

Syntactic priming in spoken production: Linguistic and temporal interference

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Current evidence about the persistence of syntactic priming effects (Bock, 1986) is equivocal: Using spoken picture description, Bock and Griffin (2000) found that it persisted over as many as 10 trials; using written sentence completion, Branigan, Pickering, and Cleland (1999) found that it dissipated if even a single sentence intervened between prime and target. This paper asks what causes it to be long lasting. On one account, the rapid decay evidenced by Branigan et al. occurs because the task emphasizes conceptual planning; on another account, it is due to the written nature of their task. If conceptual planning is the cause, this might relate to planning the prime sentence or planning an intervening sentence. Hence we conducted an experiment with spoken sentence completion, contrasting no delay, an intervening sentence, and a pure temporal delay. The results indicated that strong and similar priming occurred in all three cases, therefore lending support to the claim that spoken priming is long lasting.

Studies of naturally occurring and experimentally elicited conversations have demonstrated a tendency to repeat syntactic structure (Estival, 1985; Giles & Powesland, 1975; Levelt & Kelter, 1982; Schenkein, 1980; Tannen, 1989; Weiner & Labov, 1983). Since Bock (1986), experimental studies have provided striking confirmation that this tendency is due to the priming of syntactic structure (see Pickering & Branigan, 1999, for a review). Hence, syntactic priming can be regarded as a phenomenon akin to other forms of linguistic priming, such as the priming of individual words (e.g., Meyer & Schvaneveldt, 1971; Neisser, 1954): We can investigate its characteristics both for its own sake, and in order to explicate aspects of the representation and processing of language.

This paper addresses the persistence of syntactic priming. In most investigations of priming phenomena, facts about the time course of priming constrain possible models of process and representation. For example, models of lexical representation must take into account the fact that repetition priming in general appears to be long lasting (e.g., Roediger & McDermott, 1993), whereas associative/semantic priming generally dissipates rapidly (see Joordens & Becker, 1997). Another, related, constraint on the possible range of models has to do with the relationship between the dissipation of priming and the nature of the interval intervening between prime and target, with whether they are separated by time alone, or by intervening linguistic material.

Bock and Griffin (2000) contrasted two accounts of syntactic priming. On one account, syntactic priming is

the result of temporary activation of information in memory, in a manner analogous to semantic priming (Collins & Loftus, 1975; see De Smedt, 1990). Such rapid changes of activation levels are central to some influential models of language production (Dell, 1988; Dell, Burger, & Svec, 1997). On the other account, priming is a form of procedural or implicit learning (N. J. Cohen & Eichenbaum, 1993; Tulving & Schacter, 1990). This accords with the fact that speakers are generally unaware of the syntactic processes that are employed in production (Bock, 1982) and hence that they can be primed (Bock, 1990). Such an account implies that effects are long lasting in at least some circumstances. Long-lasting repetition priming does occur in production (Wheeldon & Monsell, 1992), and it may be that syntactic priming should be regarded as a form of repetition priming of syntax.

Pickering, Branigan, Cleland, and Stewart (2000) interpret syntactic priming effects in terms of activation within a lexico-syntactic representation located at the level known as the lemma stratum (Levelt, Roelofs, & Meyer, 1999; Pickering & Branigan, 1998; Roelofs, 1992, 1993). Such an activation-based account is equally compatible with short- or long-term priming effects. However, the facts about persistence constrain the details of the model. For example, long-lasting priming effects in other aspects of cognition are generally attributed to activation of links between nodes. In that case, long-lasting syntactic priming effects can be straightforwardly accommodated in a model wherein activation resides in links between nodes, but it would be harder to accommodate in a model wherein activation resides in the nodes alone. It is important to point out that long-lasting activation is entirely consistent with an implicit-learning account.

However, current evidence regarding the persistence of syntactic priming is equivocal. Two recent studies have demonstrated apparently irreconcilable findings (Bock & Griffin, 2000; Branigan, Pickering, & Cleland, 1999).

