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COGNITION

Cognition 78 (2001) 123–164

www.elsevier.com/locate/cognit

Syntactic priming in spoken sentence production – an online study

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Received 16 July 1999; received in revised form 4 July 2000; accepted 25 August 2000

Abstract

Six experiments investigate syntactic priming online via a picture description task in which participants produce target sentences whose initial phrase is syntactically similar or dissimilar to that of the prime sentence produced on the previous trial. In the first experiment it is shown that a syntactically related prime sentence speeds onset latencies to a subsequent target sentence by approximately 50 ms relative to a syntactically unrelated prime sentence. In the second experiment, the cost of the process of lemma access is factored out via a picture previewing technique but a priming effect is still obtained demonstrating that the effect is not a product of the priming of lemma access processes. In Experiment 3, the related and unrelated prime trials feature the same picture display but the 50 ms facilitation effect is still observed indicating that the effect does not result from the priming of visual perception of the picture movements. This is further strengthened in Experiment 4 which uses written prime sentences rather than a picture description task on the prime trial and still obtains a facilitation effect. In Experiment 5, the effect disappears when the participants are instructed to name the movements but not the objects depicted in the array and this is interpreted as evidence against the view that the effect results from the conceptualization of the events depicted by the array. In the final experiment, the scope of the syntactic persistence effect is investigated by priming sentences with initial phrases of varying syntactic complexity. Significant priming is only observed for an initial phrase featuring two nouns – a finding consistent with the view that the syntactic persistence effect applies only to the generation of the first phrase of an utterance prior to speech onset. The implications of these results are analyzed in the final discussion section. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Syntactic priming; Spoken sentence production; Online study

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PII: S0010-0277(00)00110-4

1. Introduction

Although linguists have often emphasized the creativity and novelty of the language that speakers produce, the fact that our speech is highly repetitious has been confirmed by a mass of studies in corpus linguistics that have appeared over the past 25 years (cf. Aijmer, 1996; Miller & Weinert, 1998, for a review). In analyzing the London–Lund corpus of spoken English, for instance, Altenberg (1990) (cf. also Sinclair, 1991) found that close to 70% of the language contained therein was repetitious. Moreover, it seems that repetitiousness can be found no matter what population of speakers we observe, whether pre-schoolers (Miller, Potts, Fung, Hoogstra, & Mintz, 1990), second language learners (Nattinger & DeCarrico, 1992), neuropsychological patients (Van Lanckner, 1987) or even academics (Biber, 1999, Ch. 13). Such repetition, moreover, seems to affect all aspects of the grammatical structure of language such as syntactic frames (Nattinger & DeCarrico, 1992), formulaic language (Hakuta, 1974; Vihman, 1982), individual lexemes or phrases (Levelt & Kelter, 1982; Schenkein, 1980) or the lexicon itself (Altenberg, 1990). Indeed, repetition has come to assume such significance in recent studies of linguistics that some linguists have begun to adopt repetition as a central principle governing language use (Becker, 1984, 1988; Bod, 1999; Hopper, 1988; Pawley & Syder, 1983; Weber, 1997; Wray, 1992). In the words of Paul Hopper (1998, pp. 157–159), "…speakers borrow heavily from their previous experiences of communication… Our speech is a vast collection of hand-me-downs that reaches back in time to the beginnings of language."

In this paper, we investigate one specific form of linguistic repetition which has been termed syntactic persistence. This term refers to the repetition of the structural form of a sentence that has recently been uttered by a speaker or their interlocutor (Bock, 1990; Potter & Lombardi, 1998). Such a phenomenon has been confirmed as a naturally occurring feature of speech in corpus linguistic studies such as that by Weiner and Labov (1983) which demonstrate the short term repetition of passives (cf. also Estival, 1985). A study by Bock (1986), however, was also able to demonstrate evidence of the effect in an experimental setting. In this study, participants heard and then repeated aloud a priming sentence with a particular syntactic structure such as the following passive sentence:

1. The man was kicked by the donkey.

They would then be presented with a picture which they were instructed to describe using a single sentence featuring no pronouns. Thus, they might see a picture representing an action involving two objects (i.e. a church being struck by lightning) which could be described using either an active or a passive sentence. Bock's study demonstrated a significant tendency for the syntactic structure employed in the priming trial to be re-deployed more frequently during the picture description task. Passive target sentences, for instance, were found to be more frequent after passives than actives and thus participants would tend to describe

the picture of the lightning and the church via a passive sentence such as 'The church was hit by the lightning'.

Subsequent work has extended the findings of Bock's pioneering study in a number of directions. Crucially, the basic phenomenon has been replicated in different modalities such as writing and in a variety of different languages also (Branigan, Pickering, Liversedge, Stewart, & Urbach, 1995; Hartsuiker, Kolk, & Huiskamp, 1999; Heydel & Murray, 2000; Pickering & Branigan, 1998). Through such studies intriguing new observations have come to light such as the fact that in Dutch the priming of actives and passives is unidirectional (rather than bidirectional as in English) with only passives and not actives demonstrating priming (Hartsuiker & Kolk, 1998). The bulk of subsequent research, however, has been devoted to determining the precise stage of the speech production process at which syntactic priming arises. Initial studies of this issue provided strong support for the view that the effect arises during grammatical processing. Bock and Loebell (1990), for instance, provided evidence against the view that the effect is influenced by thematic role information and thus in favour of the view that the effect arises at the grammatical rather than the conceptual processing stage. This study also ruled out the repetition of closed class lemmas as a possible source of the effect and thus suggested that the effect had its origin in syntactic planning rather than lemma access processes (on this issue cf. also Levelt & Kelter, 1982). Further empirical support for a grammatical level account of syntactic persistence has been provided by Bock, Loebell, and Morey (1992) who demonstrate two distinct effects of structural priming which, they claim, arise separately at the functional and positional levels of the grammatical encoding stage. More recently, however, there has been a renewed emphasis on the role of the conceptual planning stage as a source of effects of structural priming (Heydel & Murray, 2000; Smith, submitted for publication). Thus, Hare and Goldberg (1999) provide empirical evidence in support of the view that thematic role information does influence structural priming contra Bock and Loebell (1990). Moreover, Hartsuiker et al. (1999) argue that the two effects of structural priming demonstrated in Bock et al. (1992) need to be relocated to the conceptual and functional planning stages in speech production and provide evidence of the influence of conceptual factors on structural priming. Similarly, Fox-Tree and Meijer (1999) provide data in support of the view that the effect of structural priming observed by Bock (1986) occurs early on in the speech production process prior to the formulation of the internal grammatical structure of individual phrases. Clearly, a consensus has yet to emerge over the issue of the stage at which structural priming effects arise. Given the evidence for the influence of a diverse range of information on structural priming, however, it seems likely that there is not a single structural priming effect but rather that it is possible to selectively prime structural decisions taken at a number of different stages of the speech production process (cf. Bock et al., 1992; Hartsuiker et al., 1999).

In the current study, we aim to extend the investigation of syntactic persistence still further by investigating the phenomenon online for the first time. The reasons for doing so are obvious enough. Although extant studies of syntactic persistence have done much to define precisely what kind of a phenomenon syntactic persis-

tence is they have not as yet addressed empirically the issue of why the phenomenon occurs. The hypotheses that have so far been advanced in this regard all bear on the issue of processing effort and thus processing speed. It is therefore necessary to probe syntactic persistence online in order to test out these hypotheses and thus to obtain evidence regarding the function of syntactic persistence. One such hypothesis is the view that repetitious features of speech are produced by a speaker because they reduce the processing burden on the listener and render a text easier to comprehend (Pawley & Syder, 1983 – cf. also Hawkins, 1994). Such a view is undermined, however, by recent studies which have emphasized that the self interest of a speaker exerts a stronger influence on the process of formulation than the speaker's altruistic concern to ease the processing burden on the listener (Clark & Wasow, 1998; Keysar, Barr, & Horton, 1999; Smith, 2000). The present study will confine itself to testing out the far more plausible hypothesis, first advanced by Levelt and Kelter (1982) (cf. also Bock, 1986), that syntactic persistence functions to reduce the speaker's own processing effort. As Levelt and Kelter (1982, p. 105) put it, "…reusing previous discourse elements has the function of facilitating the fluency of the formulation process itself. It may require less effort to reuse available surface materials wherever possible than to generate speech every time anew from a semantic base." At present there is little to recommend this hypothesis beyond its inherent plausibility. However, some support has been found for Levelt and Kelter's effort reduction hypothesis in relation to formulaic language. Such language is comprised of prefabricated phrases or clauses which can be retrieved whole from the speaker's own lexicon allowing them to avoid syntactic planning (Kuiper, 1996). It has been hypothesized that this avoidance of syntactic planning is motivated by benefits in cost reduction to the speaker (Pawley & Syder, 1983) and a recent online study has provided support for this claim. In this study, Kuiper (1996) observed that the proportion of repetitious formulaic language in the speech of auctioneers and sports commentators rose as the rate at which they generated utterances rose. Clearly, if speech formulas do reduce processing effort and thereby promote rapid speech we might expect them to be unusually prevalent in such speech contexts. There is thus some support for the effort reduction hypothesis but it pertains to the repetition of speech formulas stored long term in the speaker's own lexicon rather than the short term repetition of syntactic structures drawn from recent dialogue.

