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Constituent Structure Is Formulated in One Stage

Martin J. Pickering, Holly P. Branigan, and Janet F. McLean

University of Edinburgh, Edinburgh, United Kingdom

In four syntactic priming experiments, participants completed target fragments as "prepositional object" sentences (e.g., "The patient showed his leg to the doctor") or "double object" sentences (e.g., "The patient showed the doctor his leg") or used another non-ditransitive form. The syntactic form of a prime sentence affected the form of participants' target completions. Experiments 1 to 3 used written sentence completion. Experiment 1 demonstrated that priming is a two-way process by comparing "prepositional object" and "double object" priming conditions with a baseline condition containing an intransitive verb. Experiments 2 and 3 found that "shifted" primes (e.g., "The racing driver showed to the helpful mechanic the problem with the car") did not prime the production of "prepositional object" sentences but instead behaved like baseline primes. Experiment 4 found similar results to those of Experiment 3 in spoken sentence production, where participants repeated the prime and then completed it. We interpret the results in terms of accounts that assume that constituent structure is formulated in one stage.

Key Words: syntax; priming; production; formulation; constituent; dative.

How do people make use of grammatical information when they produce utterances? According to most current models, language production involves three stages: *conceptualization* or when the prelinguistic message is generated, *formulation* or when the message is encoded in linguistic form, and *articulation* or when this form is turned into sound or marks on a page. Formulation encompasses both grammatical encoding, whereby the syntactic content of appropriate lexical elements is retrieved and used to generate syntactic structure, and morphophonological encoding, whereby the morphophonological content is assembled (Bock & Levelt, 1994; Levelt, 1989; Levelt, Roelofs, & Meyer, 1999). In this article, we are concerned with the nature of grammatical encoding. It is uncontroversial that grammatical encoding results in the construction of a constituent structure representation. Our concern is with the stages that the processor goes through in reaching this representation.

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Address correspondence and reprint requests to Martin Pickering, Department of Psychology, University of Edinburgh, 7 George Square, Edinburgh EH8 9JZ, United Kingdom. Fax: +44 (0) 131 650 3461. E-mail: martin.pickering@ed.ac.uk.

The Construction of Constituent Structure

Most models agree that each level of processing is independent in the sense that each level is concerned with its own characteristic information and its own representations for dealing with that information. For example, representations of grammatical encoding do not include specifications of conceptual structure or phonology. Such independence holds in both strictly feedforward models of production (Levelt, 1989) and models that allow feedback between levels (Dell, 1986). This means that it should be possible, in principle, to determine the nature of the representations at each level.

As in many current models, we assume that the first stage of grammatical encoding is the construction of a functional representation (Bock & Levelt, 1994; Garrett, 1980). The precise nature of this representation is beyond the scope of this article. However, we assume that it contains noun and verb lemmas, that is, the syntactic information such as grammatical category, number, and gender that is associated with an individual lexical concept (Kempen & Hoenkamp, 1987). Following Bock and Levelt (1994), we assume that each noun lemma in the functional representation is tagged for one of the grammatical functions specified by the verb lemma (e.g., subject–nominative, object accusa-

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tive) and that the functional representation does not specifically encode information about hierarchical relationships between nouns and verbs. The representation is also partial in that it is concerned simply with functions (verbs) and their arguments (nouns); for example, it does not contain specifications for adjectives or determiners. It serves as input to the processes that ultimately result in the construction of a fully specified constituent structure that relates all of the lexical elements in the sentence.

Strong evidence that a constituent structure representation is constructed comes from syntactic priming. Under the guise of a memory test, Bock (1986) had speakers alternate between repeating prime sentences and describing semantically unrelated target pictures. She manipulated the syntactic forms of the sentences that speakers repeated. For example, the prime sentence might use the *prepositional object* (PO) form of an alternating dative verb in one condition (e.g., "A rock star sold some cocaine to an undercover agent") and the *double object* (DO) form in the other condition (e.g., "A rock star sold an undercover agent some cocaine"). The target pictures could be described using either form. Participants tended to produce a PO target picture description after a PO prime, a DO target picture description after a DO prime, and so on. Bock also found similar effects for active/passive sentences.

It is less clear whether these effects are *balanced* such that both alternative structures can be primed. For example, presentation of a PO prime would lead to an increased tendency to produce a PO target, and presentation of a DO prime would lead to an increased tendency to produce a DO target. If priming is balanced, then both PO and DO primes would produce target responses that differ from a neutral baseline prime. Alternatively, priming could be *biased* such that one construction could be primed but the other could not. In that case, a baseline prime would have a similar effect to either the PO prime (if POs are not primed) or the DO prime (if DOs are not primed). Perhaps the most likely possibility is that a marked construction could be primed by another instance of that construction but an unmarked one could not. Assuming that the DO construction is marked (e.g., because many verbs do not admit this construction), we might expect priming for the DO construction but not for the PO construction. Some evidence suggests that priming is balanced (Bock & Griffin, 2000, Experiment 2), but other effects have not been reliable (Bock, 1986) or have involved baseline primes presented at the beginning of the experimental session (Hartsuiker & Kolk, 1998).

Other experimental work helps to rule out alternative loci for these priming effects. Bock and Loebell (1990) showed that PO sentences containing prepositional phrases that specify locations (e.g., "The wealthy widow drove her Mercedes to the church") primed PO descriptions when the prepositional phrase did not specify a location (e.g., "A rock star sold some cocaine to an undercover agent"). These findings suggest that Bock's (1986) priming effects could not be due to priming at an earlier stage of production concerned with the encoding of thematic (or event structural) relations. Furthermore, Bock and Loebell (1990) found no priming between "Susan brought a book to study" and "The girl gave a brush to the man," despite their metrical similarities. This suggests that the effects are not due to priming at a metrical level. In addition, these priming effects cannot be due to lexical repetition (Bock, 1989; Pickering & Branigan, 1998) or discourse factors given that all of these experiments involve isolated sentences. Another alternative explanation is that syntactic priming is actually sensitive to functional level representations. For example, an active sentence contains a subject and an object, whereas a full passive sentence contains a subject and a phrase with an oblique grammatical function (the *by*-phrase). However, Hartsuiker and Westenberg (2000) and Hartsuiker, Kolk, and Huiskamp (1999) found priming of word order when no functional-level explanation was possible. Hence, we can conclude that priming of constituent structure representations occurs.

On one account, the processor constructs these representations from the functional-level input in a single stage. We call this a *single-stage account* of the formulation of constituent structure. Alternatively, the processor might

construct the final constituent structure representation via one or more intermediate representations. We call accounts of this type *multiple-stage accounts*. Multiple-stage accounts hold that fully specified constituent structure representations are the ultimate output of syntactic processing but that intermediate levels of representation are computed as well.

There is good evidence against one multiple-stage account, which we call the *deep-structure account*. This account draws on the assumptions of transformational grammar, namely that sentences involve (at least) two fully specified levels of constituent representation: a surface structure, and a deep (or underlying) structure (Chomsky, 1965, 1981). It assumes that language production involves the construction of syntactic structure in (at least) two stages. The functional representation is first mapped onto an underlying structure representation, which is in turn mapped onto a surface structure representation. However, Bock, Loebell, and Morey (1992) found that speakers processed (and hence represented) in a related manner the subject of an active sentence and the subject of a passive sentence. They claimed that the argument associated with the subject function of a passive sentence is directly assigned to the constituent structure position reserved for subjects. Their main criticism is of the assumption that functional relations are defined at two levels of representation, as assumed within some theories of linguistics, for example, relational grammar (Pearlmutter, 1983). In other words, they argued that production does not involve relation-changing operations during functional processing such that, for example, underlying objects become surface subjects. However, their results are similarly incompatible with a model in which a fully specified representation of underlying structure is mapped onto a representation of surface structure.

