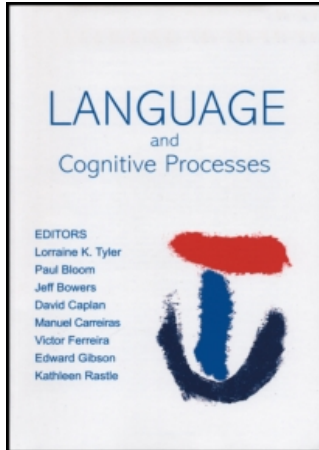


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The role of local and global syntactic structure in language production: Evidence from syntactic priming

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The role of local and global syntactic structure in language production: Evidence from syntactic priming

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Experimental research has provided evidence for an autonomous stage of syntactic processing during language production. We report eight syntactic priming experiments that investigated whether this stage uses the same procedures to produce phrases with a particular structure when they appear in different syntactic contexts. Experiments 1–3 demonstrated syntactic priming for verb phrase structure in main clauses, irrespective of whether the global structure of the prime and target sentences varied. Experiments 4–6 demonstrated syntactic priming for verb phrase structure in subordinate clauses, both when prime and target were both subordinate clauses, and when one was a subordinate clause and the other was a main clause. Experiments 7 and 8 directly compared syntactic priming between main and subordinate clauses with priming between main clauses and priming between subordinate clauses. We interpret these results as evidence that the processor uses the same procedures to build syntactic structure in different syntactic contexts.

When people produce sentences, they must convert a message into a series of sounds. Research on language production suggests that this conversion involves a series of intermediate levels of representation (e.g., Garrett,

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1980; Levelt, 1989). The initial stage, conceptualisation, specifies the idea or message that the speaker wishes to convey. The second stage, formulation, involves converting the message into a series of linguistic representations. In the last stage, articulation, this linguistic structure is realised as a program of motor movements. In this paper, we consider formulation, and in particular the construction of syntactic structure. Specifically, we assume the existence of at least one autonomous level of syntactic representation that is concerned with the grammatical structure of utterances independent of their sound or meaning (e.g., Bock & Levelt, 1994).

But how are such syntactic procedures specified with respect to the part of the sentence to which they make reference? One possibility is that they can be specified with respect to limited information, so that the processor does not make reference to the structure of the whole sentence or some larger expression within a sentence during the production of individual expressions. Other expressions may undergo syntactic processing in parallel, but during normal (error-free) production, they are not relevant to the construction of the target expression. For example, in producing a simple utterance like The man sneezed, it might be that people formulate the man (rather than man the or some other expression entirely) in a way that pays no attention to the production of the verb sneezed. Of course, the verb sneezed may instigate the production of a noun phrase, but it does not play any further role in determining the structure of that noun phrase. Alternatively, syntactic procedures may obligatorily make reference to more information, so that the structure of either the whole sentence or some larger expression within a sentence is relevant in the production of individual expressions.

In this paper, we report eight experiments that exploited the tendency for people to repeat syntactic structure between utterances, in order to see whether the procedures that people use to combine expressions remain constant, irrespective of the role that those expressions play within the sentence as a whole. If these procedures remain constant when the relevant expressions play very different roles, it would suggest that the procedures involved in syntactic processing need not make reference to the structure of the whole sentence or some larger expression within it.

REPRESENTING SYNTACTIC INFORMATION

Speakers must ensure that their utterance accords with the rules of their language's grammar; for example, in English it is grammatical to say The girl gave the boy the puppy (the Double Object, or DO structure) or The girl gave the puppy to the boy (the Prepositional Object or PO structure),

but not Gave the girl the boy the puppy. To do this, the speaker must apply procedures that lead to the construction of the appropriate syntactic structure. For example, in constructing the PO structure, the speaker would form the appropriate verb phrase by applying a procedure (or procedures) that combines the verb give, the noun phrase the puppy, and the prepositional phrase to the boy. More generally, the procedure would combine a verb, a noun phrase, and a prepositional phrase (in that order) to produce a verb phrase.

Such procedures may be defined with respect to just those constituents that make up that structure, in what we shall term a *local* account. In this case, the procedure would take as its input the verb, the noun phrase, and the prepositional phrase. On this account, the same procedure would be applied to construct the ditransitive verb phrase gave the puppy to the boy in The girl gave the puppy to the boy and John said that the girl gave the puppy to the boy. In contrast, in a *global* account the procedure would make reference to aspects of the sentence that do not form part of the structure. In this case, different procedures might be used to construct gave the puppy to the boy for the two sentences. Note that the two accounts are not necessarily mutually exclusive: the processor might make use of both locally and globally defined procedures. In this paper our primary concern is with whether it can make use of locally defined procedures, or whether it must obligatorily make use of procedures that make reference to (some aspect of) global structure.

Most research on language production appears to assume a local account (e.g., Bock & Loebell, 1990; Garrett, 1980; Kempen & Hoenkamp, 1987; Pickering & Branigan, 1998). For example, Pickering and Branigan (1998) proposed a network model of lexico-syntactic representation in which individual verbs are associated with combinatorial nodes that specify the expressions with which they can combine to form a larger expression. These nodes make no reference to syntactic context, other than the identity of the verb. Hence in this model, the same combinatorial node is always involved in the production of a verb phrase like gave the puppy to the boy, whether it is part of a sentence like The girl gave the puppy to the boy or John said that the girl gave the puppy to the boy. But what evidence is there for the assumption that syntactic processing in production can be local in this sense?

A large body of work concerned with the building of syntactic structure has drawn on data from syntactic priming, or the tendency for people to repeat syntactic structure across utterances. Studies of naturally occurring speech suggest that people tend to repeat grammatical structure (Schenkein, 1980; Tannen, 1989). For example, interviewees were more likely to use a passive if a passive had recently been employed in the interview (Weiner & Labov, 1983). Bock (1986) provided a controlled

experimental demonstration of this tendency to repeat syntactic structure. Under the guise of a memory test, speakers alternated 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 PO form of an alternating dative verb in one condition (e.g., A rock star sold some cocaine to an undercover agent) and the DO form in the other condition (e.g., A rock star sold an undercover agent some cocaine). Participants tended to produce a PO description of the target picture after a PO prime and a DO description of the target picture after a DO prime. Active/passive sentences produced comparable effects. This phenomenon is known as *syntactic priming* (or syntactic persistence).

There have been many subsequent demonstrations of syntactic priming with a range of constructions and methods, and in other languages (see Ferreira & Bock, 2006; Pickering & Branigan, 1998). Such research has provided clear evidence that the effects are truly syntactic and are unlikely to be a byproduct of repetition at other levels, such as lexical, semantic, prosodic, or focus structure (Bock, 1989; Bock & Loebell, 1990; Hartsuiker & Westenberg, 2000). They occur in the absence of closed class and open class lexical repetition (Bock, 1989); when the prime and target sentences share syntactic structure but not event structure (e.g., locative sentences prime passive sentences; Bock & Loebell, 1990); and for structural alternations that do not differ in focus structure (e.g., main/auxiliary verb word order in Dutch; Hartsuiker & Westenberg, 2000). A focus-based account is also excluded by Scheepers (2003), who found no priming for sentences that shared focus structure (in terms of which entity was modified by a subordinate clause) but did not share syntactic structure. We can also exclude prosodic explanations, as grammatically distinct sentences with similar prosodic structure do not prime each other (Bock & Loebell, 1990).

Bock and Loebell (1990) argued that the repetition of sentence structure therefore provides evidence for hierarchical constituent representations in language production, which are not associated with conceptual, phonological, or metrical information. On the basis of evidence for syntactic priming between verb phrases that differed in detailed syntactic structure, Pickering and Branigan (1998) argued explicitly for the existence of processes and representations in language production that make reference to only immediate syntactic structure (i.e., do not make reference to aspects of syntactic structure other than the identity of the verb and the immediate expressions with which it combines to form a larger expression). More specifically, they found reliable priming when the prime and target verb phrase differed with respect to the internal structure of complement noun phrases. Hence it appears that speakers recognise

relationships between sentences that have the same constituent structure at one level (in this case, at the level of the verb and its complements) but not at another level (in this case, the internal structure of the complements). Pickering and Branigan explained syntactic priming in terms of combinatorial nodes. When a prime sentence is processed, it activates the relevant combinatorial nodes; these nodes subsequently retain activation, facilitating their re-use. Alternative accounts explain priming as the result of implicit learning of syntax (Bock & Griffin, 2000; Chang, Dell, Bock, & Griffin, 2000).

But in all of the experiments described above, prime and target sentences had the same global structure (i.e., structure above the level of the verb phrase). Hence these experiments are equally compatible with the possibility that the processor obligatorily makes reference to (some aspect of) global syntactic structure when constructing a phrase like gave the puppy to the boy. Certainly there is evidence that speakers are able to process more than one clause at a time. For example, speech error data show that speakers may simultaneously process more than one clause (Bock & Cutting, 1992; Garrett, 1980) and Smith and Wheeldon (1999) demonstrated that speakers take longer to initiate utterances involving two clauses than one clause. These results suggest that some aspect of the second clause can be processed prior to articulation of the second clause. However, they do not necessarily mean that speakers make reference to global syntactic structure when constructing local syntactic structures.