In order to tap into the phenomenon of syntactic persistence online, in the current study we prime a contrast in the internal structure of the initial phrases in the sentences produced by participants. Importantly, the online study of syntactic persistence is inherently restricted to the investigation of the formulation of the sentence initial phrase because, as a number of recent online studies of speech production have shown, grammatical encoding is not conducted for the whole of a sentence prior to speech onset but only for the first phrase (Schriefers & Teruel, 1999; Schriefers, Teruel, & Meinshausen, 1999; Smith & Wheeldon, 1999a). Specifically, participants in the current study produce target sentences with an initial phrase comprising a co-ordinated noun structure (as in 1) and, in the trial immediately prior to it, prime sentences with an initial phrase featuring a co-ordinated noun structure (as in 2) or a single noun structure (as in 3).

1. Target trial: the spoon and the car move up.
2. Syntactically unrelated prime trial: the eye moves up and the fish moves down.
3. Syntactically related prime trial: the eye and the fish move apart.

Clearly, if it is the case that a sentence initial co-ordinated noun phrase such as that in the target trial sentence is produced prior to speech onset and that syntactic persistence serves to significantly reduce the cost of such syntactic planning then we should expect speech onset latencies to be shorter to targets following a prime featuring a sentence initial co-ordinated noun phrase as in (2) than a sentence initial single noun phrase as in (3). A failure to observe such facilitation in target sentences following syntactically related prime sentences as in (2) would clearly be incompatible with the processing effort hypothesis and raise doubts over its validity as an explanation of the function of the short term repetition of syntax in speech. Of course, such failure to observe an effect of facilitation in the case of targets preceded by syntactically related primes would also be compatible with the stronger possibility that syntactic persistence affords no reduction in processing costs because syntactic planning is essentially an automatic process which does not incur processing costs. It may seem obvious that syntactic planning should, like any other process, incur processing costs. In fact, however, there is a long history of failed attempts to observe empirically the cost of syntactic planning in speech production (this is particularly true of work concerned with hesitation in speech cf. Beattie, 1980; Butterworth, 1980; Goldman-Eisler, 1972). Many other online studies of syntactic planning in speech production, moreover, have simply not been designed to address the issue of the temporal cost of syntactic planning. A recent electrophysiological study by Van Turrennout, Hagoort, and Brown (1998), for instance, demonstrated that syntactic and phonological planning occur at different points in time rather than determining how much time syntactic planning takes. This failure to observe costs attached to syntactic planning in speech has led to the view that syntactic planning may be a non-costly, automatic process or a process which is essentially a by-product of other processes and which, consequently, does not incur independent processing costs of its own. Such a view has been attacked by Garrett (1982) who affirms that syntactic planning is an independent process incurring its own processing costs. Evidence that syntactic persistence reduces the time dedicated to syntactic planning would also be important insofar as it would affirm that syntax generation costs time and effort.

However, observing facilitation due to syntactic priming would not by itself provide confirmation of the processing effort hypothesis. For this to occur, several other potential accounts of the effect would have to be ruled out. Most obviously, it is crucial to rule out low level processes such as phonological planning and visual similarities between the picture display used in target and prime trials as possible sources of any facilitatory effect observed. In the current experiments this is achieved by matching the relevant portions of the phonological structure of the prime and target sentences in terms of complexity and by matching the relevant

features of the visual displays used in the prime and target trials. Also, of course, in order to pinpoint the source of any facilitatory effect observed, it is necessary to determine whether it has arisen from other differences between the syntactic structure of the prime and target trials besides that of the initial phrase. Specifically, it is necessary to determine whether any facilitatory effect arises because both the related prime and target sentence, unlike the unrelated prime sentence, contains only one noun phrase and one clause. As argued above, previous studies of grammatical processing scope indicate that any effect on speech onset latencies should stem from the syntactic planning of the initial phrase and in the present study we provide evidence compatible with this view by manipulating the number of noun phrases and clauses in the unrelated prime. Finally, it is necessary to rule out the generation of conceptual structure as a source of the effect. This is, of course, extremely difficult to achieve with absolute certainty. Bock and Loebell (1990), for instance, provided evidence ruling out aspects of conceptual structure such as thematic roles as a potential source of the offline effect of syntactic persistence that they observe. However, Hare and Goldberg (1999) have recently shown that the effect observed by Bock and Loebell reflects the priming of thematic role assignment. Nevertheless, despite the difficulties associated with this issue we provide some preliminary evidence against the view that our effect is conceptual rather than grammatical in nature in Experiments 5 and 6. It is at this point when all of these alternative sources of the effect have been ruled out that we can begin to conclude that the facilitatory effect provides support for the processing effort hypothesis of syntactic planning.

As well as affording an investigation of structural priming in an online context, however, the design of the current study also allows for an investigation of the priming of co-ordinate noun phrases. Such phrases have not previously been investigated in a syntactic priming experiment and offer a significant contrast to the types of syntactic structure typically investigated in such experiments. Most syntactic priming experiments, for instance, have primed a choice either between actives or passives or between datives and ditransitives. Accounts of the production of such structure, moreover, invariably emphasize the critical role played by grammatical (or in some cases thematic) role assignment decisions. Hartsuiker et al. (1999), for instance, are particularly strident in emphasizing that the selection of such structures is determined by the act of assigning the nouns within a clause to phrases marked for grammatical role (cf. also Bock, 1987; Fox-Tree & Meijer, 1999; Hare & Goldberg, 1999; McDonald, Bock, & Kelly, 1993). In contrast, analyses of co-ordinate noun structures have identified processes such as linear ordering and constituent assembly as critical for their generation rather than grammatical role assignment (cf. especially Bock & Warren, 1985, pp. 60–61). This contrast has been reinforced, moreover, by empirical studies demonstrating that whilst the assignment of lemmas to phrases marked for grammatical role is influenced by factors such as the imageability, animacy or concreteness of the lemma, the assignment of lemmas within a co-ordinate noun phrase is instead influenced by factors such as word length or word frequency (Bock, 1986, Tables 3 and 5; Bock & Warren, 1985; Fenk-Oczlon, 1989; James, Thompson, & Baldwin, 1973; Kelly, 1986; McDonald et al., 1993; Murcia-

Serra, 1999; Palmer, 1994; Tomlin, 1995). Indeed, so striking is this empirical contrast between the generation of co-ordinate noun phrase structures and other phrase generation processes that Branigan and Feleki (1999) have argued that the generation of co-ordinate noun phrase structures is anomalous and unrepresentative of standard phrase production processes in general.[1] In short, co-ordinate noun phrase structures present a striking contrast to the types of structures that have previously been investigated in the syntactic priming literature. The current experiments provide an opportunity to gain further data on these structures from an online perspective and also to expand the range of linguistic structures and production processes that have been investigated in the context of syntactic priming.

Finally, in this study, we aim not only to test for an online effect of structural priming but also to begin to apply the effect to the investigation of wider issues in syntactic planning. Thus, in the final experiment we provide a test of the scope of syntactic planning in an experiment which attempts to determine whether syntactic persistence facilitates the generation of syntactic structure beyond the first phrase of an utterance prior to speech onset. Also, in a number of the experiments we probe whether syntactic planning facilitates planning after speech onset and thus has a significant effect on sentence durations. Conceivably such durations might reflect at least in part the speed with which the portions of the sentence beyond the first phrase have been planned. Alternatively, they may only reflect the speed at which a sentence is articulated. Of course, such an online effect of syntactic planning can be used to investigate many other questions beyond those asked in the present article. In particular, it would be fascinating to determine whether priming certain types of syntactic structures gives rise to larger reductions in processing costs than others. Also, we could seek to determine the lag over which the online effect persists, to what extent the repetition of syntactic structure interacts with lexical repetition and so on. For the present, however, such issues must remain the subject of further studies.

In the following study, six experiments are presented which investigate structural priming online via a picture description task adapted from Bock (1986). In the first experiment it is shown that a syntactically related prime trial speeds the production of a subsequent sentence during the target trial by 50 ms relative to a syntactically unrelated prime trial. In Experiment 2, the cost of the process of lemma access is factored out via a picture preview technique but a priming effect is still obtained indicating that the effect is not a product of the priming of lemma access processes. In the third experiment the picture display is held constant over related and unrelated

[1] Of course, not all of the structures so far primed in syntactic priming experiments can be accounted for in terms of the priming of grammatical role assignment. Hartsuiker et al. (1999), for instance, demonstrate priming of the fronting of a locative phrase – an effect which they explain in terms of the priming of an association between the locative phrase and its linear position rather than its grammatical role within the sentence as a whole. Clearly, though, the data from the current experiment cannot be explained in these terms either since the related and unrelated primes contrast in terms of the internal structure of the sentence initial phrase rather than in the linear position of a particular type of phrase as in the experiment by Hartsuiker et al.

prime trials but the same 50 ms facilitation effect is observed indicating that the effect cannot be attributed to the priming of visual perception of the picture movements. This is reinforced in Experiment 4 which uses written prime sentences rather than a picture description task on the prime trial and still obtains a facilitation effect. In Experiment 5, the effect disappears when the participants are instructed to describe the movements but not the objects depicted by the array and this is interpreted as preliminary evidence against the view that the effect has its origin in the conceptualization of the events depicted by the array. In the final experiment, the scope of the syntactic persistence effect is investigated by priming sentences with initial phrases of varying syntactic complexity. Significant priming is only observed for an initial phrase featuring two nouns – a finding consistent with the view that the syntactic persistence effect applies only to the generation of the first phrase of an utterance prior to speech onset. The broader implications of these results are then analyzed in Section 8.