Further evidence against the deep-structure account comes from Bock and Loebell (1990), who found that sentences containing a locative by-phrase such as "The foreigner was loitering by the broken traffic light" primed passive descriptions involving an agentive by-phrase just as much as another agentive sentence did (but cf. Potter & Lombardi, 1998). Apart from ruling out thematic accounts of priming, these results are also difficult to reconcile with transformational approaches to syntax, which assume a very different representation for passive sentences (involving transformed structures and traces) than for locative sentences (Chomsky, 1981). In other words, there is good evidence against a multiple-stage account involving two fully specified constituent structure representations.

However, there are strong theoretical and experimental reasons to advocate an alternative multiple-stage account, which we call the *dominance-only account*. On this account, constituent structure is computed in two stages. The first specifies the hierarchical aspects of constituent structure but does not specify linear order. For "gave the hay to the horses," the first stage would compute a representation consisting of a verb phrase node that dominates a verb node, a noun phrase node, and a prepositional phrase node but would not specify that the verb node preceded the noun phrase node or that the noun phrase node preceded the prepositional phrase node. Note that this representation is not a local tree because the precedence relations between the daughter nodes are not specified (Partee, ter Meulen, & Wall, 1990).

Following linguistic terminology, we say that this intervening representation constitutes a dominance-only level of representation. In other words, it contains "dominance" information about which phrases dominate others (e.g., a verb phrase node dominates verb, noun phrase, and prepositional phrase nodes) but not "precedence" information about the order of phrases (e.g., between the verb, noun phrase, and prepositional phrase nodes). This distinction is proposed within various linguistic theories, most notably modern theories of phrase structure grammar (Gazdar, Klein, Pullum, & Sag, 1985; Pollard & Sag, 1994). It allows, for example, parsimonious generalizations about word order: Many languages require particular constituents to occur at a specific point in a phrase (e.g., verbs come clause-finally in Japanese and Turkish), and an autonomous precedence component allows such a generalization to be made in a single statement.

Under the dominance-only account, the processor then converts this representation into

a second representation, which is specified for order. This second process has been called *linearization* (Hartsuiker et al., 1999; Hartsuiker & Westenberg, 2000; Vigliocco & Nicol, 1998). It is compatible with computational models proposed by Kempen and Hoenkamp (1987) and De Smedt (1990). To understand the difference between the single-stage and dominance-only accounts, let us consider the choices to be made in the production of dative sentences. In fact, alternating dative verbs are compatible with three constructions, namely PO, DO, and a shifted construction illustrated in (1):

(1a) The racing driver showed the extremely dirty and badly torn overall to the mechanic. (PO)
(1b) The racing driver showed the mechanic the extremely dirty and badly torn overall. (DO)
(1c) The racing driver showed to the mechanic the extremely dirty and badly torn overall. (shifted)

In a *shifted* construction like (1c), the prepositional phrase precedes the noun phrase. In English, such sentences occur consistently in corpora and are acceptable but relatively rare. Wasow (1997) estimated their occurrence in the Brown corpus at 5.6% of eligible sentences. The occurrence of shifted constructions appears to be closely linked to the length and new information content of the direct object noun phrase (hence the alternative name for the construction, "heavy NP shift"). Indeed, when the noun phrase is longer than the prepositional phrase and conveys new information, shifted constructions may actually be produced more frequently than PO constructions (Arnold, Wasow, Losongco, & Ginstrom, 2000). Shifted constructions have been the subject of both linguistic and psycholinguistic investigation (e.g., Arnold et al., 2000; Hawkins, 1994; Stallings, MacDonald, & O'Seaghdha, 1998).

According to standard analyses, all three sentences have different (fully specified) constituent structures. In (1a), the verb phrase comprises a verb followed by a noun phrase followed by a prepositional phrase (*V NP PP*); in (1b), it comprises a verb followed by two noun phrases (*V NP NP*); and in (1c), it comprises a verb followed by a prepositional phrase followed by a noun phrase (*V PP NP*). But (1a) and (1c) share dominance relations; both involve a verb phrase dominating a verb, a noun phrase, and a prepositional phrase. In contrast, (1b) involves a verb phrase dominating a verb and two noun phrases.

Figure 1a illustrates the single-stage account, where a simple choice among the three structures is made. Figure 1b illustrates the dominance-only account, where the first stage involves selecting between a dominance-only representation consistent with the DO analysis and a dominance-only representation consistent with the PO and shifted analyses and where the second (linearization) stage involves selecting between the PO and shifted analyses if the appropriate choice is made at the first stage.

We suggest that the dominance-only and single-stage accounts can be distinguished using syntactic priming. Priming effects appear to provide evidence for levels of representation in language production (Branigan, Pickering, & Cleland, 2000a; Branigan, Pickering, Liversedge, Stewart, & Urbach, 1995; Pickering & Branigan, 1999). For one stimulus to prime another, the stimuli must have related representations at some level of structure to which the cognitive system is sensitive. There is evidence that priming is sensitive to representations used at both early and late stages in formulation. Bock et al. (1992) found that after producing a sentence with an animate subject, participants were more likely to produce another sentence with an animate subject. For example, a passive sentence with an animate subject was primed by an active sentence with an animate subject as compared to an active sentence with an animate object. These results provide evidence for priming of the mapping of conceptually specified elements to grammatical functions at a stage of formulation that precedes constituent structure generation.

Priming effects during single-word production have also provided substantial evidence about the representations that are implicated in phonological encoding, following syntactic encoding. For example, Roelofs and Meyer (1998) demonstrated priming effects based on number of syllables and stress pattern, and Sevald, Dell, and Cole (1995) demonstrated priming of the structure (as opposed to the phonological content) of syllables (see also Costa & Sebastian-Galles, 1998). These experiments

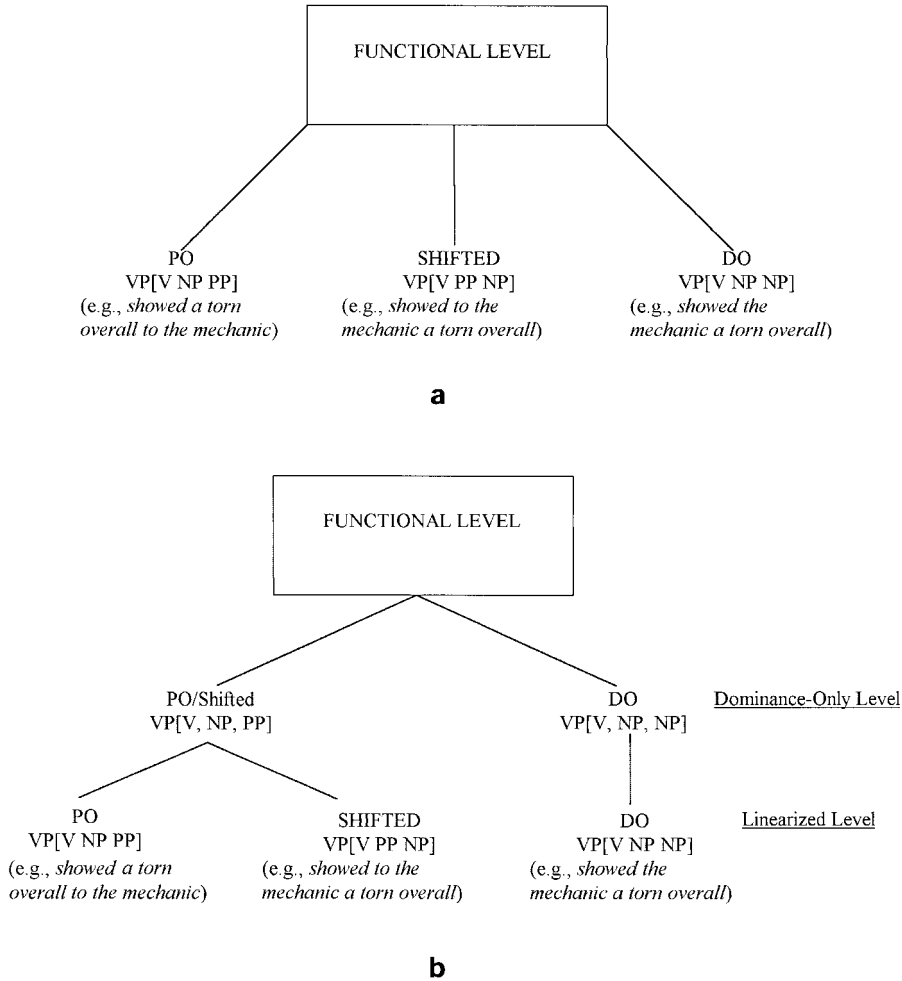

FIG. 1. Single-stage and dominance-only accounts of constituent structure formulation. (a) Single-stage account. (b) Dominance-only account. PO, prepositional object; DO, double object; VP, verb phrase; V, verb; NP, noun phrase; PP, prepositional phrase.

suggest the existence of a level of representation concerned with syllable structure (Sevald et al., 1995). Other evidence from priming has provided support for the existence of representations concerned with morphological structure (Roelofs, 1996) and perhaps grammatical gender (Jescheniak & Levelt, 1994; but cf. Van Berkum, 1997).