The order of the first two authors is arbitrary. We acknowledge the assistance of Stuart Boutell. This research was supported by a British Academy Postdoctoral Fellowship (awarded to H.B.) and ESRC Grant R000237418. Correspondence should be addressed to M. J. Pickering, Department of Psychology, University of Edinburgh, 7 George Square, Edinburgh EH8 9JZ, Scotland (e-mail: martin.pickering@ed.ac.uk).

Other work, though not directly addressing the issue of persistence, has provided further equivocal evidence. We now review this research, and outline different possible causes of the different results.

How Long Does Syntactic Priming Persist?

Experimental studies of syntactic priming have demonstrated that the effect cannot be explained by non-syntactic factors and have established some of the circumstances under which it occurs: It cannot be explained by repetition of closed-class lexical items (Bock, 1989), or metrical structure or thematic roles (Bock & Loebell, 1990); it is found in Dutch (Hartsuiker & Kolk, 1998; Hartsuiker, Kolk, & Huiskamp, 1999) as well as English; it occurs in a range of construction types (Bock, 1986; Hartsuiker et al., 1999); and it occurs whether the verb is repeated between prime and target or not, but it is stronger if the verb is repeated (Pickering & Branigan, 1998). Researchers have also employed three different methods: spoken picture description (e.g., Bock, 1986; Bock, Loebell, & Morey, 1992), written sentence completion (Pickering & Branigan, 1998), and sentence recall (Potter & Lombardi, 1998).

More recently, attention has turned to the time-course of priming. Bock and Griffin (2000) used spoken picture description. Under the guise of a memory test, participants repeated sentences such as the following:

- 1a. The rock star sold some cocaine to an undercover agent.
- 1b. The rock star sold an undercover agent some cocaine.

These sentences describe the same situation, but involve different syntactic structures: In (1a), the verb *sold* is followed by a noun phrase (*some cocaine*) and a prepositional phrase (*to an undercover agent*); in (1b), the verb is followed by two noun phrases (*an undercover agent* and *some cocaine*). We call (1a) a *prepositional object* (PO) sentence and (1b) a *double-object* (DO) sentence. Participants subsequently saw a picture which could be described using a PO or a DO construction (e.g., a girl handing a paintbrush to a man). The form of the prime affected the form of the target description. Participants were more likely to produce a PO sentence like *The girl handed a paintbrush to the man* after a PO prime than after a DO prime, and more likely to produce a DO sentence like *The girl handed the man a paintbrush* after a DO prime than after a PO prime. Prime and target were separated by 0, 1, 4, or 10 intervening sentences consisting of intransitives and predicate adjective constructions. Similar patterns of priming emerged at all delays. Hence, under these circumstances, priming was extremely long lasting. Bock and Griffin interpreted their results as evidence that syntactic priming is a form of implicit learning. Note also that Boyland and Anderson (1998) reported priming over an interval of 20 min when participants first produced a series of sentences of the same syntactic form.

In contrast, Branigan et al. (1999) had participants write completions to sentence fragments (as in Pickering

& Branigan, 1998). Prime fragments like (2) induced either a PO or a DO completion:

- 2a. The woman sent the insurance claim ...
- 2b. The woman sent the insurance company ...
3. The fan sent ...

For example, (2a) is most compatible with a PO completion like *to the company*, whereas (2b) is most compatible with a DO completion like *the claim*. In contrast, target fragments like (3) are compatible with either type of completion. Branigan et al. found strong priming when prime and target were adjacent, just as in Pickering and Branigan. But when one intransitive-inducing fragment (e.g., *the boy laughed ...*) separated prime and target, there was only a weak and nonsignificant tendency toward priming. When four fragments intervened, the tendency disappeared entirely. This decay was reliable and appeared to be extremely rapid. The most obvious interpretation of these results is that priming is a transient phenomenon not obviously related to implicit learning. Since this contradicts Bock and Griffin's (2000) conclusions, it is important to determine whether the pattern of effects was specifically related to the task employed.

