Proactive interference effects on sentence production

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Proactive interference refers to recall difficulties caused by prior similar memory-related processing. Information-processing approaches to sentence production predict that retrievability affects sentence form: Speakers may word sentences so that material that is difficult to retrieve is spoken later. In this experiment, speakers produced sentence structures that could include an optional *that*, thereby delaying the mention of a subsequent noun phrase. This subsequent noun phrase was either (1) conceptually similar to three previous noun phrases in the same sentence, leading to greater proactive interference, or (2) conceptually dissimilar, leading to less proactive interference. Speakers produced more *thats* (and were more disfluencies) before conceptually similar noun phrases, suggesting that retrieval difficulties during sentence production affect the syntactic structures of sentences that speakers produce.

A speaker can communicate an idea with more than one linguistic utterance.¹ A common (and commonsense) explanation for this observation is that different syntactic structures that convey the same general meaning in fact convey subtly different specific meanings. The implication that naturally follows is that speakers use one syntactic structure rather than another to convey the specific meaning that they intend.

A different explanation for this observation comes from what is here termed the *information-processing theory of syntactic formulation* (e.g., Bock, 1982, 1987a; Ferreira, 1996; Ferreira & Dell, 2000). According to this theory, the grammars of languages have evolved to allow different syntactic structures to convey the same general meaning because of the influence of information-processing pressures on sentence production mechanisms. One such pressure arises because the words to be produced in a sentence must be retrieved from lexical memory, an unpredictable and variable process that results in some words being retrieved quickly and others slowly. Importantly, a quickly retrieved word is best mentioned early (so that it need not remain accessible as other sentence material is produced), whereas a slowly retrieved word is best mentioned later (so that the production of other sentence material buys time as it is made accessible). To accommodate this pressure, grammars might allow some flexibility, so

that speakers can express the same proposition even when producing a particular word earlier or later.

Indeed, sentence production research supports this general claim, because speakers do tend to produce quickly retrieved words early in sentences and slowly retrieved words later. For example, Bock (1986) showed that semantically primed words were likely to appear earlier in spoken sentences than unprimed words. Other factors that influence sentence production in this manner include (but are not limited to) repetition (Wheeldon & Monsell, 1992), phonological accessibility (Bock, 1987b), imageability (Bock & Warren, 1985), and animacy (McDonald, Bock, & Kelly, 1993).

Ferreira and Dell (2000) extended such effects by showing that the mention of an optional complementizer *that* in a *sentence complement structure* (e.g., *I knew [that] you had booked a flight for tomorrow*) was sensitive to the retrievability of the material produced after the *that* (e.g., *you* in the example). Specifically, speakers were more likely to omit the *that* if the material after it was repeated and was thus more accessible. This suggests that retrievability, at least as it is influenced by repetition, influences whether basic syntactic processes include or omit words like *that* (see Ferreira, 2001, for evidence that the mention of optional *thats* is determined by syntactic operations).

Note that alternative approaches that claim that the production of one sentence form rather than another is driven only by meaning differences are inconsistent with this information-processing approach to sentence production (and the evidence that supports it). However, such meaning-based approaches might claim that retrievability is correlated with communicatively relevant information, and that the production of particular sentence forms is driven by representations of such communicatively relevant information. For example, in many languages, speakers tend to produce sentences so that al-

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ready introduced or *given* information is mentioned before *new* information (see, e.g., Bock & Irwin, 1980; MacWhinney & Bates, 1978; Sridhar, 1988). Perhaps factors such as repetition and semantic priming influence sentence production because, in everyday situations, repetition or semantic (or thematic) relatedness is taken as a cue to givenness, and a representation of givenness then determines the choice of syntactic structure.

This meaning-based explanation of retrievability effects predicts that sentence production should not be sensitive to a retrievability manipulation that is not correlated with any communicative factor. We tested this by assessing the influence of a traditional list-memory effect: proactive interference (see, e.g., Keppel & Underwood, 1962; see also Wickens, 1972, for review). This well-researched effect refers to the deleterious influence of prior memory performance on current recall, which is greater when the current material is similar in some respect to the previous material. For example, after recalling the names of nine fruits, people have more difficulty recalling the names of three more fruits than they have recalling the names of three items of furniture (e.g., Craik & Birtwistle, 1971). This suggests that proactive interference arises when currently recalled material is conceptually similar to previously recalled material. Proactive interference can appear as decreased recall accuracy or increased recall latency (e.g., Wixted & Rohrer, 1993). The retrieval difficulty stems from the decline in the effectiveness of a context-determined recall cue (e.g., *fruit*) as the size of the set of the applicable items for that recall cue increases (e.g., Watkins & Watkins, 1975).