Thus, we propose that any level involved in constituent structure encoding should be sensitive to priming. More specifically, priming should occur whenever an earlier level of representation can be mapped onto more than one later level of representation. This means that it should be possible to prime the construction of constituent structure in the single-stage account. In the dominance-only account, it should be possible to prime both the construction of the dominance-only representation and the construction of the linearized representation.

Hartsuiker et al. (1999) and Hartsuiker and Westenberg (2000) found syntactic priming of word order (in Dutch). In Hartsuiker et al. (1999), participants tended to perseverate in the production of "locative-inverted" sentences such as "Op de tafel ligt een bal" ("On the table

is a ball") or their uninverted counterparts. In Hartsuiker and Westenberg (2000), participants tended to perseverate in the production of sentences ending with a main verb followed by an auxiliary or sentences ending with an auxiliary followed by a main verb. Hartsuiker and Westenberg argued that the alternatives have the same hierarchy of constituents and functional relations and, in particular, that their findings cannot be explained in terms of conceptual differences in topic–comment order. They argued that these word order priming effects imply that the syntactic procedures associated with placing words in their appropriate positions are primed. More specifically, they claimed that their results demonstrate priming from a dominance-only representation to an ordered representation (i.e., during linearization).

An alternative explanation of these findings is that the fully specified constituent structure representation is primed. Hartsuiker and Westenberg (2000) argued that such an explanation is incompatible with priming effects obtained for active/passive transitives (e.g., Bock, 1986). Actives and passives differ at the functional level so that if, for example, the conceptual representation is of lightning striking a church, and if the subject role is assigned to *lightning* and the object role is assigned to *church*, then the only possible sentence type is an active one such as "Lightning is striking the church." In such cases, constituent structure is predetermined by functional relations. Thus, such priming effects appear to be due to the priming of functional relations rather than to constituent structure. However, although their argument might exclude a constituent structure priming account for actives and passives, it does not demonstrate that constituent structure priming never occurs. Hence, the findings of Hartsuiker et al. (1999) and Hartsuiker and Westenberg (2000) are consistent with both a multistage account, as they argued, and a single-stage account. One way of distinguishing between these accounts would be to determine whether two forms prime each other when they share hierarchical relations but differ in word order.

In other work, Hartsuiker and Kolk (1998) presented results that are compatible with both the single-stage and dominance-only accounts. They employed PO, DO, and shifted primes ("medial datives," in their terminology) and a baseline condition that should not prime any form of the test sentence. The baseline condition used intransitive primes and constituted the first trials in the experiment. Shifted constructions are more common in Dutch than in English, and so participants produced reasonable numbers of PO, DO, and shifted target responses.

According to the single-stage account, shifted target responses should be increased by a shifted prime relative to a PO, DO, or baseline prime but should not be increased by a PO prime relative to the baseline prime; and PO target responses should be increased by a PO prime relative to a shifted, DO, or baseline prime but should not be increased by a shifted prime relative to the baseline prime. According to the dominance-only account, shifted target responses should be increased by a shifted prime relative to a PO, DO, or baseline prime (due to linearization priming); and PO target responses should be increased by a PO prime relative to a shifted, DO, or baseline prime. However, the effects of a PO prime on shifted target responses and of a shifted prime on PO target responses cannot be predicted without knowledge of the strength of priming at the dominance-only and linearization levels. Under some assumptions, a PO prime will increase the proportion of shifted target responses and vice versa. But if a PO prime has a weak effect at the dominance-only level but a very strong effect at the linearization level, then the proportion of shifted target responses will actually be reduced relative to the baseline.[1] Thus, both accounts predict priming effects due to repeating the same construction.

[1] To make this more concrete, assume "baseline" weightings of .5 for PO/shifted and .5 for DO at the dominance-only level and .8 for PO and .2 for shifted at the linearization level. This translates into .4 PO responses, .5 DO responses, and .1 shifted responses. If a shifted prime increases the PO/shifted weighting to .6 at the dominance-only level and the shifted weighting to .4 at the linearization level, then the proportions become .36 PO responses, .40 DO responses, and .24 shifted responses. Thus, the shifted prime has decreased the proportion of PO responses. It should be clear that different assignments of weightings lead to different patterns of responses.

The single-stage account predicts no priming of shifted responses by PO primes or vice versa. The dominance-only account is compatible with positive or negative priming or no priming.

In two experiments, Hartsuiker and Kolk (1998) found increased shifted target responses following a shifted prime and increased PO target responses following a PO prime (in accord with both accounts). In one experiment, they found a numerical increase in shifted responses following a PO prime versus a baseline prime, but in the other experiment they did not. In two experiments, they found a numerical increase in PO responses following a shifted prime versus a baseline prime. If these numerical increases are significant (no statistics were conducted on these comparisons), then this provides some support for the dominance-only account. However, Hartsuiker and Kolk's baseline primes all were produced at the beginning of the experiment, and the combined proportions of PO, DO, and shifted target responses after PO, DO, and shifted primes were considerably higher than after baseline primes (15% in Experiment 1 and 9% in Experiment 2). Thus, participants may have been primed through the course of the experiment to produce one of the three target response categories (rather than other responses), or they may have been primed at a stage in production in which PO, DO, and shifted responses do not differ relative to intransitive primes to produce one of these categories of response.

In summary, two multiple-stage accounts of constituent structure generation have been proposed. The deep-structure account, which is compatible with proposals in transformational grammar, is difficult to reconcile with the syntactic priming findings of Bock et al. (1992) and Bock and Loebell (1990). The dominance-only account is also compatible with proposals in theoretical linguistics, although its inspiration comes from nontransformational accounts such as generalized phrase structure grammar. Some experimental and computational research is compatible with this proposal, although Hartsuiker and Kolk's (1998) findings can also be interpreted in terms of the single-stage account.

Rationale for Experiments

At this point, it appears hard to use syntactic priming to distinguish the dominance-only and single-stage accounts. But it might be possible to do so by considering constructions that are very rarely used as target responses. This may be the case with the shifted construction in English. Stallings et al. (1998) found that participants produced shifted sentences in a production task in which they were told which phrases to use but could choose the order themselves. However, their task used particularly long noun phrases that are known to induce shifted orders fairly often (Hawkins, 1994). In tasks that involve freer production, shifted forms may be extremely rare in comparison to PO and DO forms.

Our experiments used free production for target responses. Participants simply had to complete sentences after being presented with a subject and verb (e.g., "The racing driver showed . . ."). Previous studies using the same method have not led to the production of shifted forms (Branigan, Pickering, & Cleland, 1999; Branigan, Pickering, Stewart, & McLean, 2000b; Pickering & Branigan, 1998). However, we constrained production of prime sentences so that shifted sentences would regularly be produced. It is possible that including a shifted prime will induce some shifted target responses via syntactic priming, but probably fairly infrequently (see Experiments 2-4); note in particular that participants undertaking the sentence completion task usually produce short completions.