Using spoken picture description, Hartsuiker and Kolk (1998) manipulated whether adjacent primes and targets were separated by a 1-sec delay or not. This manipulation had no appreciable effect, so they collapsed over this factor in further analyses of their data. This provides some further evidence for persistence, but the delay was very short. More interestingly, the delay was simply temporal; unlike in both the experiments discussed above, no linguistic material intervened between prime and target. It is possible that interference occurs only if prime and target are separated by linguistic material, which would be the case if activation only dissipates if relevant material intervenes between prime and target. We address this issue in the experiment below.

Evidence from syntactic repetition in dialogue is also equivocal. Levelt and Kelter (1982) asked some shop assistants *What time do you close?* (in Dutch) and found that they tended to say *Five o'clock*; they asked other shop assistants *At what time do you close?* and found that they tended to say *At five o'clock*. However, when the question was followed by another clause and a tag question (*because I have to come in specially, do you see?*), this tendency disappeared. This might be a demonstration of syntactic priming and hence evidence for rapid decay of activation. However, it is equally possible that this priming effect was partly or entirely lexical (related to the word *at*), so it might not serve as evidence against the persistence of syntactic priming. It also involved priming between comprehension and production in a very particular kind of environment (question answering). In contrast, Weiner and Labov (1983) found that the occurrence of a passive in the preceding five utterances was a predictor of participants' producing another passive. This might suggest a long-term effect. Again, though, these effects

might not reflect syntactic priming; for example, they might be due to a localized tendency to use a more formal register, rather than to the priming of syntactic information itself.

Hartsuiker and Kolk (1998) and Hartsuiker et al. (1999) also argued for long-term priming on the basis of a comparison between descriptions produced at the beginning of the experiment following intransitive baseline primes and descriptions produced during the experiment. For example, Hartsuiker and Kolk found that the combined proportion of PO and DO responses (vs. other responses) was higher during the experiment than at the beginning. They argued that both structures have been primed during the course of the experiment as a result of repeated exposure to sentences with these structures. However, another possibility (acknowledged by the authors) is that the long-term effect is due to priming of the number of arguments in the prime (or, alternatively, the number of entities in the event described by the prime); see Pickering, Branigan, and McLean (2000).

Hence, there is one clear demonstration of long-term syntactic persistence (Bock & Griffin, 2000) and one experiment in which long-term syntactic persistence did not occur (Branigan et al., 1999). There is little evidence about whether the effect of intervening linguistic material is different from a temporal interval alone.

If priming can persist, why did Branigan et al. (1999) find such rapid decay? One possibility is that written production induces fast decay. Writing is presumably more effortful, and certainly slower, than speaking, and the additional processing involved may interfere with priming. Written sentence completion allows participants more time to think of a response as well as to actually "articulate" it, compared with spoken methods of eliciting priming, such as spoken picture description or spoken sentence completion. It is plausible that this additional time allows other factors to affect the choice of sentence form (e.g., one form may accord better with the focus structure of the sentence that the participant chooses to produce). Such an account predicts that priming would not decay rapidly in a spoken analogue of the written production method, in which participants completed sentences orally.

Alternatively, the rapid decay may be due to the fact that the task requires sentence completion, which may emphasize conceptual-level processing, as participants have to generate a state of affairs that they wish to communicate. The picture description task, on the other hand, provides participants with a state of affairs to communicate. Picture description may therefore emphasize syntactic encoding (see, e.g., Bock & Levelt, 1994; Levelt, 1989). This focus on syntactic encoding may ensure that syntactic information remains activated in this task, whereas the completion method may cause the conceptual message rather than the syntactic information to remain activated. Finally, it should be noted that the persistence found by Bock and Griffin (2000) might be related to the fact that their paradigm requires participants to memorize sen-

tences, thereby increasing the importance of maintaining surface form (cf. Bock et al., 1992).