2. Experiment 1

Experiment 1 was designed with the aim of investigating the hypothesis that syntactic persistence reduces the time dedicated to syntactic planning (Bock, 1986; Levelt & Kelter, 1982) and thus speeds onset latencies. In order to investigate these issues an experiment was designed in which participants describe an array of moving pictures on both an initial prime trial and a subsequent target trial. In the 'syntactically related' condition, the prime and target trial sentences were matched both in terms of the grammatical role of the phrases they assigned nouns to (i.e. a subject phrase) and in terms of the complexity of the internal structure of the phrase they assigned nouns to (i.e. a conjoined noun phrase). In contrast, in the 'syntactically unrelated' condition, the prime trials matched the target trials in terms of the grammatical role of the phrases they assigned nouns to but not in terms of the complexity of the internal structure of the phrase they assigned nouns to (i.e. a simple noun phrase rather than a conjoined noun phrase).

1. Target trial: the spoon and the car move up.
2. Syntactically unrelated prime trial: the eye moves up and the fish moves down.
3. Syntactically related prime trial: the eye and the fish move apart.

Target trials were then measured for production latencies to determine whether there was a significant difference between target trials in the related and unrelated conditions. Clearly, if onset latencies were faster to targets in the related than in the unrelated conditions this would be compatible with the view that syntactic persistence reduces the time spent generating syntactic structures.

To secure this interpretation of the effect, however, a whole host of other potential sources of the effect have to be ruled out. In Experiment 1 the design allows a number of these potential sources to be ruled out (with subsequent experiments serving to rule out the remainder). Firstly, the sentences in Experiment 1 were

matched in terms of prosody in order to rule out a phonological source for the effect. Specifically, the experimental sentences were designed to ensure that the first phonological word was of equivalent complexity in the prime and target trial sentences since research indicates that the phonological word is the unit of phonological encoding, that it is the minimal unit of output during articulation and that significant differences in latencies can reflect differences in the complexity of the first phonological word (Ferreira, 1991; Levelt, 1992; Wheeldon & Lahiri, 1997 – cf. also Meyer, 1996, who shows that the second noun in a conjoined noun phrase is not processed phonologically prior to speech onset). The prosody of the sentences was also matched insofar as the sentence types featured an equal number of phonological phrases and a single intonational phrase.

It was also necessary to ensure that any facilitation effect seen in the case of related target sentences was not due to a greater similarity between the movement of the prime and target pictures in the related condition than in the unrelated condition. To ensure this, Experiment 1 was designed so that there was a greater similarity of picture movement between the unrelated prime and target trial than between the related prime and target trial. Thus, in the unrelated prime trial (i.e. sentence 2) two pictures move in opposing vertical directions. As such the movement of the unrelated prime trial shares two movement features with that of the target sentence trial (i.e. sentence 1) wherein two pictures move in a similar vertical direction. The related prime trial (i.e. sentence 3) shares only one movement feature with the target sentence, however, for whilst it again features two moving pictures these pictures, unlike those in the target sentence trial, are moving in opposing, horizontal directions.

The experiments were also designed so that the pictures used during a prime trial would always differ from the pictures employed in the following target trial. This ensured that the nouns corresponding to the pictures were not repeated across prime and target trials and so would not prime the nouns in the target trials. The experiments were also designed so that the related and unrelated prime trials contained the same closed class words as the target trials and would thus prime the target trials equally in this respect. Despite such matching, however, the related and unrelated prime trials still differed in terms of the syntactic position and function in which they employed their conjunction. Thus, in the related prime trial ‘and’ co-ordinates two nouns within the sentence initial noun phrase of the related prime trial whilst in the unrelated prime trial it co-ordinates two clauses. However, it was reasoned that these differences were syntactic in nature rather than lexical in nature and thus could not be interpreted as a possible source of lexical priming in the event of a facilitatory effect. The precise contribution of these syntactic differences to any facilitatory effect can be gauged moreover by comparing experiments employing a conjunction in the unrelated prime trials (i.e. Experiments 1 and 2) with experiments not employing a conjunction in the unrelated prime trials (i.e. Experiments 3 and 4). Clearly, if the presence of the conjunction ‘and’ in the prior priming trial is critical in determining sentence latencies we should expect to see a greater difference between latencies to related and unrelated target sentences in Experiments 3 and 4 than in the first two experi-

ments.[2] Also, the experiments were designed so that the same set of verbs featured in equal numbers in both the unrelated and related prime trials ensuring that any latency differences observed cannot be attributed to the verb. Also, on a conceptual level, the pictures used during a prime trial always differed from the pictures employed during the target trial. This ensured that the conceptual processing of the picture set carried out during both related and unrelated prime trials would be equally dissimilar to that carried out during the target trials and so would not lead to the selective conceptual priming of a condition. Also for this reason, the verbs employed during both related and unrelated prime trials were conceptually dissimilar to those in the target trials. Other sources of conceptual priming were addressed in later experiments.

In summary, Experiment 1 will either rule out the claim that syntactic persistence reduces the cost of syntactic planning or it should provide us with a facilitation effect compatible with this claim. The design of Experiment 1, in ruling out various non-syntactic sources of this effect, renders such a syntactic interpretation of the effect more likely although further experiments are needed to render it certain.

2.1. Method

2.1.1. Materials

A set of 84 simple black and white line drawings of everyday concrete objects was used. Of these 84 pictures, 32 were used on the experimental target trials and 32 were used on the experimental prime trials. The remaining 20 pictures were used in the filler trials. The pictures were taken mostly from the Snodgrass and Vandervart (1980) picture norms with the rest being free drawn in a similar size and style. Also, all of the pictures had been pre-tested in a simple picture naming paradigm (cf. Wheeldon, 1989; Wheeldon & Monsell, 1992) and the selection of items was based on the norming data from this pre-test. Particular care was taken in selecting pictures for use during the experimental target trials. Specifically, it was important that such pictures could be identified and named by subjects quickly and easily. Therefore, all pictures used on experimental target trials had a naming latency of less than 600 ms. Their mean naming latency and standard deviation were 530 and 133 ms, respectively. All experimental target pictures had a word frequency of more than 19 occurrences per million (N.B. word frequencies were calculated by averaging the orthographic token and stem frequency count for noun uses in Kucera and Francis

[2] Still stronger evidence against the role of 'and' in producing any facilitatory effect observed would be provided by an experiment in which the conjunction did not feature in the related prime trial (cf. Bock & Loebell, 1990, who employ differing closed class words on related prime and target trials). Evidence to this effect is provided in an experiment reported as Experiment 6 in Smith (1998) and Experiment 1 in Smith and Wheeldon (1999b). In this experiment, the initial phrase of the related prime and target trials featured a simple noun phrase with no conjunction whilst the initial phrase of the unrelated prime featured either a complex noun phrase or a simple noun phrase modified by a relative clause. In this instance, a facilitatory effect was observed which was similar in magnitude to that observed in the priming of conjoined noun phrase sentences. Such a finding supports the view that the effect does not stem from the presence of the conjunction 'and' in the initial phrase of the related prime sentence. It also suggests the effect is bidirectional rather than unidirectional.

Table 1
Properties of two matched sets of picture names for Experiment 1 target trials

	Set 1	Set 2
Naming latency (ms)	529	531
Standard deviation (ms)	132	134
No. of syllables	1	1
No. of phonemes	3.1	3
Log frequency	3.9	3.8

(1967), the orthographic token count from Hofland and Johansson (1982), and the same count summed with the count for any orthographic tokens that could be the noun suffix, e.g. *bowls* was included but not *bowled*). The mean word frequency was 163 occurrences per million. Percentage error rates for experimental target pictures were less than 4%. All picture names were monosyllabic.

From the set of 32 pictures used in the experimental target trials, we generated 32 picture pairs to be employed exclusively in the experimental target trials. In order to do this the 32 pictures were first divided into two sets of 16 pictures. These sets were matched for various properties (cf. Table 1). Pictures in these two sets were then combined to give two sets of 16 pairs for use on the experimental target trials. The two sets of 16 pairs were constructed so as to ensure that the 16 pictures occupying the leftmost position in a set of pairs were matched with those occupying the rightmost position. We also ensured that the pictures occupying the leftmost position in the first set of pairs were matched with the leftmost pictures in the second set of pairs and likewise with the rightmost pictures. All of this ensured that individual pictures made a balanced contribution to production latencies for words at both of the two screen positions. We also ensured that there was no phonological or conceptual similarity between the two pictures in a pair, that each picture was combined with different pictures on each of the two pairs in which it occurred (to prevent associations forming between pictures) and that each picture occurred in both screen positions once.