If people produce shifted constructions as prime responses but the probability of producing shifted target responses is close to zero, then the predictions of the dominance-only and single-stage accounts become clearly distinct. In the single-stage account, there is simply a binary choice between PO and DO target response, with a PO prime increasing the proportion of PO target responses and a DO prime increasing the proportion of DO target responses. The single-stage account predicts that shifted primes should have no effects on the production of PO target responses relative to a baseline. In contrast, the dominance-only account predicts that both PO

and shifted primes should increase the likelihood that the PO/shifted representation is activated at the dominance-only level to a similar extent. Because shifted responses are hardly produced, all such activation should proceed to the PO representation at the linearized level.[2] Therefore, both PO primes and shifted primes should prime the production of PO responses to a similar extent.

Thus, evidence from syntactic priming experiments may allow us to distinguish the single-stage and dominance-only accounts. If the dominance-only account is correct, then the PO prime (1a) and the shifted prime (1c) have the same representation at the dominance-only level. Thus, according to the dominance-only account, (1a) and (1c) both should prime the production of PO sentences, whereas (1b) should prime the production of DO sentences. This prediction holds whether priming is biased or balanced.

In contrast, the single-stage account implies that shifted sentences and PO sentences do not share a common representation. Hence, under the single-stage account, (1c) should not prime PO target responses (or, of course, DO target responses). If priming is balanced, then the shifted prime (1c) should behave differently from the PO prime (1a) and the DO prime (1b) and should behave more similarly to a baseline prime than either of these. Thus, if there are no other (nonsyntactic) priming effects on these constructions, then the shifted prime should be indistinguishable from a baseline prime.

Note, however, that if priming is biased, then no difference is necessarily predicted between the shifted prime and the PO prime. If only the DO prime had any effect on target production, then the shifted prime should behave like the PO prime, just as in the dominance-only account. Thus, a prerequisite for using priming to distinguish the single-stage and dominance-only accounts is that the PO construction can be primed, as predicted by the balanced account.

Hence, our first purpose was to determine whether priming is balanced. Experiment 1, therefore, uses PO, DO, and (intransitive) baseline primes to investigate whether priming occurs for both PO and DO structures and employs written sentence completion (Branigan et al., 1999; Pickering & Branigan, 1998). On the basis of Experiment 1, which shows balanced priming effects, Experiments 2 to 4 include a shifted prime condition, which allows us to contrast the single-stage and dominance-only accounts. Experiment 2 directly contrasts PO, DO, and shifted primes in written production. Experiment 3 adds a baseline condition to allow a direct comparison between shifted and baseline primes. Experiment 4 is similar to Experiment 3 except that responses are spoken rather than written and that participants repeat the preamble as well as complete the sentence (Branigan et al., 2000b).

[2] Formally, the weightings at the linearization level are close to 1 for PO and 0 for shifted.

EXPERIMENT 1

Participants

A total of 27 participants from the University of Glasgow community took part.

Items

We constructed 24 sets of items. Each comprised two sentence fragments (see Appendix).

(2a) The racing driver showed the torn overall . . . (PO-inducing prime)
(2b) The racing driver showed the helpful mechanic . . . (DO-inducing prime)
(2c) The racing driver fainted . . . (baseline prime)
(3) The patient showed . . .

The first fragment (2a–c) was the prime; the second fragment (3) was the target. The prime fragment was designed to induce a PO completion, a DO completion, or an intransitive completion (the baseline condition). All fragments contained a subject noun phrase and a verb. In the PO- and DO-inducing conditions, the prime fragment contained a postverbal noun phrase, comprising a determiner followed by a noun, a noun compound, or an adjective and a noun. This phrase always had the same verb and the same syntactic structure across conditions for these two versions of an item. The baseline condition employed a different verb, which was standardly used intransitively. The target fragment consisted of a subject noun phrase and a

verb, which was the same verb as in the PO- and DO-inducing conditions of the prime.

For the PO- and DO-inducing conditions, we manipulated the postverbal noun phrase in the prime fragment to induce PO or DO completions. In (2a), the postverbal noun phrase is a plausible patient but an implausible beneficiary for the action denoted by the verb. Therefore, participants should be likely to complete these fragments using the PO construction, where the postverbal noun phrase is the patient of the verb (e.g., "The racing driver showed the torn overall to the team manager"). In (2b), the postverbal noun phrase is a plausible beneficiary but an implausible patient. Therefore, participants should be likely to complete these fragments using the DO construction, where the postverbal noun phrase is the beneficiary of the verb (e.g., "The racing driver showed the helpful mechanic the damaged tyre"). Sentences such as (2c) were designed so that participants could produce intransitive sentences, but obviously a range of completions were possible (actual examples of baseline completions include "The grandmother ached all over" and "The car salesman snored as he slept") The experimental items employed seven verbs (see Appendix). Previous experiments showed that participants were likely to produce both PO and DO completions for these verbs without producing a high proportion of other constructions.

The experimental items were placed into three lists, each comprising eight items from each condition, such that one version of each item appeared in each list. In addition, we constructed 96 filler fragments (48 noun phrases followed by a verb and 48 noun phrases followed by a verb and a noun phrase). None of the filler fragments contained a verb that could be completed with a PO or DO construction. Some verbs appeared in more than one filler fragment.

We constructed 27 nine-page booklets of 144 fragments consisting of 48 experimental fragments (i.e., 24 items) and the 96 filler fragments. Each page (except the last page) contained 20 fragments. The order of fragments was individually randomized for each booklet, with the constraint that at least 3 filler fragments intervened between experimental items. This means that there were at least four trials between one target completion and the next. Note that Branigan et al. (1999), using written sentence completion, found no long-term priming when four trials intervened between prime and target, and so it is highly unlikely that any effects would carry over from one trial to another in this paradigm. Even if they did, baseline trials were preceded equally often by PO and DO (and previous baseline) trials.

Instructions on the front page of the booklet explained that we were interested in seeing what sorts of sentences people produce and that participants should complete the fragments in any way they liked, ensuring that they produced a grammatical sentence. The instructions stressed completing each fragment as quickly as possible with the first completion that came to mind. Participants were told to fill in the booklet in order, without leaving out any fragments.

Procedure

Participants were given a booklet to complete and were told to hand it back to the experimenter when they were finished. The experimenter answered any questions that the participants had. The experiment took about 25 min.

Scoring

We always scored the first legible completion. Each baseline prime completion was scored as a baseline (i.e., none was excluded). For all other prime completions plus all target completions, the completions were scored as POs, DOs, or "others." They 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 was scored as a DO only if it completed a DO-inducing fragment. For example, if a participant com-

pleted a DO-inducing prime fragment as a PO (e.g., completing "The headmaster gives the naughty pupils" with "to his assistant"), then 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 where the order of the patient and beneficiary was reversed. All other completions were scored as others.

Design and Data Analysis

Every participant completed 24 target fragments, 8 in each of the three priming conditions defined by the three levels of the prime completion factor (PO vs DO vs baseline prime completion). Every experimental item was presented to all 27 participants, with 9 participants seeing any one version of an item.

We first analyzed the results for the other target completions to determine whether the combined proportion of PO and DO target completions was comparable across priming conditions. Thus, we compared the proportion of other completions following PO prime completions, the proportion of other completions following DO prime completions, and the proportion of other completions following baseline prime completions. We computed the relevant proportions by dividing the number of other target completions following PO prime completions by the total number of PO prime completions (i.e., PO prime completions followed by other, PO, and DO target completions), dividing the number of other target completions following DO prime completions by the total number of DO prime completions (i.e., DO prime completions followed by other, PO, and DO target completions), and dividing the number of other target completions following baseline prime completions by the total number of baseline prime completions (i.e., baseline prime completions followed by other, PO, and DO target completions). These proportions were calculated for each participant and for each item. Analyses of variance (ANOVAs) were performed on these data, with separate analyses treating participants (F_1) and items (F_2) as random effects. The analyses were within-subjects and within-items.