Scheepers (2003) reported data that suggest that syntactic priming may not straightforwardly reflect the repetition of local syntactic structure. He investigated (the German translation of) sentences such as The assistant announced the score of the candidate, which was unexpectedly poor. Such sentences are globally ambiguous: The relative clause which was unexpectedly poor might modify the first noun phrase the score or the second noun phrase the candidate. He found that prior production of a German sentence with a high-attached relative clause (RC) such as (the German translation of) The assistant announced the score of the candidate, which was unexpectedly poor increased the likelihood of subsequently producing another high-attached relative clause, whereas prior production of a low-attached relative clause such as The assistant announced the score of the candidate, who had performed very well increased the likelihood of producing a low-attached relative clause. Both types of sentence involve the same local syntactic structure ([NP RC]), but they differ in the noun phrase to which this structure applies. In the high-attached case, it applies to the first noun phrase (in which the second noun phrase is embedded); in the low-attached case, it applies to the second noun phrase (which is embedded in the first noun phrase). Hence, Scheepers' results cannot be explained in terms of the increased activation

of one structure over another; instead the priming effect is associated with the same syntactic structure in two different global syntactic structures. A straightforward explanation of his results is that the processor makes reference to global syntactic structure when constructing local syntactic structures.

Thus although most research seems to have implicitly assumed that syntactic processing in production makes reference to just those constituents that immediately make up a structure, there is little evidence to support this claim, and some evidence which may argue against it. It is therefore an open question whether syntactic activation obligatorily makes references to global syntactic structure. To test this, we would need to see whether priming occurs when prime and target involve different global structures, for example if the prime contains a dative-alternating construction embedded in a complex sentence whereas the target involves a simple main-clause dative.

EXPERIMENTS

We now report a series of experiments that investigated whether people construct syntactic structure using procedures that obligatorily make reference to (some aspect of) global structure. The experiments employed syntactic priming to investigate the conditions under which people tend to repeat syntactic structure between sentences. In all experiments, we manipulated the syntactic structure of a verb phrase in the prime sentence, and examined whether this primed the production of the same verb phrase structure in an immediately following target sentence. We will refer to the manipulated verb phrase as the experimental verb phrase and the verb as the experimental verb. Hence, the prime and target sentences always involved verb phrases with the same local structure, meaning that they had the same constituents in the same order. Additionally, we manipulated whether the verb phrase appeared in sentences that had the same or different global structure, meaning that the sentences were the same or different with respect to the syntactic structure of those parts of the sentence that did not form part of the verb phrase.

In all experiments, the experimental verb was a dative-alternating verb like give, lend, or show, which meant that the experimental verb phrase could occur in one of two forms with very similar meanings. For example, the verb show is compatible with the PO form the patient showed his injury to the doctor or the DO form the patient showed the doctor his injury. Prior research has made extensive use of this construction, and it provides some of the clearest evidence that priming is truly syntactic in origin (Bock, 1986, 1989; Bock & Loebell, 1990; Branigan, Pickering, &

Cleland, 2000a; Pickering & Branigan, 1998; Pickering, Branigan, & McLean, 2002). Priming of such structures occurs both when the verb is repeated between prime and target (e.g., Branigan et al., 2000a; Pickering & Branigan, 1998; Cleland & Pickering, 2006), and when it is not (e.g., Bock, 1986, 1990), but is stronger when the verb is repeated (Branigan et al., 2000a; Pickering & Branigan, 1998; Cleland & Pickering, 2006); for this reason our experiments used the same verb in prime and target.

In Experiments 1–6, we examined whether syntactic priming occurred in the absence of shared global structure. Experiment 1 established that syntactic priming occurred when prime and target sentences were both simple main clause sentences comprising a subject noun phrase and the experimental verb phrase. In Experiments 2 and 3, we introduced an additional phrase at the beginning of the prime sentences, so that the global structure ceased to be identical between prime and target. Experiments 4, 5, and 6 introduced a potentially more important manipulation of global structure, by using a complex sentence for either prime or target sentence or both. Specifically, we manipulated whether the experimental verb phrase appeared in a main clause or in a subordinate clause. If syntactic processing in production makes use of locally defined procedures, as many accounts of production implicitly assume, then syntactic priming should occur under all of these conditions, as the local syntactic structure associated with the experimental verb phrase remained constant. However, if syntactic processing does not make use of locally defined procedures and obligatorily makes reference to global structure, then priming should occur in Experiments 1 and 4, where the prime and target sentences had the same global structure, but not necessarily in the other experiments.

EXPERIMENT 1: PRIMING FROM 'SIMPLE' MAIN CLAUSE TO MAIN CLAUSE

Method

Participants. Eighteen participants from the University of Glasgow community were paid to participate. The participants in this experiment and in all the subsequent experiments were native speakers of English.

Items. We constructed 18 sets of items. Each comprised two sentence fragments (see Appendix):

- 1a. The racing driver shows the torn overall . . . (PO-inducing prime)
- 1b. The racing driver shows the helpful mechanic . . . (DO-inducing prime)
2. The patient shows . . . (target)

The prime fragments (1a-b) contained a subject noun phrase followed by a present-tense verb that could appear in the PO or DO construction, and a post-verbal noun phrase that was compatible with a PO (1a) or DO completion (1b). The target fragment (2) contained a subject noun phrase followed by the same verb as the prime fragments. We employed six verbs which previous work had shown to reliably induce PO and DO completions (e.g., Pickering & Branigan, 1998). Noun phrases comprised a determiner followed by a noun, a noun compound, or an adjective and a noun. We also constructed 72 filler fragments: 36 were noun phrases (of varying types), 18 comprised a subject noun phrase and a verb, and 18 comprised a subject noun phrase, a verb, and a post-verbal noun phrase.

Procedure. The experimental items were placed into two lists, each comprising nine items from each condition, such that one version of each item appeared in each list. The 108 fragments (18 prime fragments, 18 target fragments, and 72 filler fragments) were individually randomised, with the constraints that each prime fragment immediately preceded its associated target fragment, and at least 3 filler fragments intervened between experimental items. Each fragment was presented as an individual trial; participants were not informed of any relationship between prime and target fragments.

Participants were told that we were interested in seeing what sorts of sentences people produce. They were asked to read each fragment, then to complete it with the first grammatical completion that came to mind, saying the entire sentence aloud.

The experimental files were presented using PsyScope software (Cohen, MacWhinney, Flatts, & Provost, 1993). First, a fixation point ('+') appeared in the centre of the screen for 1000 ms. This was then replaced with a sentence fragment, with the first letter appearing in the location where the fixation point had been presented. After 5000 ms, the fragment was replaced with a blank screen for 1000 ms, then a beep sounded. The screen remained blank for a further 1000 ms, and then the next trial began. Participants' responses were recorded. The experiment began with a practice session of 10 further filler fragments. The experiment took about 20 minutes and contained two breaks whose duration was under participants' control.

Scoring. Participants' responses to each experiment fragment were scored as PO, DO, or Other. A completion of a PO-inducing prime fragment was scored as a PO prime response if it contained a goal noun phrase which was the object of the preposition *to*. A completion of a DO-inducing prime fragment was scored as a DO prime response if it contained a patient or theme noun phrase. To be scored as either a PO or a

DO response, the verb provided in the fragment could not be part of a phrasal verb (e.g., The architect hands the latest plan over to the builder). All other prime completions were scored as Others. Note that if a participant completed a DO-inducing prime fragment as a PO (e.g., completing The mother gives the baby . . . with . . . to her husband), or completed a PO-inducing fragment as a DO, the completion was scored as an Other.

A completion of a target fragment was scored as a PO target completion if the verb provided in the fragment was immediately followed by a noun phrase which acted as the patient or theme and then by a prepositional phrase beginning with to which acted as the recipient/goal. A completion of a target fragment was scored as a DO target completion if the verb was immediately followed by a noun phrase which acted as the recipient/goal and then by a noun phrase which acted as the patient or theme. To be scored as either a PO or DO response, it had to have a grammatical alternative in the other category, where the order of the patient and recipient/goal was reversed. Additionally, the verb provided in the fragment could not form part of a phrasal verb. All other target completions were scored as Others.

Design and data analysis. Each participant completed 18 target fragments, nine in each of the two priming conditions defined by the Prime Completion factor (PO vs. DO prime response). Each experimental item was presented to all 18 participants, with 9 participants seeing any one version of an item.

We analysed the results by treating the PO, DO, and Other target completions separately. Our first set of results, the *PO target analyses*, was performed over the proportion of PO target completions following PO prime completions and the proportion of PO target completions following DO prime completions. We calculated proportions because participants may have produced different numbers of Other completions in the different prime completion conditions.

We computed the relevant proportions by dividing the number of PO target completions that were produced after the prime had been completed as a PO (we term these *PO-PO completions*, with the first PO referring to the structure of the prime completion and the second PO referring to the structure of the target completion) by the total number of PO prime completions (i.e., PO-PO completions / (PO-PO + PO-DO + PO-OTHER completions)); and the number of PO target completions that were produced after the prime had been completed as a DO (DO-PO completions) by the total number of DO prime completions (i.e., DO-PO target completions / (DO-PO + DO-DO + DO-OTHER completions)).

Similarly, we computed the *DO target analyses* using the equivalent formulae: PO-DO completions / (PO-PO + PO-DO + PO-OTHER completions); and DO-DO completions / (DO-PO + DO-DO + DO-OTHER completions). We conducted analyses for both PO and DO target completions because it would be arbitrary to choose one rather than the other. We can be more confident about any conclusions if both sets of analyses are significant. A final set of analyses, the *Other target analyses*, was performed over the proportions of Other target completions following PO prime completions, and over the proportion of Other target completions following DO prime completions. If there are no differences in the Other analyses, it suggests that the effects of priming relate to choice of which syntactic structure to use to describe a particular message, rather than influencing choice of which message to convey.