A separate set of 32 pictures was also employed during the prime trials. To ensure that the pictures in the prime set were easy to name various criteria were employed in their selection. All of the pictures had a naming latency of less than 700 ms. Their mean naming latency and standard deviation were 570 and 162 ms, respectively. All

Table 2
Properties of two matched sets of picture names for Experiment 1 prime trials

	Set 1	Set 2
Naming latency (ms)	574	566
Standard deviation (ms)	168	156
No. of syllables	1.6	1.7
No. of phonemes	4.4	4.4
Log frequency	2.7	3.1

experimental target pictures had a word frequency of more than ten occurrences per million. The mean word frequency was 46 occurrences per million. Percentage error rates for experimental target pictures were less than 4%. All picture names were either one or two syllables in length. From this set, we generated 32 picture pairs to be employed exclusively in the experimental prime trials. To do this the pictures were divided into two sets of 16 pictures. These sets were matched for a number of properties detailed in Table 2. Pictures in these two sets were then combined to produce two experimental sets of 16 pairs. The same constraints were applied to the construction of these sets as were applied to the target sets.

During the experiment pictures could move in four possible directions: up, down, right and left. On the target trials these were combined together to give two movement categories:

1. The pictures move in the same vertical direction (i.e. up and up or down and down).
2. The pictures move in opposing horizontal directions (i.e. left and right or right and left).

Participants were instructed to describe these pictures from left to right using single clause sentences which referred to both of the objects depicted in the display (i.e. 'The spoon and the car move up'). These movement types were also used in the related prime trials. It was also ensured that a horizontal target trial was always preceded by a vertical prime trial and vice-versa in order to minimize movement priming. The unrelated prime trials featured the following distinct movement categories:

3. The pictures move in opposing vertical directions (i.e. up and down or down and up).

Participants were again instructed to describe this picture movement from left to right via a double clause sentence which referred to both objects in the display (i.e. 'The spoon moves up and the fish moves down'). It was felt that movement (3) shared more features with both movement (1) (i.e. both movements are vertical) and movement (2) (i.e. both movements feature pictures moving in opposing directions) than movements (1) and (2) shared with each other. It was reasoned on this basis that unrelated prime trials should, if anything, give rise to more movement priming than related prime trials. Consequently, if target trials in the related condition were speeded relative to those in the unrelated condition, this effect could not be attributed to movement priming. In total, there were six different movements in three different categories in the experimental trials. These six movements were distributed so that subjects would see equal numbers of all movements. The order in which the movements were distributed was also pseudorandomized to ensure that subjects could not predict an upcoming movement type.

A further set of 20 pictures was also constructed for use during the filler trials. These trials included sentences which were syntactically different to the experimen-

tal sentences. In this way the filler trials increased the variety of syntactic structures and so minimized inter-trial priming. These fillers featured movements designed to stimulate the following kinds of descriptions:

1. The house moves up, down, right or left (one picture moves).
2. The pictures move up, down, right or left (three pictures move in the same direction).
3. No pictures appear (no pictures appear on the screen).

Filler trials also featured sentence types which were syntactically similar to those in the experimental trials. These trials were always preceded and followed by filler trials featuring sentence types syntactically dissimilar to those used in experimental trials. It was reasoned that without such trials experimental trials would always occur in pairs and might enable the upcoming movement to be predicted. The purpose of 'decoy' filler trials was to discourage the formation of any anticipation. A strategy of combining at least two pairs of experimental trials per block into consecutive trials was also used to discourage the view that experimental trials occurred always in pairs. After the experiment interviews were conducted to check the participant's awareness of the experimental structure.

2.1.2. Design

The two sets of 16 target pairs were assigned to the related and unrelated conditions. Over the course of the experiment, the two sets of 16 target picture pairs were rotated so that each target picture pair occurred an equal number of times in both conditions. The two matched sets of prime pairs were likewise assigned to the related and unrelated conditions and were rotated so that each prime pair occurred an equal number of times in both types of trials. The experiment consisted of eight blocks of trials. The first of these was used to demonstrate typical experimental and filler trials to participants. This was followed by three practice blocks of 16 trials. The sentence types of the practice blocks resembled those of the experimental blocks. During the practice blocks, participants encountered each of the 32 experimental pictures once. Lastly, participants were presented with four experimental blocks each consisting of 16 experimental trials and 24 filler trials. The 16 experimental trials in each block consisted of eight prime trials and eight target trials. Eight of these 16 trials were assigned to the related condition and eight were assigned to the unrelated condition. Finally, we ensured that there was an equal number of trials featuring each movement category in each block and that each condition within a block featured an equal number of trials of each movement category. The distribution of the experimental trials across the pairblock was pseudorandomized. We also ensured that the same picture never occurred in two consecutive trials. The distribution of the filler trials across a block was also randomized. Finally, the ordering of the blocks was rotated across participants to ensure that each block occurred an equal number of times in each position in the experiment.

2.1.3. Apparatus

Participants were tested individually in a sound attenuating booth facing the screen of a monitor positioned 80 cm away from them. Participants wore headphones with a microphone attachment through which they would give their responses. The experimenter was seated outside of the booth out of sight of the participant. The experiments were run using a Kay computerized speech laboratory.

2.1.4. Procedure

Prior to the experiment, participants were instructed to describe the picture movements from left to right using specific sentence types. Each trial began with the appearance of a 19×6.5 cm frame in the centre of the screen. This black on white frame delimited the area in which the pictures would appear and was displayed for 1500 ms. At its offset, the pictures were presented on the screen and immediately began to move. The movement covered 2.5 cm of the screen and lasted 1500 ms. Participants then began describing the movement as soon as they could and pictures were removed from the screen 500 ms after response completion. After a 2 s interval, the next trial was initiated.

2.1.5. Participants

The participants were 13 male and 11 female students from Birmingham University. All participants were monolingual native speakers of English who were paid in participation credits or at the rate of £4/h. Each participant took part in only one of the experiments we report.

2.2. Results

Responses with latencies less than 300 ms and longer than 1500 ms were excluded from the analyses as were trials on which technical errors occurred. This resulted in the loss of 2.2% of the data. Three further types of response were categorized as errors and excluded from the analyses: responses in which participants did not use correct picture names; responses in which participants used incorrect syntax; and dysfluent responses. Separate analyses were carried out with subjects and items as random variables, yielding F_1 and F_2 statistics. The units of analysis in the item analyses were the picture pairs. Error rates were highest in the condition with the longer latencies, thus providing no evidence of a speed–accuracy trade-off. Mean latencies, sentence durations and percentage error rates in each condition are given in Table 3. Latencies were 55 ms longer for the related than for the unrelated sentences. An

Table 3
Production latencies, sentence durations and error rates for target sentences in Experiment 1

Target type	Latency (ms)	Duration	Error rate (%)
Primed	855	1163	1.5
Unprimed	910	1166	1.7
Difference	55	3	0.2

Table 4
Production latencies for vertical and horizontal target sentences in Experiment 1

Target type	Vertical latency (ms)	Horizontal latency (ms)
Primed	844	865
Unprimed	888	929
Difference	44	64

ANOVA on latencies featuring the variable Prime (related versus unrelated) showed that the latency difference between the Prime (related versus unrelated) sentences was significant ($F_1(1,23) = 24.7$, $P < 0.01$, $F_2(1,31) = 13.8$, $P < 0.01$). An ANOVA on sentence durations featuring the variable Prime (related versus unrelated) showed that the difference between the Prime (related versus unrelated) sentence durations was non-significant ($F_1(1,23) = 0.01$, $F_2(1,31) = 0.29$). A similar ANOVA on the Target sentence error rates proved to be non-significant ($F_1(1,23) = 0.24$, $F_2(1,31) = 0.12$).

An analysis was also conducted to determine whether performance differed across vertical and horizontal target trials in the related and unrelated conditions. The latencies for the vertical and horizontal target trials are given in Table 4. An ANOVA on latencies featuring the variable Prime (related versus unrelated) and Direction (vertical versus horizontal) yielded a significant main effect of Direction ($F_1(1,23) = 24.6$, $P < 0.01$, $F_2(1,31) = 12.6$, $P < 0.01$), but no interaction between Prime and Direction ($F_1(1,23) = 0.63$, $P > 0.4$, $F_2(1,31) = 0.72$, $P > 0.4$).

Latencies to prime sentences were also analyzed and it was found that the related primes had greater latencies (by approximately 83 ms) than unrelated primes. Specifically, whilst the 'up–down' and 'down–up' unrelated primes had latencies of 797 and 820 ms, respectively, the 'up', 'down', 'apart' and 'together' related primes had latencies of 859, 871, 924 and 910 ms, respectively. An ANOVA including the variable Primetype (related versus unrelated) proved to be significant ($F_1(1,23) = 22.9$, $P < 0.01$). Such a finding is in line with previous studies demonstrating significantly greater latencies to sentences featuring an initial co-ordinate phrase than to sentences featuring an initial single noun phrase (i.e. Levelt & Maassen, 1981; Meyer, 1996; Smith & Wheeldon, 1999a). Crucially, since primes have longer latencies in the related condition but targets have longer latencies in the unrelated condition, the differences in latencies to targets cannot be explained as stemming from the differences in latencies to primes.