In the present experiment, we determined whether proactive interference affects syntactic formulation by looking at the production of the optional *that* in sentence complement structures. Examples of the materials are shown in Table 1. Sentences began with a main subject that included three noun phrases, then a verb, and then an embedded subject that included one noun phrase. In these sentences, a *that* may be mentioned immediately before this embedded subject. We manipulated the conceptual similarity of the embedded-subject noun phrase to the three main-subject noun phrases. If proactive interference operates within a sentence, the embedded-subject noun phrase should be retrieved with more difficulty when it is conceptually similar to the main-subject noun phrases. The information-processing theory of syntactic formulation predicts that this slower retrieval of the embedded

subject should cause it to be preceded by *thats* more often. On the other hand, meaning-based accounts do not posit that speakers use optional *thats* to communicate greater conceptual similarity between a current noun phrase and previously produced noun phrases (e.g., Bolinger, 1972; Elsness, 1984; Thompson & Mulac, 1991; Yaguchi, 2001). Thus, if speakers produce more *thats* when the embedded-subject noun phrase is conceptually similar to the main-subject noun phrases, this would selectively support the information-processing theory of syntactic formulation.

To elicit sentences, speakers participated in a recall-based sentence production task. When recalling sentences, speakers are known to have good memory for meaning but weak memory for surface form (see, e.g., Bates, Masling, & Kintsch, 1978; Sachs, 1967). This implies that whereas recall tasks control for the meanings that drive production, the surface forms of produced sentences will vary in a way that allows normal language production effects to emerge (e.g., Bock & Brewer, 1974; Bock & Irwin, 1980; Ferreira & Dell, 2000; Fox Tree & Meijer, 1999; Lombardi & Potter, 1992; Potter & Lombardi, 1990, 1998; Stallings, MacDonald, & O'Seaghdha, 1998). Also, in addition to measuring speakers' productions for occurrences of *that*, we measured their fluency and their recall accuracy, to determine other ways in which proactive interference might affect task performance specifically and sentence production generally.

METHOD

Speakers

Sixty-four native-English speakers from the UCSD community participated for class credit or cash payment.

Apparatus

The experiment was administered using PsyScope 1.2.5 (Cohen, MacWhinney, Flatt, & Provost, 1993), run on Macintosh 6500/250 computers with 17-in. color monitors. Voice responses were collected with Shure SM10A unidirectional headworn microphones, providing input to Marantz PMD201 cassette recorders (for recording voice responses).

Materials

Thirty-two sets of four conceptually similar, human-referent noun phrases were designed. To create conceptually similar embedded-subject sentences, each set was formed into a sentence complement structure with a unique verb, with three noun phrases in the main subject and the remaining noun phrase in the embedded subject (the noun phrase that seemed most typical was the embedded subject). To create conceptually dissimilar sentences, the embedded-subject

Table 1
Two Sample Sentences in Each Condition

Embedded Subject Similarity Condition	Examples
Conceptually similar	The author, the poet, and the biographer recognized (that) <i>the writer</i> was boring. The tennis player, the swimmer, and the bowler assumed (that) <i>the golfer</i> was going to make much more money than them.
Conceptually dissimilar	The author, the poet, and the biographer recognized (that) <i>the golfer</i> was boring. The tennis player, the swimmer, and the bowler assumed (that) <i>the writer</i> was going to do a story about their careers.

noun phrases were reassigned among sentences so that each appeared with conceptually dissimilar main subjects. The remainder of each sentence varied to make it sound as reasonable as possible. All sentences were designed with and without the *that*. Two example sentences of each type are shown in Table 1. The materials are available from the authors upon request.

In addition, 32 filler sentences were created that included four conceptually similar noun phrases from more varied categories and in more varied sentence structures. All sentences were divided into roughly phrase-sized units for presentation.