These proportions were calculated for each participant and for each item. Analyses of variance were performed on these data, with separate analyses treating participants (F_{1s}) and item (F_{2s}) as random effects. Prime completion was the within-participants and within-items factor.

Results and discussion

Participants completed prime fragments on 324 trials, of which 292 were completed as either a PO or a DO prime response (90% of all responses). Of these, 49% were completed as PO prime responses and 51% as DO prime responses. In these 292 trials, participants produced 124 (42%) PO target completions, 104 (36%) DO target completions, and 64 (22%) Other target completions.

Table 1 shows the proportions of PO, DO, and Other target completions in the two experimental conditions. Inspection of Table 1 shows a priming effect for both the PO and DO target responses. Priming, the mean of the difference between the PO prime-PO target and DO prime-PO target, and the difference between DO prime-DO target and PO prime-DO target, was 28% in both cases. For the PO target analyses, one-way ANOVAs revealed significant differences between the prime conditions, $F_1(1, 17) = 31.7, p < .001, MSe = 0.025$; $F_2(1, 17) = 18.8, p < .001, MSe = 0.035$: there were more PO target completions after a PO prime than a DO prime. Similarly, for the DO target analyses, one-way ANOVAs revealed significant differences between the Prime Completion conditions, $F_1(1, 17) = 24.0, p < .001, MSe = 0.028$; $F_2(1, 17) = 23.4, p < .001, MSe = 0.029$: there were more DO target completions after a DO prime than a PO prime. There was no difference for the Other target completions ($F_s < 1$).

An additional set of analyses was performed on the arcsine-transformed proportions of responses for both participants and items. Since the results of these additional analyses showed the same pattern of effects as those on

TABLE 1
 Proportion of PO, DO, and Other target completions produced in each condition in
 Experiments 1–6 (using participant means)

<i>Experiment</i>	<i>PO targets</i>	<i>DO targets</i>	<i>Other targets</i>
Experiment 1: Priming from simple main clause to simple main clause			
PO Prime	.56	.22	.22
DO Prime	.28	.50	.23
Priming effect	.28	.28	
Experiment 2: Priming from main clause with preceding adverbial phrase to simple main clause			
PO Prime	.53	.28	.19
DO Prime	.35	.48	.17
Priming effect	.18	.20	
Experiment 3: Priming from main clause with preceding subordinate clause to simple main clause			
PO Prime	.51	.28	.21
DO Prime	.34	.47	.19
Priming effect	.17	.19	
Experiment 4: Priming from subordinate clause to subordinate clause			
PO Prime	.57	.10	.33
DO Prime	.37	.33	.29
Priming effect	.20	.23	
Experiment 5: Priming from main clause to subordinate clause			
PO Prime	.49	.16	.34
DO Prime	.39	.26	.35
Priming effect	.10	.10	
Experiment 6: Priming from subordinate clause to main clause			
PO Prime	.57	.18	.25
DO Prime	.43	.32	.25
Priming effect	.14	.14	
Experiments 1–6: Combined analysis:			
Same-Clause-Type PO Prime	.54	.22	.24
Same-Clause-Type DO Prime	.34	.45	.22
Different-Clause-Type PO Prime	.53	.17	.30
Different-Clause-Type DO Prime	.12	.29	.30
Priming effect (Same-Clause-Type)	.20	.23	
Priming effect (Different-Clause-Type)	.12	.12	

Note: PO = Prepositional Object; DO = Double Object.

the raw proportions, we have omitted them from this Experiment and Experiments 2–6 and 8.

These effects are consistent with accounts of syntactic priming in which priming arises from activation of processes or representations that make no reference to constituents other than those that immediately make up the relevant structure (i.e., V, NP, NP comprising a VP, in the case of DO structures; V, NP, PP comprising a VP, in the case of PO structures). However, because the global structure was the same in prime and target, we cannot rule out the possibility that priming relies upon the repetition of global syntactic structure.

EXPERIMENT 2: PRIMING FROM MAIN CLAUSE WITH INITIAL ADVERBIAL PHRASE TO MAIN CLAUSE

In Experiment 2, we conducted an initial test of whether priming occurred between sentences that differed in global structure, by investigating whether syntactic priming effects occur between main clauses that differ in their overall structure. Participants completed the same prime fragments as in Experiment 1, but this time as part of a main clause containing an initial adverbial prepositional phrase (e.g., On Friday, the racing driver showed the torn overall . . .). Target fragments were as in Experiment 1. For this experiment, all verbs were presented in the past tense, because it sounded more natural to combine past-tense verbs with the initial adverbials. If priming occurs between sentences that differ in global syntactic structure, then the structure of the prime completion should reliably affect the structure of the target completion.

Method

Participants. Eighteen participants from the University of Glasgow community were paid to participate.

Items. We constructed 18 sets of items. Each comprised two sentence fragments (see Appendix):

- 3a. On Friday, the racing driver showed the torn overall . . . (PO-inducing prime)
- 3b. On Friday, the racing driver showed the helpful mechanic . . . (DO-inducing prime)
4. The patient showed . . . (target)

The items were the same as Experiment 1, except that the prime fragment included an initial adverbial phrase, and the verbs were in the past tense.

The fillers were the same as in Experiment 1, except that the verbs were in the past tense, and the subject noun phrase was replaced by a proper name in the 18 fillers containing a subject noun phrase, verb, and post-verbal noun phrase.

Procedure, scoring, design, and data analysis. All sentence fragments were presented for 7000 ms rather than 5000 ms, as the prime fragments were longer than in Experiment 1. In other respects, procedure, scoring, design, and data analysis were as in Experiment 1.

Results and discussion

Participants completed 304 trials as either a PO or a DO prime response (94% of all responses); 48% of these were completed as PO primes and 52% as DO primes. In these 304 trials, participants produced 134 (44%) PO target completions, 115 (38%) DO target completions, and 55 (18%) Other target completions.

Table 1 shows the proportions of PO, DO, and Other target completions in the two experimental conditions. It reveals a priming effect for both the PO and DO target responses, with the mean being 19%. For the PO target analyses, one-way ANOVAs revealed significant differences between the Prime Completion conditions, $F_1(1, 17) = 6.73, p < .05, MSe = 0.047$; $F_2(1, 17) = 20.8, p < .001, MSe = 0.019$: there were more PO target completions after a PO prime than a DO prime. Similarly, for the DO target analyses, one-way ANOVAs revealed significant differences between the Prime Completion conditions, $F_1(1, 17) = 8.57, p < .01, MSe = 0.045$; $F_2(1, 17) = 24.1, p < .001, MSe = 0.019$: there were more DO target completions after a DO prime than a PO prime. There was no difference for the Other target completions ($F_s < 1$).

As in Experiment 1, participants showed strong and reliable priming effects when producing consecutive main clauses. Previous research has demonstrated that priming occurs when the internal structures of the constituents of the verb phrase in prime and target are not identical (Pickering & Branigan, 1998). This experiment demonstrates that priming also occurs when the global structures of the prime and target are not identical. It suggests that the same syntactic procedures are involved in producing a PO or DO structure in two different global structures, and specifically that these procedures do not obligatorily distinguish between a PO or DO structure in a 'simple' main clause that contains a subject noun phrase and a verb phrase, and a PO or DO structure in a main clause that contains an initial adverbial phrase, a subject noun phrase, and a verb phrase.

The results also show that priming is not dependent upon prime and target having the same global prosodic structure (cf. Bock & Loebell, 1990), and that priming effects occur between structures that differ substantially in phonological length. As an indication, the average length of the pre-verbal elements and verb in the prime fragment was 9 syllables; in the target fragment, it was only 5 syllables.

EXPERIMENT 3: PRIMING FROM MAIN CLAUSE WITH INITIAL SUBORDINATE CLAUSE TO MAIN CLAUSE

In Experiment 2, the difference between prime and target in terms of global syntactic structure was fairly small. Syntactically, prime and target only differed by the presence of a peripheral (adjunct) phrase like On Friday in the prime. The processor might be sensitive to some but not all aspects of the global syntactic structure. Thus it is possible that the difference in global structure between our primes and targets was not relevant to the processor. Stronger evidence that the syntactic processes or representations that underlie priming do not depend upon the repetition of global syntactic structure would be found if priming occurred when prime and target differed more substantially. Given the apparent importance of the clause as a unit in language production (e.g., Bock & Cutting, 1992; Holmes, 1988), a strong candidate for a relevant difference in syntactic structure is the presence or absence of another clause.

In Experiment 3, we therefore employed the same prime fragments as in Experiment 2, but replaced the initial adverbial phrase with an initial subordinate clause, such as As Anne claimed, the racing driver showed the torn overall. This initial clause contained the same number of phonological words and syllables as the corresponding prepositional phrase in Experiment 2. However, it introduced another clause. The target fragments were identical to those used in Experiment 2.

If the same processes or representations are involved in the production of a PO structure such as showed the torn overall to the mechanic, then production of a prime sentence such as As Anne claimed, the racing driver showed the torn overall . . . should be effective in inducing production of a target PO sentence such as The patient showed the doctor his bruises. Notice that the initial clause is unlikely to affect priming of the experimental verb phrase because the initial clause does not contain a dative-alternating verb, and because it precedes the experimental verb phrase (containing showed).