In the experiment below, we employed spoken sentence completion to distinguish between these accounts. As in Branigan et al. (1999), participants read and completed sentence fragments. Apart from the difference in modality, the only potentially relevant differences between the studies were that the time between sentence completions was fixed and that participants repeated the fragments before completing them (and that different fragments were used). If the lack of persistence in Branigan et al. was due to the written nature of the task, persistence should occur in spoken sentence completion. If it was instead due to the nature of sentence completion, priming should rapidly decay. In one version of this account, syntactic activation under such circumstances decays fairly rapidly simply because it is relatively defocused (in comparison to conceptual information). If this is the case, any interval between prime and target is likely to lead to decay, whether this interval is filled with a linguistic stimulus or not. An alternative is that decay does not occur on its own, but only if the participant completes sentences between prime and target. In order to contrast these possibilities, it is necessary to conduct a controlled comparison between a (linguistically) filled and an unfilled delay between prime and target.

EXPERIMENT

We conducted an investigation of syntactic priming in spoken sentence completion in three different pairs of conditions. In the first pair, which served as a control for the other two pairs, the prime and target were adjacent. In the second pair, the prime and target were separated by a single intervening fragment. This corresponds to the one-intervening-fragment pair of conditions employed by Branigan et al. (1999). In the third pair, precisely the same temporal gap intervened between the prime and target, but no intervening fragment was presented. In other words, there was simply a temporal delay.

If the reason for the discrepancy between Branigan et al. (1999) and Bock and Griffin (2000) was that priming decays rapidly in written but not spoken production, there should be similar priming in all three cases. If, however, characteristics of the sentence completion task caused priming to decay in Branigan et al.'s experiment, there should be decay when the prime and target were separated by an intervening fragment. If priming decayed as a function of time alone, there should also be decay when the delay was unfilled. Conversely, if decay in priming results solely from interference from intervening linguistic material, there should be no decay when the delay was unfilled.

Method

Participants. Sixty participants from the University of Glasgow community were paid to take part.

Items. We constructed 22 sets of items. (A complete list is available from the authors.) Each included two intransitive fragments (e.g., 3 and 4), a prime fragment (e.g., 5a or 5b), and a target fragment (e.g., 6):

3. The athlete coughs . . .
4. The stage manager yells . . .
- 5a. The headmaster gives the severe punishment . . . (PO-inducing prime)
- 5b. The headmaster gives the naughty pupils . . . (DO-inducing prime)
6. The pharmacist gives . . .

The prime and target fragments each contained a dative verb that could appear with both the PO and the DO construction. The prime fragments also contained a postverbal noun phrase. In (5a), the postverbal noun phrase was a plausible patient for the action denoted by the verb, so it encouraged PO completions (e.g., . . . *to the child.*); in (5b), it was a plausible beneficiary, so it encouraged DO completions (e.g., . . . *a warning.*). The prime and target fragments employed six verbs. Previous experiments demonstrated reliable priming effects with a wider range of verbs, but these six verbs produced particularly low proportions of other (non-PO and non-DO) completions (Pickering & Branigan, 1998). The prime and target fragments had the same linguistic characteristics as those in Branigan et al. (1999) but employed different words.

The intransitive, prime, and target fragments appeared in three orders. In the *zero-intervening-fragments* conditions, the order was as follows: both intransitive fragments, prime, target. In the *one-intervening-fragment* conditions, the order was the following: first intransitive fragment, prime, the second intransitive fragment, target. In the *time-delay* conditions, a line of asterisks was used instead of the second intransitive fragment, and the order was as follows: first intransitive fragment, prime, line of asterisks, target. The intransitive fragments always appeared in the same order in each item. Together with the manipulation of prime fragment, this led to six conditions.