Design

We manipulated embedded-subject similarity (conceptually similar or dissimilar to the main-subject noun phrases) and whether the encoded sentence included a *that* within speakers and items in counterbalanced fashion. Each speaker saw each sentence once, so that each speaker produced eight sentences in each experimental condition. Items were rotated through the four conditions, so that each was presented 16 times per condition across the 64 speakers.

Procedure

Speakers were tested individually. Each trial began with the message "<get ready>." When the experimenter pressed the space bar, the sentence was visually presented one phrase at a time centered on the screen in bold Courier 14-point font, with standard sentence capitalization and standard punctuation. To ensure accurate encoding, the speaker read each phrase out loud, after which the experimenter pressed the space bar to advance to the next phrase. The final phrase of the sentence was followed by a 1-sec delay and then the message "<recall>." The speakers were instructed to recall as much of the just encoded sentence as they could. The sentences were presented in a fixed, randomly determined order, constrained so that no more than three filler or critical trials were presented consecutively. The main experiment was preceded by a practice session that included two sample sentences and a practice block of five sentences. The practice sentences were similar to the fillers.

Scoring and Analysis

From the tape recordings, an experimentally naive research assistant (1) coded whether each sentence was read aloud accurately upon initial presentation, and (2) transcribed each recalled sentence, including any disfluencies (defined as filled or unfilled pauses, repetitions, corrections, or lengthening). The first author then coded each transcribed sentence for (1) whether it was produced as a sentence complement structure (if the main verb was followed by an embedded subject, before which a *that* could be mentioned or omitted), (2) number of accurately recalled main-subject noun phrases (in any order), (3) embedded-subject accuracy, (4) the presence or absence of the *that*, and (5) the presence of at least one disfluency before the end of the embedded-subject noun phrase (which are especially likely to reflect an influence of proactive interference). A sentence was included

in the analyses reported below if it was accurately encoded, it was produced as a sentence complement structure, its main subject included at least two of its three noun phrases, and it was produced with the correct embedded-subject noun phrase. Four speakers were excluded from the speaker analyses and two items from the items analyses because these exclusions left one cell of that speaker's or item's design empty. The percentages of scored utterances are shown in Table 2. Other criteria yielded similar results.

The proportions of *thats* produced and of disfluencies utterances in each experimental condition for each speaker (across items) and each item (across speakers) were calculated, arcsine transformed (Winer, Brown, & Michels, 1991), and entered into analyses of variance (ANOVAs) with speakers (F_1) and items (F_2) as random factors. All significant effects reached the .05 level or better.

RESULTS AND DISCUSSION

Along with the percentages of scorable utterances in each condition, Table 2 reports the percentages of scorable utterances that included a *that* and that included a disfluency before the end of the embedded subject. In addition, the percentages of otherwise scorable utterances that included an erroneous embedded subject are reported, as are the recall accuracies of the *that* in each embedded-subject similarity condition.

That Production

Proactive interference affected *that*-mention, since speakers produced 5.9% more *thats* when the embedded-subject noun phrase was similar to the main-subject noun phrases in comparison with when it was not, both when the presented sentences contained a *that* (a 4.9% difference) and when they did not (a 6.9% difference). Speakers also produced more *thats* when the presented sentence contained one. Statistical analyses confirm these observations. The main effect of embedded-subject similarity was significant [$F_1(1,59) = 5.3$, $MS_e = 0.399$; $F_2(1,29) = 6.4$, $MS_e = 0.272$], as was the effect of whether the presented sentence contained a *that* [$F_1(1,59) = 22.3$, $MS_e = 0.651$; $F_2(1,29) = 31.6$, $MS_e = 0.335$]. The interaction was not significant [$F_1(1,59) < 1$, $MS_e = 0.544$; $F_2(1,29) = 1.9$, $MS_e = 0.264$], suggesting that proactive interference effects do not differ as a function of whether the presented sentence contains a *that*. Thus, the pattern of *that*-mention supports the prediction of the information-processing theory of syntactic formulation.