We then computed a measure designed to determine the relative proportions of PO versus DO target completions in each of the priming conditions. This measure was the proportion of PO target completions divided by the sum of the proportion of PO target completions and the proportion of DO target completions.[3] We call this the PO target ratio. We employ this measure because it allows us to compare priming between conditions in cases where the proportions of other completions are not equivalent.

TABLE 1
Results

Experiment	Prime completion	Target completion	
		PO target ratio	Other
1	PO	.76	.31
	DO	.51	.29
	Baseline	.62	.37
2	PO	.72	.27
	DO	.46	.26
	Shifted	.61	.32
3	PO	.68	.28
	DO	.44	.31
	Shifted	.60	.32
	Baseline	.61	.40
4	PO	.70	.21
	DO	.46	.18
	Shifted	.59	.26
	Baseline	.62	.27

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

Results and Discussion

Participants produced POs, DOs, or baseline completions for the prime fragments on 92% of trials (596 trials); of these, 30% were PO completions, 34% were DO completions, and 36% were baseline completions.

We considered the proportions of other target completions first. Table 1 shows that such completions are numerically more frequent after baseline primes than after PO or DO primes. This trend was not significant, $F_1(2,52) = 2.61$,

[3] In fact, this is equivalent to computing the number of PO target completions divided by the sum of the number of PO target completions and the number of DO target completions. Our discussion is in terms of proportions because the means reported all are in terms of proportions. The use of PO rather than DO is arbitrary because the proportions are complementary. Note that the (overall) proportion of PO target responses = PO target ratio × (1 − others) and that the proportion of DO target responses = (1 − PO target ratio) × (1 − others).

$p = .08$, $MSe = .052$; $F_2(2,46) = 1.97$, $p = .15$, $MSe = .047$.

ANOVAs on the PO target ratio revealed an effect of prime completion, $F_1(2,52) = 12.07$, $p < .001$, $MSe = .036$; $F_2(2,46) = 12.21$, $p < .001$, $MSe = .034$. Newman–Keuls tests, treating both participants and items as random effects, revealed that all three ratios differed from each other (all ps $< .05$).

Experiment 1 demonstrates that priming is a two-way effect. PO target completions (relative to DO target completions) were more frequent following PO prime completions than following baseline prime completions and were less frequent following DO prime completions than following baseline prime completions. In other words, both PO prime completions and DO prime completions affected the likelihood of producing a PO target completion on the subsequent trial. Indeed, the magnitude of priming was similar in both cases: The overall 25% priming effect (PO target ratio following PO prime completions minus PO target ratio following DO prime completions) was due to a combination of a 14% priming effect of PO prime completions (relative to baseline prime completions) and an 11% priming effect of DO prime completions.

Experiment 1 also shows an intriguing, but nonsignificant, trend toward a higher proportion of other target completions following baseline primes than following either PO or DO primes. We return to this in Experiment 3.

EXPERIMENT 2

Experiment 2 investigated whether shifted primes, containing a prepositional phrase followed by a noun phrase, behaved like PO primes. Because Experiment 1 supported balanced priming, such a finding would provide strong evidence for the dominance-only account. However, it is also possible that shifted primes do not behave like PO primes. Therefore, this experiment employed three conditions, just like Experiment 1, but replaced the baseline prime condition by the shifted prime condition. It also included PO and DO prime conditions.

Participants

A total of 30 participants from the University of Glasgow community took part.

Items

We constructed 24 sets of items. Each comprised two sentence fragments (see Appendix).

(2a) The racing driver showed the torn overall . . . (PO-inducing prime)
(2b) The racing driver showed the helpful mechanic . . . (DO-inducing prime)
(2d) The racing driver showed to the helpful mechanic . . . (shifted-inducing prime)
(3) The patient showed . . .

The items were the same as those in Experiment 1 except that the baseline condition (2c) was replaced by the shifted prime condition (2d), which was intended to induce shifted completions (e.g., "The racing driver showed to the helpful mechanic the serious problem with his car that had developed"). The critical characteristic of these primes is that they induce the order verb, prepositional phrase, or noun phrase, not that the noun phrase is especially long or "heavy" (see scoring below). In all three conditions, prime and target shared the same verb. A total of 96 filler fragments were constructed in the same way as in Experiment 1.

Procedure, Scoring, and Design and Data Analysis

These were the same as Experiment 1 except in the following respects. A shifted-inducing prime was scored as a shifted prime completion if the completion contained a patient (or theme) noun phrase (and other otherwise). There was no requirement for this noun phrase to be long. The prime completion factor had three levels (PO vs DO vs shifted prime). Note that target completions that employed the shifted construction were scored as others. Such cases were extremely rare and are discussed separately below.

Results and Discussion

Participants produced POs, DOs, or shifted completions for the prime fragments on 94% of trials (680 trials); of these, 31% were PO completions, 35% were DO completions, and 34% were shifted completions. Two cells on the par-

ticipants analysis in the DO prime completion condition were empty and, therefore, were replaced by the grand mean.

The proportions of other completions did not differ across conditions (both Fs < 1.2). ANOVAs on the PO target ratio revealed a significant effect of prime completion, $F_1(2, 58) = 9.59$, $p < .001$, $MSe = .052$; $F_2(2, 46) = 17.64$, $p < .001$, $MSe = .032$). Newman–Keuls tests revealed that all three ratios differed from each other ($p < .05$) except that the difference between the PO and shifted prime conditions was marginal on the participants analysis ($p = .065$). Participants produced shifted target responses on three occasions, all of them following a shifted prime (with two being from the same participant).

These results demonstrate that shifted primes do not produce the same proportion of PO target completions as do PO primes. In other words, at least some component of the representation of PO sentences that brings about syntactic priming is not replicated in the shifted prime sentences. Therefore, this is compatible with the claim that no dominance-only representation is constructed. However, it is possible that both the intermediate representation and a final ordered representation produce priming. In that case, we would expect to find a priming effect in the shifted prime condition but reduced relative to the PO prime condition. This explanation is unlikely for two reasons. First, the PO target ratio in the shifted condition (61%) was roughly halfway between the PO target ratios in the PO and DO conditions (72% and 46%, respectively). Second, the pattern was very similar to that in Experiment 1, where the baseline condition also fell roughly halfway between the other conditions. Thus, the shifted condition in Experiment 2 behaved very similarly to the baseline condition in Experiment 1. But to determine whether baseline primes and shifted primes produce equivalent PO target ratios, it is necessary to compare shifted and baseline conditions within a single experiment.

EXPERIMENT 3

Participants

A total of 60 participants from the University of Glasgow community took part.

Items

We constructed 32 sets of items. Each comprised two sentence fragments (see Appendix).

(2a) The racing driver showed the torn overall . . . (PO-inducing prime)
(2b) The racing driver showed the helpful mechanic . . . (DO-inducing prime)
(2c) The racing driver sneezed very . . . (baseline prime)
(2d) The racing driver showed to the helpful mechanic . . . (shifted-inducing prime)
(3) The patient showed . . .

The items were based on those in Experiments 1 and 2 and employed all four conditions within a single experiment. In (2a,b,d) but not in (2c), prime and target shared the same verb. The baseline prime included an adverb such as very after the verb. There were 128 fillers (48 noun phrases followed by a verb, 56 noun phrases followed by a verb and a noun phrase, 8 noun phrases followed by a verb in an *it*-cleft construction [e.g., “It was the park warden who spotted . . .”], 8 noun phrases followed by a verb in a *wh*-cleft construction [e.g., “What the kid hated . . .”], and 8 noun phrases followed by a verb and a noun phrase in an extraposed construction [e.g., “The waiter insulted the customer yesterday who . . .”]). We included these somewhat unusual sentence types so that the shifted-inducing primes would be less conspicuous.

Procedure, Scoring, and Design and Data Analysis

A shifted-inducing prime was scored as a shifted if the completion contained a patient (or theme) noun phrase (and other otherwise). The prime completion factor had four levels (PO vs DO vs shifted vs baseline). The experiment took about 35 min.