Procedure. The experimental items were placed into six lists, two each for the zero-intervening-fragments, one-intervening-fragment, and time-delay conditions. Each list comprised 11 items from each condition, such that one version of each item appeared in each list. In addition, we constructed 68 filler fragments: 16 contained a noun phrase (which sometimes contained an adjective or a noun modifier); 34 contained a noun phrase and a verb; and 18 contained a noun phrase, a verb, and a noun phrase. Some verbs appeared in more than one filler fragment. In addition, there were 36 fillers that consisted of a line of asterisks. Because the time delay conditions had lines of asterisks, these fillers disguised the experimental items by ensuring that the presence of asterisks was not a reliable indicator of an experimental item. They were included in the zero- and one-intervening-fragment conditions to ensure similarity between sets of items. The order of items was individually randomized for each participant, with the constraint that at least 3 fillers (whether fragments or asterisks) intervened between experimental items.

Instructions explained that we were interested in seeing what sorts of sentences people produce, and that participants should complete the fragments in any way that they liked, ensuring they produced a grammatical sentence. The instructions stressed completing each fragment with the first completion that came to mind and pointed out that there was a limited period of time in which to respond.

The experimental files were presented with PsyScope software (J. Cohen, MacWhinney, Flatt, & Provost, 1993). Participants repeated the fragment and completed the sentence, and their responses were recorded. Each experimental trial consisted of a fixation point (“+”) appearing in the center of the screen for 1,000 msec. This was then replaced with a sentence fragment. The first letter of the first word of the fragment or the first of the line of asterisks appeared in the location where the fixation point had been presented. The fragment remained on screen for 5,000 msec. The screen was then

cleared, and after a 1,000-msec delay, a beep occurred. A further delay of 1,000 msec occurred before the next item was presented. Hence, each trial (including trials consisting of a line of asterisks) lasted 8 sec.

Participants took part in a short practice session before the experimental session. The practice session consisted of 10 sentence fragments similar in structure and length to the filler items used in the experimental session. The entire experiment took about 30 min and contained four breaks, the duration of which was under the participants’ control.

Scoring. The tape for each participant was transcribed and scored. For each experimental item, the response was scored as PO, DO, or Other. Prime and target completions were scored as POs if the dative verb was immediately followed by a noun phrase that acted as the patient or theme and then by a prepositional phrase beginning with *to* that acted as the beneficiary. They were scored as DOs if the verb was immediately followed by a noun phrase that acted as the beneficiary and then by a noun phrase that acted as the patient or theme. In addition, the dative verb could not form part of a phrasal verb (e.g., *handed over* in *The architect handed the latest plan over to the builder*). A prime completion was scored as a PO only if it completed a PO-inducing fragment, and it was scored as a DO only if it completed a DO-inducing fragment. For example, if a participant completed a DO-inducing prime fragment as a PO (e.g., completing *The headmaster gives the naughty pupils* with *to his assistant*), it was scored as an Other. A target completion was scored as a PO or DO only if it had a grammatical alternative in the other category. All other completions were scored as Others.

Design and Data Analysis. Every participant completed 22 target fragments, 11 in each of the two conditions defined by the prime completion factor (PO vs. DO prime completion). Different participants were assigned to the different levels of the intervening fragments factor (zero intervening fragments vs. one intervening fragment vs. time delay).

We analyzed the results by treating the PO and DO target responses separately. Our first set of analyses, the PO target analyses, was performed over the proportion of PO target completions following PO prime completions, and the proportion of PO target completions following DO prime completions. We calculated proportions because participants may have produced different numbers of Other completions in the PO prime completion and DO prime completion conditions. We computed the relevant proportions by dividing the number of PO target completions following PO prime completions by the total number of PO prime completions (i.e., PO prime completions followed by PO, DO, and Other target completions); and the number of PO target completions following DO prime completions by the total number of DO prime completions (i.e., DO prime completions followed by PO, DO, and Other target completions). These proportions were calculated for each participant and for each item. Analyses of variance were performed on these data, with separate analyses treating participants (F_1) and items (F_2) as random effects. We treated the prime completion factor as within subjects and within items, and the intervening fragments factor as between subjects but within items.