Method

Participants. Eighteen participants from the University of Glasgow community were paid to participate.

Items. We constructed 18 sets of items. Each comprised two sentence fragments (see Appendix):

- 5a. As Anne claimed, the racing driver showed the torn overall . . . (PO-inducing prime)
- 5b. As Anne claimed, the racing driver showed the helpful mechanic . . . (DO-inducing prime)
6. The patient showed . . . (target)

The items were identical to Experiment 2 except that the initial adverbial phrase in the prime fragment was replaced by a clause of the form As X verbed, where X was a proper name and verbed was a past tense verb that takes a clausal complement. The fillers were the same as in Experiment 2.

Procedure, scoring, design, and data analysis. These were as in Experiment 2.

Results and discussion

Participants completed 286 trials as either a PO or a DO prime response (88% of all responses). Of these, 47% were completed as PO primes and 53% as DO primes. In these 286 trials, participants produced 118 (41%) PO target completions, 114 (40%) DO target completions, and 54 (19%) Other target completions for the target fragment.

Table 1 shows the proportions of PO, DO, and Other target completions in the two experimental conditions. It reveals a priming effect for both the PO and DO target responses, with the mean being 18%. For the PO target analyses, one-way ANOVAs revealed significant differences between the Prime Completion conditions, $F_1(1, 17) = 10.89$, $p < .01$, $MSe = 0.026$; $F_2(1, 17) = 15.6$, $p < .01$, $MSe = 0.017$: there were more PO target completions after a PO prime than a DO prime. Similarly, for the DO target analyses, one-way ANOVAs revealed significant differences between the Prime Completion conditions, $F_1(1, 17) = 23.5$, $p < .001$, $MSe = 0.015$; $F_2(1, 17) = 10.5$, $p < .01$, $MSe = 0.025$: there were more DO target completions after a DO prime than a PO prime. There was no difference for the Other target completions ($F_s < 1$). Experiment 3 demonstrated strong and reliable syntactic priming effects of comparable magnitude to those found in Experiments 1 and 2. The results provide further evidence that priming effects occur between sentences that share local structure but differ in global structure. Importantly, they show

reliable priming for verb phrase structure between sentences that differ in both syntactic complexity (in terms of numbers of clauses), and semantic complexity (in terms of number of propositions and number of entities). Moreover, they demonstrate that priming for a particular verb phrase structure is not eliminated by the production of a verb phrase with a different structure in a clause that precedes the locus of priming.

EXPERIMENT 4: PRIMING FROM SUBORDINATE CLAUSE TO SUBORDINATE CLAUSE

In Experiments 1–3, the experimental verb phrases formed part of the main clause of the sentence. Experiments 1 and 2 employed single-clause sentences; Experiment 3 employed subordinate clauses in the prime, but these clauses were not the locus of priming. Hence, the locus of priming was a set of procedures associated with the construction of the main clause. Experiments 4–6, in contrast, consider priming under conditions where the experimental verb phrase may form part of a subordinate clause. The distinction between main and subordinate clauses is one of particular importance to linguistic theory. However, an account of syntactic processing in which the processor does not need to make reference to aspects of syntax other than the immediate constituents involved in a structure predicts that the same set of representations and processes can be involved in producing subordinate clauses as in producing main clauses. With regard to the dative alternation, the relevant constituents are VP[V NP PP] and VP[V NP NP], irrespective of whether the verb phrase forms part of the main clause or the subordinate clause.

Hence, the account in which the processor does not need to make reference to aspects of syntax other than the immediate constituents involved in a structure predicts that syntactic priming should occur between main and subordinate clauses, because the relevant processes and representations would be the same in each case. We can straightforwardly test priming from subordinate clause to main clause, as the experimental verb phrases in prime and target are adjacent, and because Experiment 3 has shown that an experimental verb phrase preceded by another verb within the same sentence still serves as an effective prime.

However, there is a potential problem with testing priming from main clauses to subordinate clauses in English, because the main clause of the target (e.g., The rumours alleged that in the target The rumours alleged that the patient showed the doctor his wound) intervenes between the experimental verb phrase in the prime and the experimental verb phrase in the target. Evidence from spoken picture description (Bock & Griffin, 2000) and spoken sentence completion (Branigan, Pickering, Stewart, & McLean, 2000b) suggested that intervening material does not cause

priming to decay rapidly. But other work suggests that intervening material can reduce or eliminate syntactic priming. Using written sentence completion, Branigan, Pickering, and Cleland (1999) found priming (of main clause sentences) was greatly diminished if a single sentence intervened between prime and target (and was eliminated when four sentences intervened). Rapid decay also occurred in an arguably related study (in Dutch) by Levelt and Kelter (1982) involving question answering. Although it is far from certain that priming would greatly decay 'over' a short main clause in spoken production, we would be unable to determine whether a lack of priming reflected the activation but subsequent decay of locally defined procedures, or alternatively supported a different account of syntactic encoding. It is also conceivable that priming does not occur in subordinate clauses at all, for reasons unrelated to potential differences between main and subordinate clauses. Hence, we first decided to investigate priming between subordinate clauses. If priming did occur, we would then investigate priming between main and subordinate clauses.

One previous study has found evidence for priming between subordinate clauses. In Dutch, main and auxiliary verbs can occur in either order in some subordinate clauses. Hartsuiker and Westenberg (2000) found priming of main and auxiliary verb order using both written and spoken sentence completion. However, priming of word order may represent a different situation from priming of PO versus DO structure in English, which clearly involves two different constructions.

Method

Participants. Eighteen participants from the University of Edinburgh community were paid to participate.

Items. We constructed 18 sets of items. Each comprised two sentence fragments (see Appendix):

- 7a. The report claimed that the racing driver showed the torn overall . . .
(PO-inducing prime)
- 7b. The report claimed that the racing driver showed the helpful mechanic . . .
(DO-inducing prime)
8. The rumours alleged that the patient showed . . . (target)

The prime fragments were the same as those used in Experiment 3, except that the initial subordinate clause (e.g., As Anne claimed) was replaced by a main clause fragment consisting of a subject noun phrase, a past-tense verb that allowed a clausal complement, and the word that (e.g., The report claimed that). The target fragments consisted of a subject noun phrase, a past-tense verb that allowed a clausal complement, and a

subordinate clause that was identical to the target fragment in Experiment 3. The fillers were the same as in Experiment 1, except that the verbs appeared in the past tense.

Procedure, scoring, design, and data analysis. These were the same as in Experiment 2.

Results and discussion

Application of the scoring criteria yielded 283 trials where the prime fragment was completed as either a PO or as a DO (87% of all responses); 48% of these were completed as PO primes and 52% as DO primes. In these 283 trials, participants produced 132 (47%) PO completions, 62 (22%) DO completions, and 89 (31%) Other completions for the target fragment.

Table 1 shows the proportions of PO, DO, and Other target completions in the two experimental conditions. It reveals a priming effect for both the PO and DO target responses, with the mean being 21.5%. For the PO target analyses, one-way ANOVAs revealed significant differences between the Prime Completion conditions, $F_1(1, 17) = 8.85, p < .01, MSe = 0.037$; $F_2(1, 17) = 11.8, p < .01, MSe = 0.027$: there were more PO target completions after a PO prime than a DO prime. Similarly, for the DO target analyses, one-way ANOVAs revealed significant differences between the Prime Completion conditions, $F_1(1, 17) = 13.3, p < .001, MSe = 0.037$; $F_2(1, 17) = 14.7, p < .01, MSe = 0.029$: there were more DO target completions after a DO prime than a PO prime. There was no difference for the Other target completions ($F_s < 1$).

Hence there is strong priming from subordinate-clause primes to subordinate-clause targets. This experiment therefore demonstrated that priming occurs for sentences where the locus of priming is the subordinate clause. Moreover, an intervening main clause did not eliminate syntactic priming. But the global structure was of course the same in prime and target. To demonstrate that priming for such constructions occurs when global structure is not the same, it is necessary to show priming from main to subordinate clauses, or from subordinate to main clauses, or both.

EXPERIMENT 5: PRIMING FROM MAIN CLAUSE TO SUBORDINATE CLAUSE

Method

Participants. Eighteen participants from the University of Edinburgh community were paid to participate.

Items. We constructed 18 sets of items. Each comprised two sentence fragments (see Appendix):

- 9a. The racing driver showed the torn overall . . . (PO-inducing prime)
- 9b. The racing driver showed the helpful mechanic . . . (DO-inducing prime)
- 10. The rumours alleged that the patient showed . . . (target)

Apart from a change to the past tense, prime fragments were identical to those used in Experiment 1. Target fragments were identical to those in Experiment 4. The fillers were identical to those in Experiment 4.

Procedure, scoring, design, and data analysis. These were the same as in Experiment 2.

Results and discussion

Application of the scoring criteria yielded 292 trials where the prime fragment was completed as either a PO or as a DO (90% of all responses); 49% of these were completed as PO primes and 51% as DO primes. In these 292 trials, participants produced 132 (45%) PO completions, 62 (21%) DO completions, and 98 (34%) Other completions for the target fragment.