Results and Discussion

The prime was completed as POs, DOs, shifted, or baseline on 92% of all completions (1,759 trials); of these, 22% were completed as PO primes, 25% as DO primes, 26% as shifted primes, and 27% as baseline primes. Two cells on the participants analysis, one in the PO prime completion condition and one in the DO prime

completion condition, were empty and, therefore, were replaced by the grand mean.

For the other target analyses, ANOVAs revealed a main effect of prime completion, $F_1(3, 177) = 6.83$, $p < .001$, $MSe = .024$; $F_2(3,93) = 6.05$, $p < .001$, $MSe = .015$. In accord with Table 1, Newman–Keuls tests showed that participants produced more other target completions following baseline prime completions than following PO, DO, or shifted prime completions (all ps $< .02$) but that the other three conditions did not differ (all ps $> .19$).

Table 1 also shows that the PO target ratios differ across conditions. ANOVAs confirmed this observation, $F_1(3,177) = 14.18$, $p < .001$, $MSe = .042$; $F_2(3,93) = 13.88$, $p < .001$, $MSe = .026$. Planned comparisons demonstrated that shifted prime completions differed from PO prime completions, $F_1(1,59) = 4.44$, $p < .05$, $MSe = .039$; $F_2(1,31) = 4.83$, $p < .05$, $MSe = .027$, but they did not differ from baseline prime completions (both Fs < 1.0). Participants produced a shifted target response on two occasions: one following a shifted prime and one following a DO prime. In accord with the pattern found in Experiments 1 and 2, shifted prime completions did not appear to prime in the way that PO prime completions did, and shifted prime completions behaved similarly to baseline prime completions. Thus, there was no sign that shifted prime completions served as a prime for PO target completions.

The analysis of other completions demonstrated that participants produced more PO and DO target completions (combined) after they had produced PO, DO, or shifted prime completions than after they had produced baseline prime completions. This appears to be a second priming effect that is not directly related to the syntactic priming effect demonstrated by the tendency to produce PO target completions following PO prime completions and to produce DO target completions following DO prime completions. Instead, some property shared by PO and DO target completions is primed by PO, DO, and shifted prime completions but not by baseline prime completions. It is impossible to be certain of the source of the priming. Clearly, the PO, DO, and shifted primes share many properties (related to the fact that they can constitute alternative ways of describing the same event). This contrasts with the baseline primes, which describe very different kinds of events.

Thus, PO, DO, and shifted prime completions involved three arguments, whereas baseline completions did not involve three arguments. The PO and DO target completions involved three arguments. Hence, it is possible that this second priming effect reflects priming of the production of a particular number of arguments. However, the current analyses do not test this precisely because the definitions for scoring prime completions were not expressed in terms of number of arguments. Therefore, we conducted *argument analyses*, in which we rescored a prime completion as a PO if it completed a PO-inducing fragment and resulted in a sentence containing one main verb with exactly three arguments. For example, we allowed completions containing phrasal verbs, completions that involved prepositions apart from *to*, and completions involving different thematic roles. Similarly, a prime completion was scored as a DO if it completed a DO-inducing fragment and resulted in a sentence containing one main verb with exactly three arguments and was scored as a shifted if it completed a shifted-inducing fragment and resulted in a sentence containing one main verb with exactly three arguments. It was scored as a baseline if it completed a baseline-inducing fragment and resulted in a sentence containing a single main verb that did not involve three arguments.

Second, the priming conditions differed with respect to the number of entities that were involved in the event described. PO, DO, and shifted prime completions (as originally scored) typically described events involving three entities, whereas baseline completions typically described events involving one entity. However, there were some exceptions to this because the original scoring was not in terms of the number of entities involved. In the *entity analyses*, we scored a prime completion as a PO if it completed a PO-inducing fragment and resulted in a sentence containing one main verb associated with exactly three entities. An entity was defined in terms of a head noun. For example,

"The racing driver showed the torn overall that cost him the race during the interview" would count as a PO because *the torn overall that cost him the race* involves one head noun and *during the interview* contains the head noun *interview*. Note that the entities could be abstract (e.g., temporal expressions). The completion was scored as a DO if it completed a DO-inducing fragment and resulted in a sentence containing one main verb associated with exactly three entities and was scored as a shifted if it completed a shifted-inducing fragment and resulted in a sentence containing one main verb associated with exactly three entities. It was scored as a baseline if it completed a baseline-inducing fragment and resulted in a sentence containing a single main verb that was not associated with exactly three entities.

Both argument and entity analyses produced almost identical results to the main analyses. The proportions of other responses barely differed from the main analyses, and the statistical significance of all effects remained the same. Thus, Experiment 3 demonstrated two different types of priming. The effect of the form of the prime on the PO target ratio is a syntactic priming effect. Within this general priming effect, it showed that a shifted prime had the same effect as a baseline prime and, therefore, that it did not facilitate the production of PO target completions. But the experiment also showed that participants tended to produce PO or DO target completions more often after PO, DO, or shifted prime completions than after baseline prime completions. Further analyses suggested that the production of a prime either containing three arguments or referring to three entities facilitated the production of a PO or DO target, which contained three arguments and referred to three entities. This priming effect appears to reflect processing before choice of syntactic analysis was made, although it is impossible to localize the effect precisely. Therefore, it provides some evidence for the suggestion that participants in Hartsuiker and Kolk's (1998) experiments may have been primed to produce three-argument or three-entity responses by a PO, DO, or shifted prime versus a baseline prime. It is possible, of course, that some other difference between the baseline condition and the other conditions was responsible for the effect. For example, the baseline primes used different verbs from the targets, whereas the PO, DO, and shifted primes used the same verb as the targets. However, it is unclear why this difference should affect the proportion of others.

A possible concern with Experiments 2 and 3 is that participants might sometimes have failed to notice the preposition *to* after the verb and, thus, read the fragment as a DO-inducing prime. If this were the case, then they would have effectively produced a DO completion on those occasions and, hence, the DO structure would be primed. Therefore, it is conceivable that the lack of a priming effect for the shifted sentences in Experiment 3 might have been because participants sometimes completed the shifted-inducing prime fragment as a shifted sentence and sometimes completed it as a DO sentence. For this to have happened, participants would have to have written a DO completion to a shifted prime sufficiently often that the two priming effects would have "canceled out." The possibility that participants systematically misinterpret the prime can straightforwardly be tested by using an experimental task in which the preposition to has to be reproduced. Because writing out 160 complete sentences is too laborious for participants, we turned to spoken production for Experiment 4.

EXPERIMENT 4

Experiment 4 was a replication of Experiment 3 except that spoken sentence completion was employed, participants were required to reproduce the preamble as well as complete the prime sentence, and a computerized timed procedure was used (as in Branigan et al., 2000b). Note that a comparison of the results of Experiments 3 and 4 allows us to determine the extent to which spoken and written sentence completion methods produce similar results. Some evidence suggests this to be the case (Hartsuiker & Westenberg, 2000). Other evidence suggests that the relationship between the methods may be more complex. Branigan et al. (1999) found strong priming with written sentence completion so long as no sentences intervened between prime and target, but they also found that priming rapidly decayed if even

one sentence intervened between prime and target. In contrast, Branigan et al. (2000b) found that priming persisted over an intervening sentence in spoken sentence completion. This result is in accord with Bock and Griffin (2000), who found that syntactic priming persisted over as many as 10 trials in the (spoken) picture description method (Bock, 1986).

Participants

A total of 32 participants from the University of Edinburgh community took part.

Items

The items in this experiment were identical to those in Experiment 3 (see Appendix).