Table 2
Percentages of Scorable Utterances, *That* Production, Disfluency Rates, Embedded Subject Errors, and *That* Accuracy for Sentences With Similar or Dissimilar Embedded-Subject Noun Phrases When Sentences Were Encoded With or Without a *That*

Embedded Subject Similarity	Scored %		<i>That</i> %			Disfluency %			Emb. Sub. Err. %			<i>That</i> Acc. %
	<i>That</i>	Zero	<i>That</i>	Zero	<i>M</i>	<i>That</i>	Zero	<i>M</i>	<i>That</i>	Zero	<i>M</i>	
Conceptually similar	54.0	50.4	88.4	73.3	80.9	61.1	58.5	59.9	23.1	23.9	23.5	58.9
Conceptually dissimilar	55.0	55.2	83.5	66.4	75.0	47.7	49.3	48.5	18.9	21.3	20.1	57.9

Notes—*Scored %* reports the percentages of utterances evaluated for *that* mention; *that %* reports utterances produced with *that*; *disfluency %* reports utterances with disfluency before the end of the embedded subject; *emb. sub. err. %* reports otherwise scorable utterances with an erroneously recalled embedded subject; *that acc. %* reports utterances where the *that* was produced or omitted as originally encoded; *that* and *zero* columns refer to conditions where speakers were presented with sentences with or without a *that* before the embedded subject (respectively). All percentages (except *scored %*) are of scorable utterances.

Disfluencies

The effect of proactive interference appeared not only as increased *that*-mention, but also as more disfluencies production. When the embedded-subject noun phrase was similar to the main-subject noun phrases, 11.4% more utterances included a disfluency before the end of the embedded-subject noun phrase in comparison with when the embedded-subject noun phrase was dissimilar. This was true both when the presented sentences contained a *that* (a 13.4% difference) and when they did not (a 9.2% difference). Speakers were no more disfluencies when the presented sentences contained a *that* than when they did not (a 0.5% difference).

The main effect of embedded-subject similarity on the proportion of disfluencies sentences was significant [$F_1(1,59) = 13.3$, $MS_e = 0.557$; $F_2(1,29) = 7.0$, $MS_e = 0.311$], whereas the main effect of whether or not the presented sentence contained a *that* was not [$F_1(1,59) < 1$, $MS_e = 0.607$; $F_2(1,29) < 1$, $MS_e = 0.334$]. These factors did not interact [$F_1(1,59) < 1$, $MS_e = 0.480$; $F_2(1,29) < 1$, $MS_e = 0.389$]. Thus, an embedded-subject noun phrase that suffers from proactive interference not only causes the increased mention of an optional *that*, but also causes more disfluencies at sentence positions up to the end of that embedded-subject noun phrase. (The same pattern of effects arises with equal reliability for disfluencies observed only within the embedded-subject noun phrase.)

Embedded-Subject Noun-Phrase Recall

Standard accounts of proactive interference claim that it affects the *success* of recall. This predicts that conceptually similar embedded-subject noun phrases, which should suffer from proactive interference, may be recalled less accurately than conceptually dissimilar embedded-subject noun phrases. This would provide confirming evidence that conceptually similar embedded-subject noun phrases suffer from greater proactive interference than do conceptually dissimilar ones. However, though there is a tendency in this direction, speakers only recalled embedded-subject noun phrases 3.4% less accurately when they were conceptually similar in comparison with when they were conceptually dissimilar. This difference was 4.2% when the presented sentence contained a *that* and 2.6% when it did not. Embedded-subject recall accuracy differed by only 1.6% between the two *that*-presentation conditions. The main effect of embedded-subject similarity on embedded subject accuracy was marginally significant only by speakers [$F_1(1,59) = 3.3$, $MS_e = 0.302$, $p < .08$; $F_2(1,29) < 1$, $MS_e = 0.064$]. The main effect of whether a *that* was presented was not significant [$F_1(1,59) < 1$, $MS_e = 0.414$; $F_2(1,29) < 1$, $MS_e = 0.086$], nor was the interaction between the two factors [$F_1(1,59) < 1$, $MS_e = 0.321$; $F_2(1,29) < 1$, $MS_e = 0.117$]. Thus, although there was a numerical trend for proactive interference to cause less accurate recall of the embedded subject, this effect was not robust.