To test if performance differed across the two halves of the experiment, we conducted an ANOVA including the variable Experiment half. This yielded a significant effect of Experiment half ($F_1(1,23) = 7.9$, $P < 0.01$, $F_2(1,31) = 9.37$, $P < 0.01$). Latencies were slower in the first than in the second half of the experiment (906 versus 860 ms) but the pattern of results was similar across both halves. There was no interaction of Experiment half and Prime ($F_1(1,23) = 0$, $F_2(1,31) = 0$). An ANOVA on error rates yielded no significant effects or interactions. The post-experimental interviews showed that participants were unaware of the experiment's design and had not used conscious strategies.

2.3. Discussion

Experiment 1 demonstrates that latencies to target sentences preceded by syntactically related primes are significantly faster (by 55 ms) than latencies to target sentences preceded by syntactically unrelated primes. Clearly, such a result provides the first evidence compatible with the hypothesis that syntactic persistence benefits speakers by reducing the processing costs incurred by syntactic structure generation (Bock, 1986; Levelt & Kelter, 1982). Also, however, since the primes in both conditions match the targets in assigning their nouns to subject phrases, this effect cannot be attributed to the priming of grammatical role assignment. Whilst the effect cannot be attributed to grammatical role assignment, however, it can plausibly be viewed as a product of the greater similarity in the syntactic structure of the sentence initial phrase between the related prime and target trials (which both feature co-ordinate noun phrases) than between the unrelated prime and target trials. However, at this stage such evidence of the priming of syntactic structure should be viewed as preliminary since there are a number of other potential sources of the effect which need to be ruled out. Experiment 1 also demonstrates no significant difference between the durations of syntactically related and unrelated sentences and thus fails to yield evidence of an effect of syntactic persistence on planning after speech onset. This result is consistent with the view that syntactic persistence does not affect planning after speech onset. A simpler explanation, however, is that sentence durations do not directly reflect the cost of planning processes but instead reflect simply the rate at which a speaker opts to articulate a sentence.

3. Experiment 2

The aim of Experiment 2 was to determine whether the process of lemma access rather than syntax generation had given rise to the facilitation effect observed in the previous experiment. A previous study of ours had indicated that lemma access is completed for those lemmas within the first phrase of an utterance prior to speech onset (Smith & Wheeldon, 1999a; cf. also Martin, Katz, & Freedman, 1998). This suggested the possibility that, prior to speech onset, the production of the target sentence might resemble that of the related prime in requiring the access of two nouns but differ from that of the unrelated prime which required the access of only a single noun. To rule out this potential confound we added a picture previewing technique to the design of Experiment 1. We had found previously that exposing participants to the pictures prior to trial and thus timer onset reduced latencies by around 115 ms for each lemma – a figure comparable to the estimate of 120 ms for lemma selection provided by Levelt, Praamstra, Meyer, Helenius, and Salmelin (1998). The picture previewing period, in ensuring that lemma access would occur prior to trial onset, would factor out the process of lemma access from the latencies and thus ensure that any effects would not reflect lemma access. As well as ruling out a potential confound, however, such an experiment also yields data on the relation between lemma access and syntactic planning. If the facilitation effect

remains undiminished when the process of lemma access is factored out from the production latencies, this would indicate that syntactic planning can incur processing costs independently of lemma access and thus that, as Garrett (1982) has emphasized, lemma access and syntactic planning are dissociable processes.

3.1. Method

3.1.1. Procedure

The materials and method were the same as for Experiment 1 except for a change made to the sequence of events on each trial. As with Experiment 1, each trial began with the appearance of a 19×6.5 cm frame displayed for 1500 ms. Inside the screen were displayed the two pictures featuring in the upcoming trial. It was reasoned that 1500 ms would provide sufficient time for the participants to retrieve the lexemes corresponding to the pictures as they had been instructed to do, since the pictures had an average naming latency of 530 ms. At the end of the previewing period the frame was removed, the pictures began to move and participants described the moving pictures. The participants were ten male and 14 female Birmingham University students.

3.2. Results

Outliers were excluded from the analyses as in Experiment 1 resulting in the loss of 0.9% of the data. Responses were categorized as errors as in Experiment 1 and were excluded from the analyses. Mean production latencies, sentence durations and percentage error rates in each condition are given in Table 5. Error rates were highest in the condition with the longer latencies, thus providing no evidence of a speed–accuracy trade-off. Latencies for the related sentences were 44 ms shorter than for the unrelated sentences. An ANOVA on latencies featuring the variable Prime (related versus unrelated) showed that the latency difference between the related and unrelated Target sentences was significant ($F_1(1,23) = 21.1$, $P < 0.01, F_2(1,31) = 18.5, P < 0.01$). An ANOVA on sentence durations featuring the variable Prime (related versus unrelated) showed that the difference between the related and unrelated sentences was non-significant ($F_1(1,23) = 0.87$, $F_2(1,31) = 0.01$). An ANOVA on the error rates proved to be non-significant ($F_1(1,23) = 1$, $F_2(1,31) = 1.3$).

An analysis was also conducted to determine whether performance differed across vertical and horizontal target trials in the related and unrelated conditions. The latencies for the vertical and horizontal target trials are given in Table 6. An

Table 5
Production latencies, sentence durations and error rates for target sentences in Experiment 2

Target type	Latency (ms)	Duration	error rate (%)
Primed	646	1183	0.4
Unprimed	690	1167	0.8
Difference	44	16	0.4

Table 6
Production latencies for vertical and horizontal target sentences in Experiment 2

Target type	Vertical latency (ms)	Horizontal latency (ms)
Primed	651	641
Unprimed	694	686
Difference	43	45

ANOVA on latencies featuring the variable Prime (related versus unrelated) and Direction (vertical versus horizontal) yielded neither a significant main effect of Direction ($F_1(1,23) = 1.0$, $P > 0.3$, $F_2(1,31) = 2.8$, $P > 0.1$), nor an interaction between Prime and Direction ($F_1(1,23) = 0.03$, $P > 0.8$, $F_2(1,31) = 0.01$, $P > 0.9$).

To test if performance differed across the two halves of the experiment, we conducted an ANOVA including the variable Experiment half. This ANOVA yielded a significant main effect of Experiment half ($F_1(1,23) = 15$, $P < 0.01$, $F_2(1,31) = 9.8$, $P < 0.01$). Latencies were significantly slower in the first half of the experiment than in the second half (686 versus 649 ms) but the pattern of results was similar across both experiment halves. The interaction of Experiment half and Prime was non-significant ($F_1(1,23) = 0.33$, $F_2(1,31) = 0.38$). An ANOVA on percentage error rates yielded no significant effects or interactions. The post-experimental interviews showed that participants were unaware of the experiment's design and thus that conscious strategies had not been employed.

3.2.1. Comparison of Experiments 1 and 2

Mean latencies in Experiments 1 and 2 were 883 and 668 ms, respectively. An ANOVA on latencies including the variables Experiment (Experiment 1 versus Experiment 2) and Prime (related versus unrelated) was conducted. A main effect of Experiment showed the 215 ms difference in mean latencies between the two experiments to be significant ($F_1(1,46) = 50.6$, $P < 0.01$, $F_2(1,31) = 675$, $P < 0.01$). The ANOVA also yielded a significant main effect of Prime ($F_1(1,46) = 45.7$, $P < 0.01$, $F_2(1,31) = 27.7$, $P < 0.01$). The interaction between Experiment and Prime was not significant ($F_1(1,46) = 0.53$, $F_2(1,31) = 0.14$). An ANOVA on sentence durations including the variables Experiment (Experiment 1 versus Experiment 2) and Prime (related versus unrelated) was also conducted. This ANOVA yielded neither a significant main effect of Experiment ($F_1(1,46) = 0.3$, $F_2(1,31) = 0.11$), nor of Prime ($F_1(1,46) = 0.48$, $F_2(1,31) = 2.53$). The interaction between Experiment and Prime was also non-significant ($F_1(1,46) = 0.27$, $F_2(1,31) = 0.2$). A similar ANOVA on error rates yielded a significant effect of Experiment ($F_1(1,46) = 9.35$, $P < 0.01$, $F_2(1,31) = 15.1$, $P < 0.01$), but no other significant effects or interactions.

3.3. Discussion

In Experiment 2, a picture previewing period was used to determine the relation

between the syntactic persistence effect observed in Experiment 1 and the process of lemma access. Clearly, as the results demonstrate, the introduction of the picture previewing period has been effective in removing the time dedicated to lemma access from the latencies. Thus, the mean latencies observed in Experiment 2 are 215 ms shorter on average than those observed in Experiment 1. This is in line with previous experiments (cf. Smith & Wheeldon, 1999a) in which a figure of 245 ms was observed for the removal of two lemmas and figures of 118 and 110 ms were observed for the removal of single lemmas (cf. also Levelt et al., 1998). The close correspondence between the figures observed in the present experiment and those in previous experiments indicates that the time dedicated to lemma access in the present experiment has been successfully removed from the latencies.