Procedure

This experiment was presented using PsyScope software (Cohen, MacWhinney, Flatt, & Provost, 1993).[AU4] Participants were told that we were interested in seeing what sorts of sentences people produce. They were instructed to read out loud the sentence fragments and then complete the sentence in any way they liked, ensuring that they produced a grammatical sentence. Each experimental trial consisted of a fixation point ("+") appearing at the side of the screen for 1,000 ms. This was then replaced with a sentence fragment. The first letter of the first word of the fragment appeared in the location where the fixation point had been. The fragment remained in the screen for 7,000 ms. The screen was then cleared, and after a 1,000-ms delay, a beep occurred. A further delay of 1,000 ms occurred before the next item was presented.

Participants took part in a short practice experiment 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 25 min and contained two breaks, the duration of which was under the participants' control.

Scoring

The tape for each participant was transcribed and scored. Scoring was as in Experiment 3 except that a response was scored as an other if the fragment was incorrectly repeated.

Design and Data Analysis

These were the same as in Experiment 3. The prime completion factor had four levels (PO vs DO vs shifted vs baseline).

Results and Discussion

The primes were completed as POs, DOs, shifted, or baseline on 86% of all responses (876 trials); of these, 23% were completed as PO primes, 24% as DO primes, 26% as shifted primes, and 28% as baseline primes. One cell on the items analysis, in the PO prime completion condition, was empty and, therefore, was replaced by the grand mean.

For the other target analyses, ANOVAs revealed a marginal main effect of prime completion, $F_1(3,93) = 2.45$, $p = .07$, $MSe = .027$; $F_2(3,93) = 2.54$, $p = .06$, $MSe = .027$. Although there were numerically more others following baseline primes than following the other conditions, a planned comparison of the baseline prime condition and the mean of the other conditions was not significant (both ps $> .10$).

Table 1 shows that the PO target ratios differ across conditions. ANOVAs confirmed this observation, $F_1(3,93) = 8.49$, $p < .001$, $MSe = .040$; $F_2(3,93) = 6.94$, $p < .001$, $MSe = .035$. Hence, the usual syntactic priming effect occurred in this experiment. Planned comparisons demonstrated that shifted prime responses differed from PO prime responses, $F_1(1,31) = 4.99$, $p < .05$, $MSe = .040$; $F_2(1,31) = 4.41$, $p < .05$, $MSe = .042$, but they did not differ from baseline prime responses (both Fs < 1.0). In accord with the pattern found in Experiments 1 to 3, shifted prime responses did not appear to prime in the way that PO prime responses did, and shifted prime responses behaved similarly to baseline prime responses. Thus, there was no sign that shifted prime responses served as a prime for PO target responses.

The preposition *to* in the shifted prime was missed on five prime trials (with one participant accounting for four of these trials). A shifted response was given in the target on five occasions: two after a DO prime response (both from the

same participant), two after a shifted prime response, and one after an other prime response.

In conclusion, the results of Experiment 4 are comparable to those of Experiment 3. The effects in this experiment cannot be due to participants failing to notice the preposition in the shifted prime condition. The results, therefore, provide further support for the claim that shifted primes behave similarly to baseline primes with respect to the proportions of PO and DO target responses produced. They also lend support to the claim that written sentence completion and spoken sentence completion (together with reproduction of the preamble) produce comparable results and, therefore, are likely to be equally valid methods for using syntactic priming to investigate language production.

GENERAL DISCUSSION

Experiment 1 demonstrated that priming was balanced so that it was possible to prime both PO and DO forms in relation to a baseline (that was not completed as either a PO or a DO). Experiment 2 showed that shifted primes did not behave like PO primes; production of PO target completions was less common following shifted prime completions than following PO prime completions. Experiment 3 confirmed that shifted prime completions behaved like baseline prime completions with respect to the production of PO versus DO target completions. Experiment 4 found similar results to those of Experiment 3 when participants orally repeated the preamble and completed the sentence.

Shifted target responses were extremely rare, presumably because the construction is fairly uncommon in English. They are more common when the final noun phrase is particularly long or "heavy," but such completions were not encouraged by the experimental methods used (in comparison, e.g., to the methods used by Stallings et al., 1998). Hence, syntactic priming does not appear to be strong enough to cause this tendency to be systematically overruled. In Experiments 2 to 4, there were a total of 10 shifted target responses (produced by eight different participants). Of these 10 responses, 1 followed an other prime response. Of the other 9 responses, 6 followed shifted prime responses, 3 followed DO prime responses, and none followed either PO or baseline prime responses (but recall that there was no baseline condition in Experiment 2). Although these small numbers make statistical analysis risky, the data suggest that shifted target responses are more common following shifted prime responses than following PO prime responses and perhaps that shifted target responses do not occur more often following PO prime responses than following DO prime responses. These findings suggest that the production of shifted responses is affected by the prior production of shifted responses but not by the prior production of PO responses. This is in accordance with the single-stage account but not the dominance-only account. Note that the small proportion of shifted target responses may suggest that participants do not normally produce shifted sentences in conditions comparable to those in this experiment (e.g., isolated sentence completion). If so, then participants may be producing shifted prime completions in a way that is dissimilar to sentence production in the other conditions (and elsewhere). However, the fact that participants did produce (grammatical) shifted prime completions just as often as they did PO, DO, and baseline completions provides good evidence that shifted sentences are unusual but completely acceptable (as argued in other work, e.g., Hawkins, 1994; Stallings et al., 1998).

However, our data show that the likelihood of producing a shifted target response is nearly zero. The data are compatible with the single-stage account because the shifted prime bears no special relationship with PO target responses any more than with DO target responses. They are hard to reconcile with the dominance-only account because the effect of a shifted prime, like that of a PO prime, should be to increase the activation of the PO/shifted dominance-only node (Fig. 1a). Because the likelihood of producing a shifted response is (nearly) zero, all of the increased activation at the PO/shifted node should benefit the production of PO target responses. Thus, PO and shifted primes should not differ in their effects on PO target responses, and both should differ from baseline primes. In fact, shifted primes behaved like baseline primes rather than like PO primes.

Together, the experiments reported in this paper provide evidence for the single-stage account, whereby language production involves the mapping of a pre-syntactic representation to a representation that is fully specified syntactically. Our experiments specifically suggest that production does not involve the computation of a dominance-only level of representation. Although other multiple-stage accounts are in principle possible, the results provide no reason for adopting such models.

Our conclusion appears to run counter to the conclusion of Vigliocco and Nicol (1998). Following Bock and Miller (1991), there is considerable evidence that the verb sometimes erroneously agrees with non-head nouns within a complex subject such as *helicopters* in "the flight of the helicopters." Vigliocco and Nicol (1998) found that such errors were just as common when the subject noun phrase followed the verb (e.g., "Were the flight of the helicopters safe?") as when it preceded the verb (e.g., "The flight of the helicopters were safe"). From this, they inferred two separate stages in grammatical encoding, with the first stage involving the computation of hierarchical structure and functional relations in the absence of ordering information. On their account, subject–verb agreement occurs during the first stage. However, it is also possible that agreement may have been computed before the computation of hierarchical structure, for instance, at the functional level assumed by Bock and Levelt (1994).

Combinatorial Nodes in the Lemma Stratum

So far, we have interpreted our results in terms of the levels of representation employed during the production of utterances. The results also shed light on production from a somewhat different perspective, namely the nature of the lexical representations accessed during production. Roelofs (1992, 1993) and Levelt et al. (1999) argued that this lexical information is represented at three levels or strata: a *conceptual stratum* (containing semantically specified concepts), a *lemma stratum* (encoding syntactic information), and a *word form stratum* (encoding morphological and phonological information). Pickering and Branigan (1998) expanded on the model of the lemma stratum, in particular, by characterizing the way in which it encodes syntactic information that is associated with lexical entries. This information includes (major) category information (e.g., noun, verb), featural information (e.g., number, person, tense), and combinatorial information. Combinatorial information specifies the way in which a word can combine with other linguistic units to form possible expressions of the language. Thus, a verb such as *give* can combine with arguments (e.g., *the man*, *the book*, *to the boy*) that correspond to the participants in the action denoted by the verb. Pickering and Branigan proposed that the lemma stratum encodes this information by means of lemma nodes, representing the base form of words, and syntactic property nodes, which are connected to the lemma nodes via labeled links.