Memory for *That*

A concern is that proactive interference may cause worse memory for the surface features of sentences,

which may lead to a differential tendency to mention the *that* in the two embedded-subject similarity conditions. However, as is shown in Table 2, speakers' memory for the *that* (the percentage of sentences where speakers produced a *that* when it was originally encoded or omitted it when it was not) differed only by 1% (in a direction inconsistent with worse *that*-memory with greater proactive interference). Two-tailed matched-pairs *t* tests conducted across speakers and items showed that this difference was not significant [$t_1(59) = 0.29$, $SE = 0.083$; $t_2(29) = 0.57$, $SE = 0.091$]. Thus, it is unlikely that differential memory for the *that* in the originally encoded sentence was responsible for the observed effect.

Indeed, speakers' memory for the originally presented *that* emphasizes the point that the present effects reflect sentence production performance. Although it may seem unsurprising that sentences produced in the context of a memory task are influenced by a memory manipulation, it is important to note *how* the produced sentences are affected. Specifically, speakers' memory for the *that* was not affected by the memory manipulation, but rather, speakers simply tended to produce more *thats* (accurately or inaccurately) when retrieval was more difficult. The information-processing theory of syntactic formulation provides a natural explanation for why *that*-mention should increase in this way independently of episodic memory for the *that*: Speakers choose sentence structures that allow the delay of difficult-to-retrieve sentence material.

Finally, to verify that the noun phrases tested in these sentences engendered proactive interference, we conducted an independent list-recall experiment, using a Brown–Peterson-like procedure (see Wickens, 1972). We extracted the four noun phrases from the conceptually similar and dissimilar sentences, along with the noun phrases from the filler sentences. On each trial, 96 new speakers encoded the noun phrases when they were presented one at a time in the same order as in the original sentences. After encoding the four noun phrases, the speakers were presented with a two-digit number between 52 and 98 that was not divisible by three, from which they counted backward by threes at a pace of one number every 800 msec (as determined by short computer-generated beeps). The duration of this distraction task was based on the reading times of the critical sentences within each condition from the main experiment. After the distraction task, the speakers were asked to recall one of the four noun phrases when prompted by the serial position of that noun phrase (“1st,” “2nd,” “3rd,” or “4th”). We manipulated (in counterbalanced fashion) the similarity of the fourth noun phrase to the first three noun phrases as in Experiment 1, as well as the serial position of the noun phrase that the speakers were to recall. We measured recall latency and accuracy; latency analyses were performed only on correct recalls, excluding voice key mis-detections (8.4% of correct trials) and latencies outside the range of 500–4,000 msec (3.9% of correct trials; these exclusions left 12 of the 96 speakers with an empty cell of the design, who were left out of the statistical analyses

by speakers). If these materials engendered proactive interference, then even in this simple list-recall experiment, the fourth noun phrase (which corresponded to the embedded-subject noun phrases in the main experiment) should be recalled with more difficulty when it was conceptually similar to the first three noun phrases, in comparison with when it was dissimilar.

The results of this independent experiment are shown in Table 3. Proactive interference affected recall latencies, as speakers recalled the fourth noun phrase 218 msec slower when it was conceptually similar to the first three noun phrases than when it was dissimilar. On the other hand, the speakers did not recall the first three noun phrases more slowly (3-msec difference) when the fourth noun phrase was conceptually similar to those noun phrases than when it was dissimilar. Statistical analyses with 2×2 repeated measures ANOVAs confirmed that the interaction between the serial position of the noun phrase and the similarity of the fourth noun phrase was significant [$F_1(1,83) = 5.0$, $MS_e = 195,986$; $F_2(1,31) = 4.5$, $MS_e = 63,437$]. Though recall accuracies differed somewhat among the experimental conditions (see Table 3), no differences were significant (all $ps > .1$). These results thus confirm that the noun phrases used in the sentences in the main experiment engendered proactive interference.

Overall, the results show that when an embedded-subject noun phrase was conceptually similar to a series of main-subject noun phrases, it was preceded by a *that* more often than when it was conceptually dissimilar to those main-subject noun phrases. These results thus support the information-processing theory of syntactic formulation and its claim that language's grammars allow different ways to express the same basic proposition as a result of information-processing pressures that arise during sentence production.

Note that the information-processing approach is not inconsistent with the claim that different sentence forms also differ in meaning. Meaning clearly affects syntactic production (speakers produce either *Andy tripped the goalie* or *Andy was tripped by the goalie*, depending on what they mean). The key point here is that the use of a particular utterance form is demonstrably sensitive directly to information-processing pressures, and that such sensitivity cannot be explained solely by meaning-based differences.