Yet whilst the picture previewing period has succeeded in factoring out the process of lemma access from the production latencies the facilitation effect in Experiment 2 is not significantly different from that observed in the previous experiment. Clearly, this indicates that the facilitation effect must be attributed to some process other than the priming of lemma access and once again provides evidence compatible with the view that the priming of the syntactic structure of the sentence initial phrase significantly reduces the time dedicated to the generation of syntax. Such a result is also compatible with the view that syntactic planning incurs processing costs (which are lessened by syntactic persistence) independently of the costs incurred by lemma access. This is in line with the claim advanced by Garrett (1982) that lemma access and syntactic planning form dissociable processes insofar as they can incur processing costs independently of one another. However, further potential sources of the effect must be ruled out before such a view can be adopted with certainty.

The present experiment also resembles Experiment 1 insofar as it demonstrates no significant difference between the durations observed to syntactically related and unrelated sentences. Again, this demonstrates that the present experiment fails to yield any evidence of an effect of syntactic persistence on the planning that occurs during speech. Notably, however, there is no significant difference between the sentence durations in Experiments 1 and 2 despite the introduction of a picture preview period in Experiment 2 providing lexical information in advance. This indicates that the cost of lexical access, like that of syntactic planning, is reflected in production latencies but not in sentence durations. This further supports the view that sentence durations primarily reflect the rate at which a speaker articulates a sentence rather than the time a speaker dedicates to planning it.

4. Experiment 3

Experiment 3 was designed with the aim of ruling out the priming of the moving picture array on the target trial as a source of the facilitation effect. The previous experiments had already attempted to rule out picture movement priming as a source of the effect by ensuring that the movement of the picture array on the target trial was more similar to that of the unrelated prime than that of the related prime. Whilst

this argument seemed largely compelling (it being difficult to argue that the movement of the target trial pictures was likely to be more effectively primed by the movement of the related prime pictures than by the movement of the unrelated prime pictures) it was still felt that a more rigorous test was needed to put the matter beyond dispute. For this reason, the current experiment, in which the picture movements used during the related prime trials were exactly the same as those during the unrelated prime trials, was designed. Thus, in the related trials, participants would produce a sentence featuring a conjoined noun phrase (i.e. 'The eye and the fish move apart') in response to two pictures moving in opposing vertical directions on the prime trial and would then produce a sentence featuring a conjoined noun phrase (i.e. 'The spoon and the car move up') in response to two pictures moving in the same vertical direction on the target trial. In contrast, during the unrelated trials, participants would produce a sentence without a conjoined noun phrase (i.e. 'The eye moves above the fish') in response to two pictures moving in opposing vertical directions on the prime trial and would then produce a sentence featuring a conjoined noun phrase (i.e. 'The spoon and the car move up') in response to two pictures moving in the same vertical direction on the target trial. Given that the relation between the picture movements of the prime and target trials is the same for both the related and unrelated conditions in this experiment, we can be confident that if a facilitation effect is still observed it should not be attributed to the priming of the moving picture array.

4.1. Method

4.1.1. Materials

In total, 74 simple black and white line drawings of everyday concrete objects selected on the basis of the same criteria employed in previous experiments were used. Of these 74 pictures, 12 were used on the experimental target trials and 12 were used on the experimental prime trials. The remaining 50 pictures were used in the various types of filler trials (see below). From the set of 12 pictures used in the experimental target trials, we generated 24 picture pairs to be employed only in the experimental target trials. In order to do this the 12 pictures were first divided into two sets of six pictures. These sets were matched for the properties detailed in Table 7. Pictures in these two sets were then sorted into two sets of 12 pairs as in Experiment 1 for use on the target trials.

Table 7
Two matched sets of picture names for Experiment 3 target trials

	Set 1	Set 2
Naming latency (ms)	508	509
Standard deviation (ms)	162	144
No. of syllables	1	1
No. of phonemes	3	3
Log frequency	4.9	4

Table 8
Properties of two matched sets of picture names for Experiment 3 prime trials

	Set 1	Set 2
Naming latency (ms)	522	524
Standard deviation (ms)	160	158
No. of syllables	1	1
No. of phonemes	3	3
Log frequency	3.5	3.8

From the set of 12 pictures used in the experimental prime trials in Experiment 1, we generated 24 picture pairs to be employed only in the experimental prime trials. To do this the pictures were divided into two sets of six pictures. These sets were matched for a number of properties detailed in Table 8. Pictures in these two sets were then combined to produce two experimental sets of 12 pairs according to the constraints used to construct the target pairs. In the target trials, participants described two pictures moving in the same vertical direction (either down or up) with a sentence featuring a conjoined noun phrase (i.e. 'The spoon and the car move up'). In the unrelated prime trials, participants described two pictures moving in opposing vertical directions with a sentence featuring two simple noun phrases (i.e. 'The eye moves above the fish'). In the related prime trials, participants described two pictures moving in opposing vertical directions with a sentence featuring a conjoined noun phrase (i.e. 'The eye and the fish move apart'). To ensure that the opposing vertical movement employed would be described as a related prime or as an unrelated prime participants were instructed to describe all opposing vertical movements using a sentence featuring a conjoined noun phrase during one experimental session and then in a separate experimental session conducted either a week earlier or a week later were instructed to describe all opposing vertical movements using a sentence featuring two simple noun phrases.

In order to be able to split up the two conditions into separate experimental sessions in this way it was necessary to ensure that the two sessions provided the participants with equally complex and demanding tasks overall. If this were not ensured, then faster latencies in one session might reflect not priming but simply the less demanding nature of the session overall. To effect this balancing of session difficulty, a number of trial types other than the prime and target trials were introduced. Thus, a 'syntactic counterbalance' trial was introduced so that sentences featuring simple (i.e. non-conjoined) noun phrases occurred in the related as well as the unrelated session. It was also ensured that the ratio of sentences featuring conjoined noun phrases to sentences featuring simple noun phrases was the same across the two sessions. Also, a 'prime counterbalance' trial was introduced so that participants would encounter filler related sentences (i.e. sentences preceded by a trial featuring a syntactically similar sentence) during the unrelated session and filler unrelated sentences during the related session. It was also ensured that the ratio of related to unrelated sentences was the same across the two conditions. The experiment was also designed so that sentences featuring conjoined sentences were

produced in response to an equivalent number of different visual movement types (i.e. two) in both sessions. Sentences featuring simple noun phrases were similarly matched. It was also ensured that sentences featuring conjoined noun phrases and sentences featuring simple noun phrases occurred an equivalent number of times in prime and target sentences across the two sessions. The variety and frequency of different movement types was also exhaustively matched across the two sessions. Also, the visual movement giving rise to the target conjoined noun phrase sentences was used only in the target trials in both sessions. Also, the two sessions featured the same number of trials overall. Finally, an equivalent number of 'decoy' trials was used in both sessions to prevent participants from predicting the upcoming sentence type. As a result of all this matching, it was felt that the two sessions featured an equivalent variety of both movement and sentence types and that the two sessions were thus of an equivalent complexity overall.

Filler trials in which no pictures were named were also employed. These trials included sentences which were syntactically different to the experimental sentences. In this way the filler trials increased the variety of syntactic structures occurring in the experiment and so minimized inter-trial priming. These fillers featured movements designed to stimulate the following kinds of descriptions:

1. They all move right or left (three pictures move in the same direction).
2. No pictures appear (no pictures appear on the screen).

After the experiment, we interviewed participants to check for awareness of the experiment's design.

4.1.2. Design

The two matched sets of target pairs were assigned to the related and unrelated conditions. Over the course of the experiment, the two sets of 12 target picture pairs were rotated so that each target picture pair occurred an equal number of times in both conditions. The two matched sets of prime pairs were likewise assigned to the related and unrelated conditions. As with the target pairs, the two sets of 12 prime pairs were rotated so that each prime pair occurred an equal number of times in both types of trials. Both the related and the unrelated sessions consisted of six blocks of trials. The first of these was a demonstration block of eight trials showing typical experimental and filler trials. This was followed by three practice blocks of 16 trials. The practice blocks were similar to the experimental blocks in terms of the sentences that were elicited. During the practice blocks, the subject encountered each of the 12 target pictures and each of the 12 prime pictures once. Lastly, the subject was presented in each of the two sessions with two experimental blocks. In each block there were six target trials, six prime trials, 12 syntactic counterbalance trials, 12 priming counterbalance trials, six decoy trials and 23 filler trials. The distribution of the experimental and non-experimental trials within a block was pseudorandomized. We also ensured that the same picture never occurred in consecutive trials. Finally, the block order was rotated across participants so that each block occurred equally often in each position in the experiment and the assignment of related and unrelated

conditions to sessions was rotated so that half the participants saw the related condition in the first session and half saw the unrelated condition in the first session.

4.1.3. Apparatus and procedure

The apparatus and procedure are the same as in Experiment 1.

4.1.4. Participants

The participants were ten male and 14 female Birmingham University students.