Table 1 shows the proportions of PO, DO, and Other target completions in the two experimental conditions, and reveals a mean priming effect of 10%. For the PO target analyses, one-way ANOVAs revealed significant differences between the Prime Completion conditions, $F_1(1, 17) = 5.90$, $p < .05$, $MSe = 0.016$; $F_2(1, 17) = 4.61$, $p < .05$, $MSe = 0.029$: there were more PO target completions after a PO prime than a DO prime. For the DO target analyses, one-way ANOVAs revealed a marginal trend by participants only, $F_1(1, 17) = 3.44$, $p = .08$, $MSe = 0.023$; $F_2(1, 17) = 2.87$, $p = .11$, $MSe = 0.034$: Table 1 shows that there were numerically more DO target completions after a DO prime than a PO prime. There was no difference for the Other target completions ($F_s < 1$).

The results therefore suggest that priming occurs from main to subordinate clauses (though the results were only significant for the PO target analyses). This is compatible with an account in which the processor makes use of locally defined procedures and is not necessarily sensitive to differences in global structure related to the presence or absence of an additional clause. To be more confident about this conclusion, we need to determine whether priming also occurs from subordinate to main clauses, as such an account would also predict.

EXPERIMENT 6: PRIMING FROM SUBORDINATE CLAUSE TO MAIN CLAUSE

Method

Participants. Eighteen participants from the University of Edinburgh community were paid to participate.

Items. We constructed 18 sets of items. Each comprised two sentence fragments (see Appendix):

- 11a. The report claimed that the racing driver showed the torn overall . . . (PO-inducing prime)
- 11b. The report claimed that the racing driver showed the helpful mechanic . . . (DO-inducing prime)
12. The patient showed . . .

Prime sentences were the same as those in Experiment 4. Target sentences were the same as those in Experiment 2. The fillers were identical to those in Experiment 4.

Procedure, scoring, design, and data analysis. These were the same as Experiment 2.

Results and discussion

Application of the scoring criteria yielded 270 trials where the prime fragment was completed as either a PO or as a DO (83% of all responses); 47% of these were completed as PO primes and 53% as DO primes. In these 270 trials, participants produced 133 (49%) PO completions, 72 (27%) DO completions, and 65 (24%) Other completions for the target fragment.

Table 1 shows the proportions of PO, DO, and Other target completions in the two experimental conditions. Inspection of Table 1 shows a priming effect for both the PO and DO target responses: priming was 14%. For the PO target analyses, one-way ANOVAs revealed significant differences between the Prime Completion conditions, $F_1(1, 17) = 5.49$, $p < .05$, $MSe = 0.035$; $F_2(1, 17) = 7.61$, $p < .05$, $MSe = 0.035$: there were more PO target completions after a PO prime than a DO prime. Similarly, for the DO target analyses, one-way ANOVAs revealed significant differences between the Prime Completion conditions, $F_1(1, 17) = 5.54$, $p < .05$, $MSe = 0.031$; $F_2(1, 17) = 8.58$, $p < .01$, $MSe = 0.019$: there were more DO target completions after a DO prime than a PO prime. There was no difference for the Other target completions ($F_s < 1$).

These results show significant priming from subordinate to main clauses. Together with the finding of priming from main to subordinate clauses (Experiment 5), they allow us to conclude that priming occurs between sentences that differ in global structure related to the presence or absence of a subordinate clause. Taken together, the results of Experiments 1–6 indicate that syntactic priming occurs between sentences that differ – in some cases quite substantially – in their global syntactic structure (and additionally in their global prosodic structure). Our results therefore provide empirical evidence to support the implicit assumption of many accounts of syntactic processing in production, that the production of syntactic structure involves processes and representations that are concerned with the constituents immediately making up a particular structure, but do not necessarily make reference to the larger syntactic structure. In other words, they make reference to local structure but do not need to make reference to global structure. They are also in keeping with the empirical evidence reported by Pickering and Branigan (1998) that syntactic processing does not make reference to the lower-level (complement-internal) syntactic structure.

COMBINED ANALYSES OF EXPERIMENTS 1–6: ARE THERE EFFECTS OF GLOBAL STRUCTURE?

Thus far, we have been concerned with the question of whether the syntactic processes and representations used during language production are obligatorily specified in terms of the global syntactic structure. Our results suggest that they are not. But does syntactic processing make any reference to the global syntactic structure? If so, we might expect syntactic priming effects to be stronger when prime and target share global structure than when they do not. Much evidence shows that syntactic priming is enhanced when other linguistic elements are repeated, even though syntactic priming does not require the repetition of such elements. For example, syntactic priming effects are stronger when the head of the primed phrase is repeated than when it is not (Branigan, McLean, & Jones, 2005; Branigan et al., 2000a; Cleland & Pickering, 2003; Pickering & Branigan, 1998). They are even enhanced when prime and target have semantically related heads, compared to when they do not (Cleland & Pickering, 2003). Specifically, the tendency to use a PO construction following another PO construction is greater when prime and target utterances involve the same verb than if they involve different verbs (Branigan et al., 2000a; Cleland & Pickering, 2006; Corley & Scheepers, 2002; Pickering & Branigan, 1998), and in bilingual production when prime and target utterances use verbs that are translation equivalents (Schoon-

baert, Hartsuiker, & Pickering, in press). Indeed such effects provide a central motivation for Pickering and Garrod's (2004) account of how interlocutors become aligned in dialogue, with repetition of linguistic structure at one level enhancing repetition at other linguistic levels. Taken together, these results suggest that the lexical and semantic context of syntactic rule activation affects syntactic activation. Hence the repetition of global syntactic structure might enhance syntactic priming in a similar manner.

Taken individually, Experiments 1–6 cannot cast light on this question, as none of these experiments directly compared priming between sentences with the same or different global structures. But priming was numerically greater in Experiments 1–4, where the prime and target appeared in the same type of clause (i.e., main or subordinate), than in Experiments 5 and 6, where they appeared in different types of clause (21.5%, 19%, 18%, and 27.5% vs. 10% and 14% respectively; see Table 1). We therefore carried out a combined (between-participants and within-items) analysis of all six experiments that included the factor Context (Same vs. Different global structure) to compare priming when the experimental verb phrase appeared in the same type of clause in prime and target (same global structure) versus when it appeared in different types of clause in prime and target (different global structure). Hence we grouped Experiments 1, 2, 3, and 4 as the same-global-structure condition, and Experiments 5 and 6 as the different-global-structure condition. The Prime factor (PO vs. DO) was the same as in previous analyses.

For the PO target analyses, there was a main effect of Prime, $F_1(1, 106) = 44.3, p < .001, MSe = 0.030$; $F_2(1, 17) = 42.5, p < .001, MSe = 0.013$: there were more PO target completions after a PO prime than after a DO prime. There was a trend towards an interaction (by participants only) between Context and Prime, $F_1(1, 106) = 2.91, p = .09, MSe = 0.030$; $F_2(1, 17) = 2.23, p = .15, MSe = 0.008$; Table 1 shows that priming was numerically greater when the experimental verb phrase appeared in the same type of clause in prime and target than when it appeared in different types of clause. There was no effect of Context ($F_s < 1$).

For the DO target analyses, there was a main effect of Prime, $F_1(1, 106) = 48.7, p < .001, MSe = 0.029$; $F_2(1, 17) = 48.9, p < .001, MSe = 0.011$: there were more DO target completions after a DO prime than after a PO prime. There was also an interaction between Context and Prime, $F_1(1, 106) = 5.17, p < .05, MSe = 0.029$; $F_2(1, 17) = 7.19, p < .05, MSe = 0.006$; Table 1 shows that priming was greater when the experimental verb phrase appeared in the same type of clause in prime and target than when it appeared in different types of clause. There was also an effect of Context, $F_1(1, 106) = 6.11, p < .05, MSe = 0.082$; $F_2(1, 17) = 19.1, p < .01, MSe = 0.009$: there were more DO targets in the Same Context than in the

Different Context. There was no difference for the Other target completions ($F_s < 1$).

The results of the combined analysis therefore provide some reason to believe that priming may be affected by the repetition of global structure (in terms of clause type). The DO target analyses indicated priming was reliably stronger by participants and by items when the experimental verb phrase appeared in the same type of clause in prime and target. However, the PO target analyses showed only a weak tendency, by participants only, towards the same effect. The failure to find clearly reliable effects might reflect a power problem, because the Context factor was manipulated between participants (who were run at different times and at two different universities), though it was manipulated within items. To be confident about whether there is an effect of global structure repetition on syntactic priming, it is necessary to directly compare the same participants' performance in both the same- and different-structure conditions. We therefore conducted two further (within-participants) experiments, which directly compared main- and subordinate-clause primes of main-clause targets (Experiment 7) and subordinate-clause targets (Experiment 8).

EXPERIMENT 7: PRIMING FROM MAIN AND SUBORDINATE CLAUSES TO MAIN CLAUSE

Method

Participants. Thirty-two participants from the University of Edinburgh community were paid to participate.

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

- 13a. The racing driver showed the torn overall . . .
- 13b. The racing driver showed the helpful mechanic . . .
- 14a. The report claimed that the racing driver showed the torn overall . . .
- 14b. The report claimed that the racing driver showed the helpful mechanic . . .
15. The patient showed . . .

Eighteen of the items were the same ones as in Experiment 1 and 6, and six additional items (one for each verb) were added (see Appendix). The fillers were the same as in Experiment 4.

