greater tendency to alter prepositional datives to the double-object form than vice versa, over and above any effect of the first-clause prime, suggesting that clause position is yet another factor that determines preference for one or the other form of the dative. A possible reason for the second-clause increase in use of the double-object form is that it is more abbreviated (by one word, the preposition "to") and thus reduces the processing load in the word-assembly stage, a factor that may be more significant at the end of a two-clause sentence than in the first clause. Whatever the reason for the observed asymmetry of the priming effect, this asymmetry does not affect the logic of the experiments. The hypothesis we tested was that there would be a net effect of syntactic priming, compared with control conditions, and that is what we found.

Non-dative Primes

A question raised earlier is why we failed to replicate Bock and Loebell's (1990) finding of equivalent priming from to-locatives as from prepositional datives. In the present experiments there was some priming from locatives to double-object datives (relative to unrelated control sentences), but less than from prepositional datives. As noted earlier, a possible explanation is that in Bock and Loebell's study (1990) the prepositional dative and locative priming sentences were identical, except for the verb. In the present materials there was no effort to match the arguments of the two types of prime (to-dative and locative), and they did differ markedly: for example, the noun head of the prepositional phrase was usually a spatial location, whereas the to-datives almost invariably had animate nouns as goals.

We have speculated (Lombardi & Potter, 1992) that thematic role assignments are represented abstractly in memory for a sentence, and it is possible that differences at that level have an effect on the size of priming. However, Bock and her colleagues (e.g., Bock & Loebell, 1990; Bock et al., 1992) have found evidence against thematic role differences as a factor in syntactic priming, and Bock et al.

(1992) suggest instead that conceptual factors, such as animacy, influence assignment of arguments to positions in a sentence that is being produced. Bock et al. (1992) examined the effect of the animacy of the subject of a priming sentence on participants' assignment of an inanimate agent versus an animate patient to the surface subject of the sentence they produced to describe a picture. The syntactic structure of the prime (active versus passive) and the animacy of the subject had independent effects on whether the produced sentence was active (with an inanimate subject) or passive (with an animate subject). Thus, it is possible that the difference in the proportion of animate goals in the prepositional dative primes and the locative phrases, in the present experiments, may be responsible for the difference in the size of the priming effects in these two conditions.⁷

As for the non-dative double-object primes, they had no priming effect except in Experiment 1 (see figures). That may not be surprising, since in general the prepositional-phrase targets showed little or no effect of priming even from other datives, except when the target followed recall as well as perception of the prime, in Experiment 1, and in Experiment 3's prime-first condition. Although there was some evidence of priming from the non-dative double-object primes in Experiment 1, there was none in the prime-first condition of Experiment 3. The argument structures of these verbs are somewhat heterogeneous, and distinct from that of the datives. Further work will be required to determine whether this class of double-object structures can produce priming of datives under more favorable conditions.

Conclusion

The present experiments show that syntactic priming can occur in immediate sentence recall, not just in perception and de novo sentence generation (as in previous studies of syntactic priming). Priming occurred both when

the prime itself had just been recalled and when it had only been perceived. These results provide further support for the regeneration hypothesis of Potter and Lombardi (1990) and Lombardi and Potter (1992). Reading or hearing a sentence not only conveys a message and activates lexical items, it also primes syntactic structures. It is the reuse of these syntactic structures when expressing the message (together with the reuse of activated words) that accounts for the normal "verbatim" accuracy of immediate sentence recall.

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⁷ We thank K. Bock for suggesting this possibility.

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APPENDIX A

Examples of Prime and Target Sentences Presented in Experiment 1

Each set consists of two forms of the target dative (prepositional dative, PP, and double noun phrase dative, NP) and three prime sentences: a dative in the other form, a dative-like sentence (double NP or locative), and a structurally unrelated control sentence. The three primes are shown before each target sentence.

1. Dative (NP): The husband who had disappeared sent his wife an explanatory letter secretly.

Double NP: The federal government denied those women their fundamental rights repeatedly.

Control: Often the grouchy janitor cursed loudly while sweeping and mopping.

Target (PP): The aging millionaire willed a large fortune to his only niece quite gladly.

2. Dative (NP): Ophelia handed her lover a single black rose each morning.

Double NP: A terrible accident almost cost the driver his life today.

Control: My favorite shirt glowed when the room was completely dark.

Target (PP): Jane sent her new address to several friends when the family moved.

3. Dative (NP): The slobbering grey puppy took his owner a folded newspaper eagerly.

Double NP: The curious toddler asked his mother questions all day long.

Control: After the lapsed nun had prayed feverishly all night long she felt relieved.

Target (PP): The substitute teacher read a fairy tale to her students again.