4.2. Results

Outliers were excluded from the analyses as in Experiment 1 as were trials with technical problems. This resulted in the loss of 1.7% of the data. Responses were categorized as in Experiment 1 and were excluded from the analyses. Error rates were highest in the condition with the longer latencies, thus providing no evidence of a speed–accuracy trade-off. Mean latencies and percentage error rates in each condition are given in Table 9. Latencies for the related sentences were 53 ms shorter than for the unrelated sentences. An ANOVA on latencies featuring the variable Prime (related versus unrelated) showed that the latency difference between the Prime (related versus unrelated) sentences was significant ($F_1(1,23) = 6.4$, $P < 0.02$, $F_2(1,23) = 31.2$, $P < 0.01$). A similar ANOVA on the Target sentence error rates was non-significant ($F_1(1,23) = 0.2$, $F_2(1,31) = 0.08$). An ANOVA on latencies featuring the variables Prime (related versus unrelated) and Session Order (related session conducted first versus unrelated session conducted first) gave a significant main effect of Prime ($F_1(1,22) = 6.5$, $P < 0.02$, $F_2(1,23) = 29.6$, $P < 0.01$), but not of Session Order ($F_1(1,22) = 0.5$, $F_2(1,23) = 1.99$, $P > 0.1$). The interaction between Prime and Session Order was non-significant ($F_1(1,22) = 1.4$, $F_2(1,23) = 0.35$).

Mean latencies for the related and unrelated primes were 940 and 964 ms, respectively. An ANOVA demonstrated that this difference was non-significant ($F_1(1,23) = 1.25$, $P < 0.01$). To test if performance differed across the two halves of the experiment, we conducted an ANOVA including the variable Experiment half. This yielded a main effect of Experiment half ($F_1(1,23) = 16.3$, $P < 0.01$, $F_2(1,23) = 41.3$, $P < 0.01$). Latencies were slower in the first half of the experiment than in the second half (979 and 913 ms) but the pattern of results was similar across both halves. There was no interaction of Prime and Experiment half ($F_1(1,23) = 0.4$, $F_2(1,23) = 0.1$). An ANOVA on target trial latencies featuring

Table 9
Production latencies and percentage error rates for target sentences in Experiment 3

Target type	Latency (ms)	Error rate (%)
Primed	919	1.3
Unprimed	972	1.4
Difference	53	0.1

the variables Prime (related versus unrelated) and Session Order (related trials first versus unrelated trials first) was also conducted to determine whether there was a significant difference in performance between those participants that had seen the related trials in the first testing session and those that had seen them in the second testing session, but no significant difference was found ($F_1(1, 22) = 1.43$, $P > 0.2$, $F_2(1, 23) = 0.35$, $P > 0.5$). An ANOVA on error rates yielded no effects or interactions. Post-experimental interviews showed that participants were unaware of the experiment's design and thus that conscious strategies had not been employed.

4.3. Discussion

In the present experiment, production latencies to target sentences in the related condition were again observed to be 50 ms faster than those to target sentences in the unrelated condition. The fact that this facilitation effect was observed despite the fact that the prime trials in both the related and unrelated conditions featured the same moving picture array as each other (as did the target trials) indicates that the effect cannot be attributed to the priming of the target trial sentence's moving picture array but must instead be attributed to some other non-visual source. The attribution of this effect to non-visual sources in the current experiment also reinforces the view that effects observed in previous experiments also do not have their source in the priming of picture movement.

5. Experiment 4

Experiment 4 was designed to provide a further attempt to rule out similarities between the movement of the picture display in the prime and target trials as a possible source of the facilitation effect that had been observed. The experiment follows the basic design of Experiment 1 but on the prime trials written sentences are displayed on the screen rather than moving pictures and the participants are instructed to read the sentences aloud. Precedents for such a design can be found in the syntactic priming literature in a study by Bock (1986) which required participants to repeat back sentences in the prime trials but complete a picture description task during the target trials, in a study by Pickering and Branigan (1998) which utilized written primes and in a study by Hartsuiker et al. (1999) which combined written words and pictures during both prime and target trials. Clearly, if a facilitatory effect is observed when written primes are used then the effect cannot be attributed to similarities between the movement of the picture display on the prime and target trials. To reinforce this, we employed primes which referred to static situations (i.e. 'The cat is near the table') rather than the movement of objects so that participants would neither see nor conceptualize movements that would be similar to those occurring on the target trials.

5.1. Method

5.1.1. Materials, design, apparatus and procedure

The materials, design, apparatus and procedure are the same as for Experiment 1, except that a stationary written sentence is displayed in place of moving pictures on every second trial (which includes all of the prime trials). It was reasoned that switching between written sentences and pictures in this strictly controlled manner would facilitate participants' responses and render them more consistent in contrast to a design which switched randomly between the two which might, it was felt, interfere unnecessarily with participants' responses. On the related prime trials the written sentences are comprised of a single clause featuring a co-ordinate subject phrase (i.e. 'The dog and the house are far away') and on unrelated prime trials the written sentences are comprised of a single clause featuring two single noun phrases (i.e. 'The dog is far from the house'). The non-experimental written trials also feature written equivalents of the full range of experimental and filler trials in the experiment, thus ensuring that participants do not associate the use of written sentence trials with prime trial sentence types exclusively and cannot predict whether the trial occurring after a written sentence trial will be a target trial or not.

5.1.2. Participants

The participants were nine female and 15 male Birmingham University students.

5.2. Results

Outliers were excluded from the analyses as in Experiment 1 resulting in the loss of 1.0% of the data. Responses were categorized as errors as in Experiment 1 and were excluded. Mean latencies and percentage error rates are given in Table 10. Error rates were highest in the condition with the longer latencies, thus providing no evidence of a speed–accuracy trade-off. Latencies for the related sentences were 55 ms shorter than for the unrelated sentences. An ANOVA featuring the variable Prime (related versus unrelated) showed that the latency difference between the related and unrelated Target sentences was significant ($F_1(1, 23) = 18.7$, $P < 0.01$, $F_2(1, 31) = 9.3$, $P < 0.01$).

An analysis was also conducted to determine whether performance differed across vertical and horizontal target trials in the related and unrelated conditions. The latencies for the vertical and horizontal target trials are given in Table 11. An ANOVA on latencies featuring the variable Prime (related versus unrelated) and

Table 10
Production latencies and percentage error rates for target sentences in Experiment 4

Target type	Latency (ms)	Error rate (%)
Primed	840	0.3
Unprimed	895	0.7
Difference	55	0.4

Table 11
Production latencies for vertical and horizontal target sentences in Experiment 4

Target type	Vertical latency (ms)	Horizontal latency (ms)
Primed	826	853
Unprimed	877	912
Difference	51	59

Direction (vertical versus horizontal) yielded a significant main effect of Direction ($F_1(1,23) = 5.4$, $P < 0.05$, $F_2(1,31) = 7.6$, $P < 0.01$), but no interaction between Prime and Direction ($F_1(1,23) = 0.09$, $P > 0.7$, $F_2(1,31) = 0.13$, $P > 0.7$).

To test if performance differed across the two halves of the experiment, we conducted an ANOVA including the variable Experiment half. This yielded a significant main effect of Experiment half ($F_1(1,23) = 14.2$, $P < 0.01$, $F_2(1,31) = 11.9$, $P < 0.01$). Latencies were slower in the first half of the experiment than in the second half (901 versus 834 ms) but the pattern of results was similar across both halves. There was no interaction of Experiment half and Prime ($F_1(1,23) = 0.59$, $F_2(1,31) = 0.04$). An ANOVA on error rates yielded no significant effects. The post-experimental interviews showed that participants were unaware of the experiment's design and thus had not used strategies consciously.

5.3. Discussion

In the present experiment, onset latencies to target sentences in the related condition were again observed to be approximately 50 ms faster than those to target sentences in the unrelated condition. The fact that this effect of facilitation was observed despite the fact that the prime trials in both the related and unrelated conditions featured written sentences rather than picture movements demonstrates that the effect does not stem from the priming of the target trial sentence's moving picture array but instead must be attributed to some other non-visual source. This further reinforces the view that the effects observed in previous experiments also do not have their source in the priming of picture movement.

6. Experiment 5

In Experiment 5 we sought to determine whether the facilitation effect reflected the priming of conceptual rather than syntactic planning. Specifically, it seemed possible to argue that whilst the pictures in the related primes in Experiment 1 were moving in physically different directions they were conceptualized by the participants as both moving in a single direction (i.e. 'apart from each other'). As such, they resemble the pictures in the target sentences which again are conceived of as moving in a single direction (i.e. 'up'). In contrast, the pictures in the unrelated prime sentence in Experiment 1 are conceived as moving in different directions to one another. In short, the related prime might facilitate the production of the target sentence as they both involve the description of two pictured objects engaged in a

single action, whereas the unrelated prime would fail to facilitate the target sentence as it involves two actions both of which feature a single picture.