It is also worth noting that *that*-mention and disfluencies production appear to co-occur, because both were

observed under conditions of proactive interference. Indeed, mean proportion of *that*-mention and mean disfluency rate were reliably correlated within the similar embedded-subject condition both when analyzed by speakers [$r = 0.3$, $F_1(1,62) = 5.9$, $MS_e = 0.063$] and by items [$r = 0.5$, $F_2(1,30) = 9.9$, $MS_e = 0.031$]. (*That*-mention and disfluency rate were also significantly correlated when measured as differences between the similar and dissimilar embedded-subject conditions.) This suggests that variations in utterance form do not necessarily relieve the information-processing pressures that arise in sentence production, but rather that disfluency and syntactic variation together result from such pressures (see also Bock, 1987b).

Importantly, these sentence production effects were unlikely to have resulted from some feature of meaning that is correlated with proactive interference. Most analyses of the meaning difference between sentence complement structures with and sentence complement structures without a *that* claim that *thats* communicate greater conceptual distance between the content of the main and the embedded clauses (e.g., Bolinger, 1972; Elsness, 1984; Thompson & Mulac, 1991; Yaguchi, 2001). It is unlikely that an embedded-subject noun phrase that is more conceptually *similar* to a series of main-subject noun phrases would be taken as more conceptually distanced from those main-subject noun phrases.

It may be argued that speakers mentioned *thats* more often with conceptually similar embedded subjects to assist with any proactive interference that the *listener* might experience. However, conceptually related words typically *facilitate* word recognition (see Neely, 1991, for a review). In addition, the speakers did not produce these sentences for listeners. Finally, Ferreira and Dell (2000) showed that speakers do not use *thats* to avoid difficult-to-comprehend "garden-path" sentences, suggesting that the circumstances under which speakers use *thats* to assist comprehension processes are limited.

Of course, specific details of performance from the experiment may not generalize straightforwardly to more natural language production situations. In particular, the sizes of the observed differences, the fact that episodic recall was involved, and the fact that the sentences were produced in isolation and were quite unusual all suggest that the specific effects in the experiment are unlikely to have reflected a primary determinant of the sentence choices that speakers make in natural production situations. However, proactive interference is only one kind of memory-

Table 3
Two Sample Word Lists in Each Condition and the Results of the List-Recall Experiment

Similarity of Fourth Word and Examples	Recall of First Three Words		Recall of Fourth Word	
	Latency (msec)	Accuracy (%)	Latency (msec)	Accuracy (%)
Conceptually similar				
author, poet, biographer, <i>writer</i>	1,907	63.1	1,941	60.4
tennis player, swimmer, bowler, <i>golfer</i>				
Conceptually dissimilar				
author, poet, biographer, <i>golfer</i>	1,904	57.8	1,723	59.9
tennis player, swimmer, bowler, <i>writer</i>				

specific factor that could affect sentence production performance. The importance of these results is that they reveal that production mechanisms generally are sensitive to retrievability factors (as claimed by the information-processing theory described above), of which proactive interference is only one example. Furthermore, theories of what underlies proactive interference differ in detail, but most agree that it is based on a set-size effect, in that it takes longer to search for (and one is less likely to find) a specific target item in a larger set than in a smaller set. Importantly, such set-size effects arise in semantic generation tasks as well (e.g., Rohrer, Wixted, Salmon, & Butters, 1995) and share features of codability (Lachman, Shaffer, & Hennrikus, 1974) and semantic interference effects in word production (e.g., Lupker, 1979), and are thus likely to be relevant to sentence production generally.

Although retrievability has been previously observed to affect the form of the sentences that speakers produce, this is the first demonstration in which retrievability has been manipulated in a way that is obviously unfounded with meaning features such as givenness. Yet memory directly influenced how sentences were worded. This supports the claim that variations in sentence form come from information-processing pressures that arise during sentence production and not solely from variations in intended meaning.

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NOTE

1. "An idea can be communicated by a speaker with more than one linguistic utterance." "More than one linguistic utterance can be used by a speaker to communicate an idea." And so forth.