Procedure, scoring, design, and data analysis. The experimental items were placed into four lists, each comprising six items from each condition, such that one version of each item appeared in each list. The 120 fragments (24 prime fragments, 24 target fragments, and 72 filler fragments) were

individually randomised, with the constraints that each prime fragment immediately preceded its associated target fragment, and at least 2 filler fragments intervened between experimental items. Each fragment was presented as an individual trial; participants were not informed of any relationship between prime and target fragments. The rest of the procedure was the same as in Experiments 1–6, except that the experiment lasted around 30 minutes. There were two within-participants and within-items factors: Sentence Type (main-to-main vs. subordinate-to-main) and Prime Completion (PO vs. DO prime).

The scoring and data analysis was the same as in Experiments 1–6 with the exception that where 3 or fewer Prime Completions had been completed correctly (i.e., PO primes were completed as POs and DO primes were completed as DOs), we replaced the mean proportion of target completions for participants and items with the participant mean and item mean respectively for that condition. This was done because when the number of responses per cell is 3 or fewer, the proportion calculated for that particular participant or item can be skewed by the small sample size and not be a true reflection of the pattern of responses. Note that this method of replacement may increase the likelihood of finding an interaction, against our experimental predictions. Four participants had their subordinate-to-main PO-prime mean replaced and one participant had his or her subordinate-to-main DO-prime mean replaced (3.9% of the data). One item had its main-to-main PO-prime mean replaced and three items had their subordinate-to-main PO-prime mean replaced (4.2% of the data).

Results and discussion

Application of the scoring criteria yielded 690 trials where the prime fragment was completed as either a PO or as a DO (90% of all responses); 47% of these were completed as PO primes and 53% as DO primes. In these 690 trials, participants produced 335 (49%) PO completions, 209 (30%) DO completions, and 146 (21%) Other completions for the target fragment. In the main-to-main conditions, 360 trials were completed as either a PO or a DO (94% of all responses); 45% of these were completed as PO primes and 55% as DO primes. In these 360 trials, participants produced 177 (49%) PO completions, 118 (33%) DO completions, and 65 (18%) Other completions for the target fragment. The combined proportion of PO and DO target completions was comparable in each condition: 40% following PO primes and 42% following DO primes. In the subordinate-to-main conditions, 330 trials were completed as either a PO or a DO (86% of all responses); 45% of these were completed as PO primes and 55% as DO primes. In these 330 trials, participants produced

158 (48%) PO completions, 91 (28%) DO completions, and 81 (25%) Other completions for the target fragment. The combined proportion of PO and DO target completions was comparable in each condition: 36% following PO primes and 39% following DO primes.

Table 2 shows the proportions of PO, DO, and Other target completions for both the main-to-main and subordinate-to-main conditions after the PO- and DO-prime conditions. It reveals a priming effect for both the PO and DO target responses in both the Sentence Type conditions: mean priming was 17.5% for the main-to-main Sentence Type and 12.5% for the subordinate-to-main Sentence Type. For the PO target analyses, two-way ANOVAs revealed a significant difference between the Prime Completion conditions, $F_1(1, 31) = 14.5, p < .01, MSe = 0.066; F_2(1, 23) = 32.3, p < .001, MSe = 0.028$, no interaction ($F_s < 1$), and no effect of Sentence Type ($F_s < 1$). For the DO target analyses, two-way ANOVAs revealed a significant difference between the Prime Completion conditions, $F_1(1, 31) = 10.0, p < .01, MSe = 0.055; F_2(1, 23) = 32.5, p < .001, MSe = 0.017$, no interaction ($F_s < 3$), but a significant effect (by items only) of Sentence Type, $F_1(1, 31) = 1.98, n.s.; F_2(1, 23) = 4.44, p = .05, MSe = 0.020$. For the Other target completions, there was a main effect of Sentence Type,

TABLE 2

Proportion of PO, DO, and Other target completions produced in each condition in Experiments 7 and 8 (using participant means)

<i>Experiment</i>	<i>PO targets</i>	<i>DO targets</i>	<i>Other targets</i>
Experiment 7: Priming from subordinate and main clauses to main clause			
MMPO Prime	.59	.24	.17
MMDO Prime	.41	.41	.18
SMPO Prime	.55	.24	.21
SMDO Prime	.39	.33	.29
Priming effect (MM)	.18	.17	
Priming effect (SM)	.16	.09	
Experiment 8: Priming from subordinate and main clauses to subordinate clause			
MSPO Prime	.47	.09	.43
MSDO Prime	.40	.20	.40
SSPO Prime	.58	.09	.32
SSDO Prime	.40	.28	.33
Priming effect (MS)	.07	.11	
Priming effect (SS)	.18	.19	

Note: PO = Prepositional Object; DO = Double Object; MM = main-clause prime, main-clause target; SM = subordinate-clause prime, main-clause target; MS = main-clause prime, subordinate-clause target; SS = subordinate-clause prime, subordinate-clause target.

$F_1(1, 31) = 7.79, p < .01, MSe = 0.021$; $F_2(1, 23) = 3.77, p = .06, MSe = 0.026$, but no effect of Prime Completion ($F_s < 2$) and no interaction ($F_s < 3$).

Simple main effects showed that there was significant priming for PO target completions in both the Sentence Type conditions: main-to-main, $F_1(1, 31) = 8.85, p < .01$; $F_2(1, 23) = 27.3, p < .001$; subordinate-to-main: $F_1(1, 31) = 10.0, p < .01$; $F_2(1, 23) = 13.6, p < .01$. For the DO target completions, there was significant priming for main-to-main, $F_1(1, 31) = 11.02, p < .01$; $F_2(1, 23) = 14.8, p < .01$; and a marginal effect (significant by items) for subordinate-to-main: $F_1(1, 31) = 3.59, p = .07$; $F_2(1, 23) = 10.6, p < .01$.

An additional set of analyses was performed on the arcsine-transformed proportions of responses for both participants and items. The results were nearly identical to those for the raw proportions. The only difference of note was that there was a marginal interaction for DO target completions by participants, $F_1(1, 31) = 3.54, p = .07, MSe = 0.029$, but not by items ($F_2 < 1$). Overall, the results of Experiment 7 show no difference between main and subordinate clause in their effectiveness as primes for main clause targets. They therefore provide no reason to assume that syntactic priming is stronger when global structure is repeated than when it is not repeated, and hence that syntactic processing is sensitive to the global syntactic structure.

EXPERIMENT 8: PRIMING FROM MAIN AND SUBORDINATE CLAUSES TO SUBORDINATE CLAUSE

Method

Participants. Thirty-two participants from the University of Edinburgh community were paid to participate.

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

- 16a. The racing driver showed the torn overall . . .
- 16b. The racing driver showed the helpful mechanic . . .
- 17a. The report claimed that the racing driver showed the torn overall . . .
- 17b. The report claimed that the racing driver showed the helpful mechanic . . .
- 18. The rumours alleged that the patient showed . . .

Eighteen of the items were the same ones as in Experiment 4 and 5, and six additional items (one for each verb) were added (see Appendix). The fillers were the same as in Experiment 4.

Procedure, scoring, design, and data analysis. These were the same as Experiment 7, except that the two within-participants and within-items factors were Sentence Type (main-to-subordinate vs. subordinate-to-subordinate) and Prime Completion (PO vs. DO prime). For the participants, we replaced two main-to-subordinate PO-prime means with the participant mean of that condition, and six subordinate-to-subordinate PO-prime means with the participant mean of that condition (6.3% of the data). For the items, we replaced two subordinate-to-subordinate PO-prime means with the item mean of that condition (2.1% of the data).

Results and discussion

Application of the scoring criteria yielded 677 trials where the prime fragment was completed as either a PO or as a DO (88% of all responses); 47% of these were completed as PO primes and 53% as DO primes. In these 677 trials, participants produced 309 (46%) PO completions, 116 (17%) DO completions, and 252 (37%) Other completions for the target fragment. In the main-to-subordinate prime condition, 349 trials were completed as either a PO or a DO (91% of all responses); 48% of these were completed as PO primes and 52% as DO primes. In these 349 trials, participants produced 152 (44%) PO completions, 53 (15%) DO completions, and 144 (41%) Other completions for the target fragment. The combined proportion of PO and DO target completions was comparable in each condition: 28% following PO primes and 31% following DO primes. In the subordinate-to-subordinate prime condition, 325 trials were completed as either a PO or a DO (85% of all responses); 46% of these were completed as PO primes and 54% as DO primes. In these 325 trials, participants produced 157 (48%) PO completions, 63 (19%) DO completions, and 105 (32%) Other completions for the target fragment. The combined proportion of PO and DO target completions was comparable in each condition: 31% following PO primes and 37% following DO primes.

Inspection of Table 2 shows a priming effect for both the PO and DO target responses in both the Sentence Type conditions: mean priming was 9% for the main-to-subordinate prime and 18.5% for the subordinate-to-subordinate prime Sentence Type. For the PO target analyses, two-way ANOVAs revealed a significant difference between the Prime Completion conditions, $F_1(1, 31) = 14.3, p < .01, MSe = 0.039$; $F_2(1, 23) = 14.2, p < .01, MSe = 0.034$, no effect of Sentence Type ($F_s < 3.5$) and no interaction ($F_s < 2.5$). For the DO target analyses, two-way ANOVAs revealed a significant difference between the Prime Completion conditions, $F_1(1, 31) = 18.1, p < .001, MSe = 0.037$; $F_2(1, 23) = 19.2, p < .001, MSe = 0.027$, no effect of Sentence Type ($F_s < 3$), and a marginal interaction by

participants only, $F_1(1, 31) = 3.44, p = .07, MSe = 0.012$; $F_2 < 1.5$. For the Other target completions, there was a main effect of Sentence Type, $F_1(1, 31) = 7.58, p < .05, MSe = 0.037, F_2(1, 23) = 3.57, p = .07, MSe = 0.048$, but no effect of Prime Completion ($F_s < 1$) or interaction ($F_s < 1$).