Dative (PP): The husband who had disappeared sent an explanatory letter to his wife secretly.

Locative: A batter accidentally hit the ball to the crowded bleachers this morning.

Control: Often the grouchy janitor cursed loudly while sweeping and mopping.

Target (NP): The aging millionaire willed his only niece a large fortune quite gladly.

Dative (PP): Ophelia handed a single black rose to her lover each morning.

Locative: The artist moved the marble sculpture to the empty basement secretly.

Control: My favorite shirt glowed when the room was completely dark.

Target (NP): Jane sent several friends her new address when the family moved.

Dative (PP): The slobbering grey puppy took a folded newspaper to his owner eagerly.

Locative: The elderly farmer pushed the wheelbarrow to the red barn effortlessly.

Control: After the lapsed nun had prayed feverishly all night long she felt relieved.

Target (NP): The substitute teacher read her students a fairy tale again.

APPENDIX B

Examples of Target and Prime Clauses Presented in Experiment 2

The first clause was the target dative and the second clause was the prime. For three of the six sentences in each set the target was a prepositional (PP) dative; for the other three, it was a noun-phrase (NP) dative. The dative prime was always different in form from the target. The locative prime occurred only with the NP form of the dative target, and the non-dative double-NP prime only with the PP form of the dative target. The control prime clause occurred with each form of the target.

1. Target (PP): The waitress handed two glasses to a customer

Dative (NP): and then sent the manager her resignation.

Double-NP: and forgave the apologetic bus-boy his clumsiness.

Control: because unfortunately she was seeing double.

2. Target (PP): Betsy showed affection to her family

Dative (NP): but willed a friend the house.

Double-NP: but asked several friends disturbing questions.

Control: even when she was tired or upset.

3. Target (PP): The robin taught some lessons to her chicks

Dative (NP): as the birdwatcher wrote colleagues some notes.

Double NP: but a prowling cat caused the birdwatcher concern.

Control: while a hungry stray cat watched eagerly.

Target (NP): The waitress handed a customer two glasses

Dative (PP): and then sent her resignation to the manager.

Locative: and moved the ashtray to another table.

Control: because unfortunately she was seeing double.

Target (NP): Betsy showed her family affection

Dative (PP): but willed the house to a friend.

Locative: and attracted many friends to her home.

Control: even when she was tired or upset.

Target (NP): The robin taught her chicks some lessons

Dative (PP): as the birdwatcher wrote some notes to colleagues.

Locative: and then dragged a worm to her nest.

Control: while a hungry stray cat watched eagerly.

APPENDIX C

Examples of Target and Prime Clauses Presented in Experiment 3

In each sentence one clause was the target dative and the other was the prime. The same verb phrase served as the target in each of the 12 versions of the sentence in a set; the six priming verb phrases (three for each form of the dative target) were used in each of the two orders of clauses: target first or second. The dative prime was always different in form from the target. The locative prime occurred only with the NP form of the dative target, and the non-dative double-NP prime only with the PP form of the dative target. The control prime clause occurred with each form of the target. Minor changes in wording were made to adjust to the order of the clauses.

1. *Target first:*

Target (PP): The waitress handed two glasses to a customer

Dative (NP): and then sent the manager her resignation.

Target (NP): The waitress handed a customer two glasses

Dative (PP): and then sent her resignation to the manager.

Locative: and moved the ashtray to another table.

Double-NP: and forgave the apologetic busboy his clumsiness.

Control: because she was unfortunately seeing double.

Target second:

Dative (NP): A waitress sent the manager her resignation

Double-NP: A waitress forgave the apologetic busboy his clumsiness

Control: The waitress was unfortunately seeing double

Target (PP): and handed two glasses to a customer.

2. *Target first:*

Target (PP): Betsy showed affection to her family

Dative (NP): but willed a friend the house.

Double-NP: but asked several friends disturbing questions.

Control: and was a very dedicated student.

Target second:

Dative (NP): Betsy willed a friend the house

Double-NP: Betsy asked several friends disturbing questions.

Control: Betsy was a very dedicated student

Target (PP): and showed affection to her family.

Control: because she was unfortunately seeing double.

Dative (PP): A waitress sent her resignation to the manager

Locative: A waitress moved the ashtray to another table

Control: The waitress was unfortunately seeing double

Target (NP): and handed a customer two glasses.

Target (NP): Betsy showed her family affection

Dative (PP): but willed the house to a friend.

Locative: and attracted many friends to her home.

Control: and was a very dedicated student.

Dative (PP): Betsy willed the house to a friend

Locative: Betsy attracted many friends to her home

Control: Betsy was a very dedicated student

Target (NP): and showed her family affection.

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