For example, the lemma *give* is connected to the syntactic category node *verb* and various featural nodes such as present tense, past tense, singular number, and plural number. The verb node is activated whenever *give* is activated, and the relevant feature nodes are activated as appropriate. Thus, when the form *gives* is used in a sentence, the present tense and singular number nodes are activated. The lemma *give* is also linked to combinatorial nodes that are activated when the verb is used in a particular syntactic construction. Pickering and Branigan (1998) proposed that the *NP,NP* node is activated when *give* is used in the DO construction (e.g., "give the boy a book") and that the *NP,PP* node is activated when *give* is used in the PO construction (e.g., "give a book to the boy"). However, they did not commit to a precise specification of the circumstances under which particular nodes were activated. One issue concerns whether the nodes correspond to traditional subcategorization frames or whether they are activated whenever the verb is associated with appropriate phrases, which can be either arguments or adjuncts of the verb. Pickering and Branigan noted that Bock and Loebell's (1990) findings provide some evidence for this latter account (but cf. Potter & Lombardi, 1998).

The evidence against a dominance-only representation suggests that the nodes are speci-

fied for the order of phrases. This suggests that there are three different nodes: *NP,NP*; *NP,PP*; and *PP,NP*. The processor appears to make a straightforward choice among the three nodes at a single stage during production. Selection of a verb lemma is associated with selection of a combinatorial node that mandates construction of a fully specified constituent structure. Hence, it appears that once people have constructed earlier levels of representation (e.g., functional structure), they are ready to make a choice about which construction to use. Priming affects the choice of structure. It appears that construction of syntactic structure takes place in a single stage. In this respect at least, the number of levels of representation employed during sentence formulation is minimized.

APPENDIX

Items for Experiments 1 and 2

For each item, the first sentence contains the PO-inducing prime before the slash and the DO-inducing prime after the slash. The second sentence contains the baseline prime from Experiment 1. To reconstruct the shifted-inducing prime, add the word *to* after the verb in the DO-inducing fragment (e.g., "The mother gave to the hungry baby " in Item 1). The final sentence contains the target fragment.

1. The mother gave the expensive toy/the hungry baby. The mother sneezed. The air hostess gave.
2. The architect gave the latest plans/the cheerful engineer. The architect sneezed. The teacher gave.
3. The lecturer gave the book/the professor. The lecturer coughed. The shopkeeper gave.
4. The hostess handed the dessert/the guests. The hostess hiccupped. The news agent handed.
5. The efficient secretary handed the long fax/the grumpy businessman. The efficient secretary sneezed. The little girl handed.
6. The grandmother handed the big present/the little girl. The grandmother ached. The tennis fan handed.
7. The millionaire loaned the valuable painting/the struggling artist. The millionaire coughed. The explorer loaned.
8. The swimmer loaned the towel/the diver. The swimmer ached. The draftsman loaned.
9. The woman loaned the rusty bike/the new neighbour. The woman fainted. The librarian loaned.
10. The man lent the lawnmower/the neighbour. The man fainted. The actor lent.
11. The fashion designer lent the pink jacket/the famous journalist. The fashion designer itched. The diver lent.
12. The car salesman lent the mini/the couple. The car salesman snored. The forest ranger lent.
13. The booking clerk posted the last ticket/the young fan. The booking clerk hiccupped. The serial killer posted.
14. The blackmailer posted the incriminating photos/the sleazy journalist. The blackmailer coughed. The lonely sailor posted.
15. The captain gave the spare life jacket/the old sailor. The captain ached. The bus driver gave.
16. The disgruntled employee sent the long letter/the managing director. The disgruntled employee snored. The famous novelist sent.
17. The secretary sent the invoice/the manager. The secretary coughed. The boyfriend sent.
18. The woman sent insurance claim/the insurance company. The woman hiccupped. The fan sent.
19. The racing driver showed the torn overall/the helpful mechanic. The racing driver fainted. The patient showed.
20. The youngster showed the toy/the teacher. The youngster itched. The private detective showed.
21. The lifeguard showed the lifebelt/the surfer. The lifeguard sneezed. The inventor showed.
22. The cricket player showed the ball/the umpire. The cricket player ached. The car mechanic showed.
23. The bank manager handed the cheque/the customer. The bank manager snored. The junior surgeon handed.
24. The builder lent the drill/the surveyor. The builder snored. The hairdresser lent.

Items for Experiment 3 and 4

For each item, the first sentence contains the PO-inducing prime before the slash and the DO-inducing prime after the slash. The second sentence contains the baseline prime. To reconstruct the shifted-inducing prime, add the word *to* after the verb in the DO-inducing fragment (e.g., "The racing driver showed to the helpful mechanic" in item 1). The final sentence contains the target fragment.

1. The racing driver showed the torn overall/the helpful mechanic. The racing driver sneezed very. The patient showed.
2. The youngster showed the toy/the teacher. The youngster clapped extremely. The private detective showed.
3. The lifeguard showed the lifebelt/the surfer. The lifeguard yelled quite. The inventor showed.
4. The cricket player showed the ball/the umpire. The cricket player yelled very. The car mechanic showed.

5. The efficient secretary handed the long fax/the grumpy businessman. The efficient secretary sneezed extremely. The little girl handed.
6. The grandmother handed the big present/the little girl. The grandmother yawned very. The tennis fan handed.
7. The hostess handed the dessert/the guests. The news agent handed. The hostess snored rather. The news agent handed.
8. The bank manager handed the cheque/the customer. The bank manager yelled extremely. The junior surgeon handed.
9. The captain gave the spare lifejacket/the old sailor. The captain snored extremely. The bus driver gave.
10. The mother gave the expensive toy/the hungry baby. The mother laughed quite. The air hostess gave.
11. The architect gave the latest plans/the cheerful engineer. The architect laughed very. The teacher gave.
12. The lecturer gave the book/the professor. The lecturer giggled rather. The shopkeeper gave.
13. The millionaire loaned the valuable painting/the struggling artist. The millionaire yawned quite. The explorer loaned.
14. The swimmer loaned the towel/the diver. The swimmer yelled quite. The draftsman loaned.
15. The woman loaned the rusty bike/the new neighbour. The woman giggled very. The librarian loaned.
16. The booking clerk posted the last ticket/the young fan. The booking clerk laughed quite. The serial killer posted.
17. The blackmailer posted the incriminating photos/the sleazy journalist. The blackmailer laughed extremely. The lonely sailor posted.
18. The car salesman lent the mini/the couple. The car salesman grumbled very. The forest ranger lent.
19. The man lent the lawnmower/the neighbour. The man snored rather. The actress lent.
20. The fashion designer lent the pink jacket/the famous journalist. The fashion designer clapped extremely. The diver lent.
21. The builder lent the drill/the surveyor. The builder sneezed quite. The hairdresser lent.
22. The chairman sent the long letter/the managing director. The chairman yawned extremely. The famous novelist sent.
23. The accountant sent the invoice/the client. The accountant giggled quite. The boyfriend sent.
24. The customer sent the insurance claim/the insurance company. The customer clapped quite. The fan sent.
25. The nurse showed the X-ray/the doctor. The nurse yawned extremely. The jeweler showed.
26. The courier handed the parcel/the receptionist. The courier sneezed rather. The child handed.
27. The chief librarian sent the reminder/the student. The chief librarian grumbled very. The thoughtful granddaughter sent.
28. The young woman loaned the necklace/the teenager. The young woman grumbled rather. The motorist loaned.
29. The researcher posted the detailed questionnaire/the eager journalist. The researcher snored rather. The personnel manager posted.
30. The spy sold the stolen documents/the foreign diplomat. The spy grumbled rather. The shop assistant sold.
31. The florist gave the huge bouquet/the startled butler. The florist giggled rather. The pharmacist gave.
32. The receptionist lent the spare key/the busy assistant. The receptionist clapped very. The Coast Guard lent.

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