Simple main effects showed that there was significant priming for PO target responses for main-to-subordinate primes (by items only), $F_1(1, 31) = 2.44, p = .13; F_2(1, 23) = 7.71, p < .05$; and subordinate-to-subordinate primes: $F_1(1, 31) = 12.4, p < .01; F_2(1, 23) = 7.14, p < .05$. For the DO target completions, there was significant priming for both subordinate-to-subordinate primes, $F_1(1, 31) = 8.94, p < .01; F_2(1, 23) = 12.3, p < .01$; and subordinate-to-subordinate primes: $F_1(1, 31) = 18.9, p < .001; F_2(1, 23) = 15.8, p < .01$. The results demonstrate priming from both main and subordinate clause primes to subordinate clause targets. Although there is a trend toward more priming from subordinate clause than main clause primes, this difference is not significant and does not provide good evidence that syntactic processing makes reference to the global syntactic structure.

To be more confident about this conclusion, we carried out a combined analysis of Experiments 7 and 8. It is possible that the greater power provided by a combined analysis would make it possible to detect any weak effect of the repetition of global syntactic structure. The factors were Prime Clause (main vs. subordinate), Target Clause (main vs. subordinate) and Prime (PO vs. DO). Target Clause was a between-participants but within-items factor (i.e., it corresponded to Experiment 7 vs. Experiment 8). If priming is greater when global structure is repeated than when it is not repeated, we would expect to find a three-way interaction between Prime Clause, Target Clause, and Prime.

For the PO target analyses, there was a main effect of Prime Clause, $F_1(1, 62) = 30.0, p < .001, MSe = 0.052; F_2(1, 23) = 47.5, p < .001, MSe = 0.027$: there were more PO target completions after a PO prime than a DO prime. There was no main effect of Prime Clause or Target Clause ($F_s < 1$). The only interaction that approached significance (by participants only) was Prime Clause * Target Clause, $F_1(1, 62) = 3.71, p = .06, MSe = 0.034; F_2 < 1$. For all the other interactions, $F_s < 2$. In particular, there was no three-way interaction.

For the DO target analyses, there was a main effect of Prime Clause, $F_1(1, 62) = 28.0, p < .001, MSe = 0.043; F_2(1, 23) = 69.3, p < .001, MSe = 0.015$: there were more DO target completions after a DO prime than a PO prime. There was a main effect (by participants only) of Target Clause, $F_1(1, 62) = 8.10, p < .01, MSe = 0.142; F_2 < 1$: there were more DO targets after a Main-Clause target. There was also an interaction between Prime Clause and Target Clause, $F_1(1, 62) = 5.60, p < .05, MSe = 0.022; F_2(1, 23) = 6.41, p < .05, MSe = 0.031$. There was a three-way interaction

(by participants only), $F_1(1, 62) = 4.82, p < .05, MSe = 0.017$; $F_2(1, 23) = 1.58, p = 0.22, MSe = 0.018$, providing some evidence for an effect of global structure repetition on priming.

For the Other target completions, the only significant effect was for the Prime Clause \times Target Clause interaction, $F_1(1, 62) = 16.9, p < .001, MSe = 0.030$; $F_2(1, 23) = 5.92, p < .05, MSe = 0.047$.

In summary, there was only a weak suggestion (for DO target completions only, and reliable by participants only) that priming was stronger when global structure was repeated than when it was not repeated. Hence the combined analysis does not provide strong support for the hypothesis that syntactic processing is sensitive to global syntactic structure.

GENERAL DISCUSSION

In eight experiments, we have found evidence that the syntactic procedures that people use to combine expressions remain constant, irrespective of the role that those expressions play within the sentence as a whole. Specifically, people showed a consistent tendency to repeat syntactic structure across utterances, even when the relevant structures played very different roles in the prime and target sentences. Experiment 1 found priming between two main clauses that did not differ in overall structure. Experiment 2 showed priming when the prime contained an initial adverbial phrase (e.g., On Friday), thereby demonstrating that identity of global structure was not necessary for priming. Experiment 3 showed priming when the prime contained an initial subordinate clause (e.g., As Anne claimed), thereby demonstrating that priming occurred when production of the prime involved the construction of two different verb phrases. Experiment 4 showed that priming occurred between experimental verb phrases in subordinate clauses. Experiments 5–8 demonstrated that priming occurred between main and subordinate clauses. In contrast, the experiments did not provide strong evidence that repetition of global structure enhanced syntactic priming. A combined (between-participants and within-items) analysis of Experiments 1–6 showed some suggestion of stronger priming with repeated global structure. However, Experiments 7 and 8, which directly compared priming within participants between clauses of the same type (main or subordinate) and clauses of the opposite type, did not find significant effects of global structure repetition. Furthermore, a combined analysis of Experiments 7 and 8 found only a weak suggestion of stronger priming with repeated global structure.

Hence these experiments consistently demonstrated priming for verb phrase structure in consecutive sentences, both when the global structure

was repeated and when it was not, although the magnitude of the effects and the overall pattern of responses varied between experiments. The variations in the magnitude of effects (e.g., 28% vs. 18% priming between main clauses in Experiments 1 and 8 respectively) are in keeping with those found in previous studies of syntactic priming for PO/DO structures using sentence completion (e.g., Branigan et al., 1999, 2000b; Corley & Scheepers, 2002; Pickering & Branigan, 1998; Pickering et al., 2002).

Effects of local structure

The results therefore indicate that the experimental verb phrase does not need to occur in the same position in the global structure of the sentence for syntactic priming to occur. For people to be more likely to produce verb phrases of a particular syntactic type in the target sentence, it is only necessary for a verb phrase of that type to occur somewhere in the prime sentence. For example, if people produce a verb phrase comprising a verb followed by two noun phrases when producing the prime sentence, they will be more likely to produce a verb phrase comprising a verb followed by two noun phrases when producing the target sentence. Hence, the results provide evidence that the procedures leading to the construction of individual expressions are to at least some extent autonomous of syntactic context.

These results are consistent with the (largely implicit) assumption of current models of language production that syntactic processing involves procedures that make reference to just those constituents that immediately make up a structure. Thus the same procedures are involved in constructing the verb phrase gave the puppy to the boy in sentences with quite different global structures such as The girl gave the puppy to the boy and John said that the girl gave the puppy to the boy.

The results are compatible with Pickering and Branigan's (1998) model of the lemma stratum (see also Branigan & Pickering, 2004; Hartsuiker, Pickering, & Veltkamp, 2004). Following Levelt, Roelofs, and Meyer (1999), Pickering and Branigan proposed that the lemma stratum is the level of lexical representation that is concerned with the syntactic properties of a word. Each word is represented by a lemma node that is linked to other nodes representing syntactic properties, such as grammatical category, number, and person. In Pickering and Branigan's account, the lemma nodes represent the base forms of words, and are linked to combinatorial nodes that encode combinatorial information, specifying the expressions with which that word can combine to form larger expressions. For example, the verb give can combine with a noun phrase and prepositional phrase, or with two noun phrases, to produce a verb phrase. The lemma give is therefore linked to both the NP,NP combinatorial node

and the NP,PP combinatorial node. When the verb is used in a DO construction, the NP,NP node is activated; when it is used in a PO construction, the NP,PP node is activated.

The same NP,PP combinatorial node is activated whenever a PO structure is produced. Hence it is activated during production of the verb phrase gave the puppy to the boy when this phrase appears in a main clause (The girl gave the puppy to the boy) and when it is embedded in a subordinate clause (John said that the girl gave the puppy to the boy). In Pickering and Branigan's (1998) account, syntactic priming arises from residual activation of a combinatorial node, facilitating its subsequent use in any utterance that can be generated using that node. Because the same combinatorial node is activated and subsequently retains residual activation whenever a structure is produced, irrespective of global structure, this model accounts straightforwardly for our finding that production of a PO structure in one global context (e.g., a main clause) primes production of a PO structure in a different global context (e.g., a subordinate clause).

Our results demonstrate further that such activation persists through the application of other, related rules within the same utterance. Specifically, Experiments 4, 5, and 8 showed priming of subordinate clauses when they were preceded by a main clause. Though there have been demonstrations of priming across intervening sentences (e.g., Bock & Griffin, 2000; Branigan et al., 2000b), this is the first demonstration of priming across intervening clauses within the same sentence.

Effects of global structure

As well as effects of local structure, we might have expected to find clear effects of global structure. There is good evidence that semantic and lexical similarity between prime and target enhance syntactic priming (e.g., Cleland & Pickering, 2003; Pickering & Branigan, 1998), with Pickering and Garrod (2004) arguing that such effects are central to the process by which interlocutors align their mental states in dialogue. On this basis, we might have expected that global syntactic similarity (e.g., prime and target both involving or not involving subordinate clauses) would also enhance syntactic priming.