Our second set of analyses, the DO target analyses, was performed over the proportion of DO target completions following PO prime completions, and over the proportion of DO target completions following DO prime completions. Hence, we divided the number of DO target completions following PO prime completions by the total number of PO prime completions; and we divided the number of DO target completions following DO prime completions by the total number of DO prime completions.

Results

Participants produced either a PO or a DO completion for the prime fragment on 86% of the trials; of these, 49% were PO completions and 51% were DO comple-

Table 1
Experimental Results

Condition	Prime Completion	Target Completion	
		PO	DO
Zero intervening fragments	PO	.42	.21
	DO	.23	.45
One intervening fragment	PO	.42	.29
	DO	.21	.42
Time delay	PO	.48	.19
	DO	.31	.41

Note—PO, prepositional object; DO, double object.

tions. For the target fragment in these trials, participants produced 35% PO completions, 33% DO completions, and 32% Other completions. Inspection of Table 1 demonstrates a similar priming effect in all three levels of the intervening fragments factor. The percentage priming, defined as the mean of the difference between PO prime completion–PO target completion and DO prime completion–PO target completion, and the difference between DO prime completion–DO target completion and PO prime completion–DO target completion, was 21.5% when zero fragments intervened, 17% when one fragment intervened, and 19.5% when there was a time delay.

For the PO target analyses, two-way analyses of variance revealed a main effect of prime completion [$F_1(1,57) = 52.76$, $MS_e = .021$, $p < .001$; $F_2(1,21) = 55.50$, $MS_e = .022$, $p < .001$]. Table 1 shows that participants produced more PO target completions following PO prime completions than following DO prime completions. This corresponds to the syntactic priming effect. This effect remained at a similar level across the different groups, with there being no interaction between prime completion and delay (both $F_s < 1$). The items analyses also produced a main effect of delay, but the participant analyses did not [$F_1(2,57) < 1$; $F_2(2,42) = 4.39$, $MS_e = .020$, $p < .05$]. Thus, syntactic priming occurred and was unaffected by an intervening fragment or a time delay.

The DO target analyses confirmed these findings. They revealed a main effect of prime completion [$F_1(1,57) = 50.50$, $MS_e = .023$, $p < .001$; $F_2(1,21) = 48.29$, $MS_e = .028$, $p < .001$]. No other effects approached significance (all $F_s < 1.8$).

DISCUSSION

The experiment demonstrated clear effects of syntactic priming whether the prime and target were adjacent, whether they were separated by one intervening fragment, or whether they were separated by a time delay equal to the time used to complete a single fragment. In all three cases, the magnitudes of priming were extremely similar. Priming did not decay when a filler intervened between the prime and target, or when the prime and target were separated temporally.

These results contrast with Branigan et al.'s (1999), and they demonstrate differences between spoken and writ-

ten language production with respect to syntactic priming. Branigan et al. found a dramatic reduction in priming when a filler intervened between the prime and target versus when they were adjacent; the present experiment showed no hint of any such reduction.

We can conclude that syntactic priming in spoken sentence completion is not a very short-lived phenomenon. Hence it suggests that the findings of Bock and Griffin (2000) were not dependent on the specific method that they used, in particular on the fact that the method might particularly focus on syntactic form, and required memorizing the sentences. Instead, priming decayed rapidly in Branigan et al. (1999) because of the specific method that they used—namely, written sentence completion. In conclusion, the time-course of syntactic priming in spoken production appears robust to changes in methodology and to whether the prime and target are separated by linguistic material or by time alone.

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(Manuscript received November 1, 1999;
revision accepted for publication March 21, 2000.)