However, our experiments found no strong evidence that syntactic processing in production makes reference to global structure. Syntactic priming was not reliably increased when global syntactic structure was repeated. It is unlikely that this failure to detect reliable effects arises from use of an insufficiently sensitive measure: the experimental method that we used consistently demonstrated strong and reliable syntactic priming effects based on the repetition of local syntactic structure, and analyses on

the combined data from multiple experiments (hence substantially increasing the power of the analyses) did not find reliable influences of the repetition of global syntactic structure. Our evidence therefore suggests that any component that makes reference to global structure exerts a weaker influence than the component that is concerned with strictly local syntactic relationships.

Our findings do appear to contrast with Scheepers (2003), whose priming effects can be most straightforwardly explained in terms of procedures that make reference to the global structure. As we have noted, our experiments do not rule out the existence of such procedures. However, Scheepers explained his findings in terms of the order in which rules that make reference to local structure are applied. An alternative explanation that is compatible with our findings is that high and low attachment of prepositional phrases differ in semantic content (high attachment involves modification of the main assertion of the utterance, whereas low attachment does not), and that his effects arise from priming of semantic content (i.e., during conceptualisation). On this account, Scheepers' finding (Experiment 3) that priming did not occur for sentences that shared focus structure (in terms of which entity was modified by a subordinate clause) but did not share syntactic structure presumably results from differences between the realisation of anaphoric and syntactic dependencies.

Our results therefore form part of a body of research that helps determine the stages that take place during grammatical encoding. We assume that speakers construct a functional representation (containing reference to subject, object, and so forth) and then map this to a constituent-structure representation of the utterance (e.g., Bock & Levelt, 1994). Bock, Loebell, and Morey (1992) argued that relation-changing rules (corresponding to some transformations) do not mediate between the functional and constituent-structure representations. Pickering et al. (2002) argued that speakers do not construct an initial unordered constituent-structure representation that they subsequently linearise. Together, these results suggest a direct mapping between functional structure and a fully specified constituent structure representation. The current results suggest that speakers use syntactic procedures that make reference to just those constituents that immediately make up a structure during the construction of this final constituent-structure representation. They do not provide strong evidence that speakers may also use procedures that make reference to constituents that make up the global syntactic structure.

Our distinction between local and global effects has interesting parallels with the linguistic distinction between context-free and non-context-free grammars (Chomsky, 1965; see Partee, ter Meulen, & Wall, 1990, pp. 451–453). Essentially, context-free grammars and the more powerful non-

context-free grammars occupy different points on a hierarchy that categorises grammars according to their generative power (that is, the expressions that they can produce). In both context-free and noncontext-free grammars, complex sentences can be constructed using a set of rules (or principles) that specify components (constituents) of the sentence in a recursive manner. However, they differ with respect to the amount of information to which the rules make reference. Context-free grammars use rules that do not make reference to the broader syntactic context, whereas noncontext-free rules do make reference to the broader syntactic context.

Our results therefore suggest that syntactic processing in production makes use of procedures that largely correspond to context-free rules, though we cannot rule out the possibility that it also makes some use of noncontext-free procedures. This is interesting in the light of the finding that the vast majority of constructions in natural languages such as English can be captured using context-free rules, with the exceptions requiring very modest extensions to the grammar (e.g., Shieber, 1985).

In conclusion, our experiments demonstrated that syntactic priming occurred between utterances containing a critical verb phrase, irrespective of whether the verb phrase appeared in the same position within the global syntactic structures of the utterances. This finding suggests that syntactic processing in language production uses procedures that make reference to local syntactic structure.

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APPENDIX

Item list for Experiments 1–6

The first sentence of each item is the prime and the second is the target. The first phrase in the round brackets occurred in the PO-inducing prime conditions; the second phrase occurred in the DO-inducing prime conditions. Experiment 1 employed none of the phrases within the square brackets and used present-tense verbs in both prime and target (e.g., shows rather than showed in the first item). Experiment 2 employed the first phrase within the square brackets; Experiment 3 used the second phrase; and Experiment 4 used the third phrase. All these experiments did not use the phrase in the braces before the target. Experiment 5 used none of the phrases in the square brackets, but used the phrase in the braces. Experiment 6 used the final phrase in the square brackets and the phrase in the braces.

1. [On Friday/As Anne claimed/The report claimed that], the racing driver showed (the torn overall/the helpful mechanic). {The rumours alleged that}the patient showed.
2. [Last Sunday/As Tom knew/The film revealed that], the cricket player showed (the ball/the umpire). {The documents revealed that} the car mechanic showed.
3. [This morning/As Bill said/The video revealed that], the youngster showed (the colourful toy/the kind teacher). {The programme alleged that} the private detective showed.
4. [After breakfast/As Lisa heard/The paper reported that], the grandmother handed (the big present/the little girl). {The headline claimed that} the tennis fan handed.
5. [This evening/As James claimed/The programme alleged], the barman handed (the cocktail/the customer). {The report claimed that} the postman handed.
6. [Yesterday morning/As Craig admitted/The report disclosed that], the check-out assistant handed (the bag/the shopper). {The report revealed that} the junior surgeon handed.
7. [During the voyage/As Sarah complained/The headline declared that], the captain gave (the spare lifejacket/the old sailor). {The report stated that} the bus driver gave.
8. [At lunchtime/As Jo knew/The photographs revealed that], the mother gave (the expensive toy/the hungry baby). {The advert announced that} the florist gave.
9. Last Thursday/As Neil said/The rumours alleged that], the lecturer gave (the big book/the old professor). {The programme claimed that} the shopkeeper gave.
10. [On Tuesday/As John claimed/The report stated that], the secretary sent (the invoice/the manager). {The rumours alleged that} the boyfriend sent.
11. [After the accident/As Cathy admitted/The documents revealed that], the woman sent (the insurance claim/the insurance company). {The article disclosed that} the fan sent.
12. [This morning/As Paul heard/The paper alleged that], the blackmailer sent (the photos/the politician). {The paper reported that} the lonely sailor sent.
13. [After the party/As Simon complained/The headline alleged that], the fashion designer lent (the red jacket/the tall model). {The paper reported that} the climber lent.
14. [On Sunday/As Dave knew/The report claimed that], the neighbour lent (the lawnmower/the man). {The headline declared that} the actor lent.
15. [At lunchtime/As Sue said/The film revealed that], the receptionist lent (the spare key/the new trainee). {The letters alleged that} the hairdresser lent.
16. [In April/As Ruth claimed/The documents disclosed that], the millionaire loaned (the valuable painting/the struggling artist). {The film revealed that} the teenager loaned.
17. [During the holiday/As Roger admitted/The video revealed that], the swimmer loaned (the towel/the diver). {The documents stated that} the carpenter loaned.
18. [On Saturday/As Mike complained/The paper claimed that], the student loaned (the money/the friend). {The programmed alleged that} the little girl loaned.

Item list for Experiments 7 and 8

1. [The report claimed that], the racing driver showed (the torn overall/the helpful mechanic).[The rumours alleged that] the patient showed.
2. [The film revealed that], the cricket player showed (the ball/the umpire). [The documents revealed that] the car mechanic showed.
3. [The video revealed that], the youngster showed (the colourful toy/the kind teacher). [The programmed alleged that] the private detective showed.
4. [The programme mentioned that] the journalist showed (the pictures/the editor). [The headline declared that] the spy showed.
5. [The paper reported that], the grandmother handed (the big present/the little girl). [The headline claimed that] the tennis fan handed.
6. [The programme alleged], the barman handed (the cocktail/the customer). [The report claimed that] the postman handed.
7. [The report disclosed that], the check-out assistant handed (the bag/the shopper). [The report revealed that] the junior surgeon handed.
8. [The paper reported that] the dinner lady handed (the chips/the schoolchild). [The film revealed that] the hostess handed.
9. [The headline declared that], the captain gave (the spare lifejacket/the old sailor). [The report stated that] the bus driver gave.
10. [The photographs revealed that], the mother gave (the expensive toy/the hungry baby). [The advert announced that] the florist gave.
11. [The rumours alleged that], the lecturer gave (the big book/the old professor). [The programme claimed that] the shopkeeper gave.
12. [The report stated that] the headmaster gave the (severe punishment/the troublesome pupils). [The video revealed that] the pharmacist gave.
13. [The report stated that], the secretary sent (the invoice/the manager). [The rumours alleged that] the boyfriend sent.
14. [The documents revealed that], the woman sent (the insurance claim/the insurance company). [The article disclosed that] the fan sent.
15. [The paper alleged that], the blackmailer sent (the photos/the politician). [The paper reported that] the lonely sailor sent.
16. [The rumours alleged that] the generous aunt sent (the cheque/the nephew). [The paper reported that] the famous writer sent.
17. [The headline alleged that], the fashion designer lent (the red jacket/the tall model). [The paper reported that] the climber lent.
18. [The report claimed that], the neighbour lent (the lawnmower/the man). [The headline declared that] the actor lent.
19. [The film revealed that], the receptionist lent (the spare key/the new trainee). [The letters alleged that] the hairdresser lent.
20. [The newspaper reported that] the motorist lent (the spare tyre/the stranded walker). [The documents stated that] the farmer lent.
21. [The documents disclosed that], the millionaire loaned (the valuable painting/the struggling artist). [The film revealed that] the teenager loaned.
22. [The video revealed that], the swimmer loaned (the towel/the diver). [The documents stated that] the carpenter loaned.
23. [The paper claimed that], the student loaned (the money/the friend). [The programme alleged that] the little girl loaned.
24. [The headline declared that] the father loaned (the car/the daughter). [The paper reported that] the gardener loaned.