To determine whether the facilitation effect did indeed reflect conceptual priming in this way we ran a version of Experiment 1 in which participants named the movements but not the pictures during a trial. They would thus say 'Apart' instead of 'The spoon and the car move apart' and 'Up–down' instead of 'The car moves up and the fish moves down'. Clearly, if it is the case that the 50 ms effect in Experiment 1 resulted from conceptualizing the related prime and target trials as a single action and the unrelated prime trials as two distinct actions then the current experiment, which preserves this contrast, should also give rise to the 50 ms facilitation effect. However, if the effect did not result from conceptual priming in Experiment 1 but from some other source we might expect the effect to disappear. Specifically, if the effect reflected the process of generating a conjoined noun phrase we might expect the effect to disappear since the target sentences in the present experiment do not involve the generation of syntactically complex phrases but merely the retrieval of set adjectives.

6.1. Method

6.1.1. Materials, design, apparatus and procedure

The materials, design, apparatus and procedure are the same as for Experiment 1 but with two modifications. Firstly, participants saw pictures moving only in opposing horizontal directions (described as either 'Apart' or 'Together') on the target trials and saw pictures moving only in either similar or opposing vertical directions during the prime trials in order to ensure that no lexical priming occurred (i.e. to avoid an 'Up–down' response on a prime trial being followed by an 'Up' response on the target trial). Secondly, filler trials included single picture movements in which participants were instructed to describe both the picture and the movement (i.e. 'The spoon moves up'). It was felt that this would enhance the variety of the task carried out by the participant and provide the most effective distractor from the experimental task. Decoy trials ensured that participants could not predict upcoming trials.

6.1.2. Participants

The participants were 15 female and nine male Birmingham University students.

6.2. Results

Outliers were excluded from the analyses as in Experiment 1 resulting in the loss

Table 12
Production latencies and percentage error rates for target sentences in Experiment 5

Target type	Latency (ms)	Error rate (%)
Primed	724	0.2
Unprimed	730	0.5
Difference	6	0.3

of 0.7% of the data. Responses were categorized as errors as in Experiment 1 and were excluded. Mean latencies and percentage error rates are given in Table 12. Error rates were highest in the condition with the longer latencies, thus providing no evidence of a speed–accuracy trade-off. Latencies for the related sentences were 6 ms shorter than for the unrelated sentences. An ANOVA featuring the variable Prime (related versus unrelated) showed that the latency difference between the related and unrelated Target sentences was not significant ($F_1(1, 23) = 0.49$, $P > 0.4$, $F_2(1, 31) = 0.79$, $P > 0.3$).

To test if performance differed across the two halves of the experiment, we conducted an ANOVA including the variable Experiment half. This yielded a significant main effect of Experiment half ($F_1(1, 23) = 6.9$, $P < 0.02$, $F_2(1, 31) = 10.4$, $P < 0.01$). Latencies were slower in the first half of the experiment than in the second half (740 versus 714 ms) but the pattern of results was similar across both halves. There was no interaction of Experiment half and Prime ($F_1(1, 23) = 0.63$, $F_2(1, 31) = 0.52$). An ANOVA on error rates yielded no significant effects. The post-experimental interviews showed that participants were unaware of the experiment's design and thus had not used strategies consciously.

6.3. Discussion

The results of the present experiment indicate that the facilitation effect disappears when only the movements are described by participants. Such a result is incompatible with the view that the facilitation effect results from conceptualizing the related prime and target trials as a single action and the unrelated prime as two separate actions. Yet whilst the result is not compatible with a conceptual priming account it is compatible with a syntactic account of the effect. Specifically, whilst the target sentences in Experiment 1 necessitated the online generation of novel conjoined noun phrases, target utterances in the current experiment require only the retrieval of stock adjectives. If the effect in Experiment 1 resulted from the priming of the generation of the target sentence's conjoined noun phrase we would expect to see the effect disappear in the current experiment, as indeed it has done. The present experiment, whilst providing data incompatible with a conceptual level account of the facilitation effect, provides further evidence compatible with a syntactic planning account of the effect.

7. Experiment 6

The previous experiments, in ruling out the priming of picture movement, prosody, conceptual structure and lemma access as sources of the 50 ms effect, indicate that it can only be attributed to the priming of the generation of the target sentence's syntactic structure by the related prime. This still leaves uncertain, however, whether the effect reflects the priming of the syntactic structure of the initial phrase of the sentence or the priming of structure beyond the sentence's first phrase. Experiment 6 was designed with the aim of determining whether prior to speech onset the syntactic planning of the entire sentence or only the sentence's

initial phrase was facilitated by syntactic persistence. If the latter, it would indicate that the effect resulted from the greater similarity in the structure of the sentence initial phrase between the related prime and target than between the unrelated prime and target and would thus constitute clear evidence of the priming of the syntax of the sentence initial phrase. Such a result would also suggest that such syntactic planning is completed for the first phrase of a sentence and not for the entire clause and would thus be compatible with Schriefers et al. (1999) who demonstrate that syntactic planning is not completed for the whole of a clause prior to speech onset. To effect this test of scope, an experiment was designed in which participants described an array of three moving pictures either with a sentence of the form

1. The dog and the house move above the spoon.

which we labelled a Complex-simple sentence because its first phrase contains two nouns whilst its last contains a single noun, or a sentence with contrasting form

2. The dog moves above the house and the spoon.

Which we termed a Simple-complex sentence. We aimed to obtain an effect of syntactic persistence for both of these sentences by contrasting onset times to them in a related condition where they would be preceded by a syntactically similar prime (sentence 1 would be preceded by 'The car and the shoe move below the key') and in an unrelated condition where they would be preceded by a prime trial in which participants would describe an array of three moving pictures with a sentence such as 'Three fishes move down'. We reasoned that if syntactic planning is carried out for the whole of the first clause prior to speech onset then the related Simple-complex prime should facilitate the Simple-complex target significantly more than the unrelated prime should because whilst the whole clause of the Simple-complex prime is syntactically similar to that of the Simple-complex target the unrelated prime lacks an object phrase and as such differs from the Simple-complex target over the span of the clause. We also reasoned that if the syntactic planning of only the first phrase of an utterance is facilitated prior to speech onset then there should be no difference in latencies to Simple-complex target sentences in the related and unrelated conditions since the first phrase of both the related and the unrelated prime matches the first phrase of the Simple-complex target in featuring a single uncoordinated noun. In contrast, since the first phrase of the Complex-simple related prime and target consists of a co-ordinated noun phrase whilst that of the unrelated prime features only a single uncoordinated noun, the related prime should facilitate the target significantly more than the unrelated prime if syntactic planning is facilitated for the first phrase of an utterance prior to speech onset.

7.1. Method

7.1.1. Materials

A set of 92 pictures was used in this experiment. Forty-five of these were used

Table 13
Properties of three matched sets of picture names for Experiment 6 target trials

	Set 1	Set 2	Set 3
Naming latency (ms)	533	532	534
Standard deviation (ms)	141	136	139
No. of syllables	1.1	1.1	1.1
No. of phonemes	3.3	3.2	3.3
Log frequency	3.6	3.8	3.6

during the target trials and 30 were used during the prime trials with the remainder being used on filler trials. From the set of 45 pictures used in the target trials, we generated 60 picture triples (i.e. sets of three pictures) to be employed exclusively in the target trials. In order to do this the 45 pictures were first divided into three sets of 15 pictures. These sets were matched for a number of properties listed in Table 13.

Pictures in these three sets were then combined to produce four sets of 15 triples for use on the target trials. The four sets of 15 triples were constructed so as to ensure that the 15 pictures occupying the leftmost position in a set of triples were matched with those occupying the middle position and the rightmost position. We also ensured that the pictures occupying the leftmost position in the first set of triples were matched with the leftmost pictures in the second set of pairs and likewise for pictures occupying the middle position and the rightmost position. All of this ensured that individual pictures made a balanced contribution to production latencies for words at each of the three screen positions. We also ensured that there was no phonological or conceptual similarity between the pictures in a triple, that each picture was combined with different pictures on each of the triples in which it occurred and that each picture occurred in each screen position no more than twice.

A set of 30 pictures was used to generate the 60 picture triples to be employed exclusively in the prime trials. To do this the pictures were divided into two sets of 15 pictures. These sets were matched for a number of properties detailed in Table 14. Pictures in these two sets were then combined to produce four experimental sets of 15 triples. The same constraints were applied to the construction of these two sets as were applied to the target sets.

Pictures could move in four directions: up, down, right and left. On the target trials the three pictures would move in opposing vertical directions with either the

Table 14
Properties of two matched sets of picture names for Experiment 6 prime trials

	Set 1	Set 2
Naming latency (ms)	572	565
Standard deviation (ms)	161	153
No. of syllables	1.5	1.4
No. of phonemes	4.1	4
Log frequency	2.5	3

leftmost and middle pictures moving together or the rightmost and middle pictures moving together. This resulted in four possible movements and, since participants were instructed to describe pictures always from left to right, four distinct sentences:

1. Left–up, middle–up, right–down: 'The A and the B move above the C.'
2. Left–up, middle–down, right–down: 'The A moves above the B and the C.'
3. Left–down, middle–down, right–up: 'The A and the B move below the C.'
4. Left–down, middle–up, right–up: 'The A moves below the B and the C.'

These four movements were also employed on the related prime trials. We also ensured that target trials were preceded by prime trials with different movements. This minimized the movement priming between prime and target trials. The unrelated prime and filler trials featured three pictures all moving in the same direction, either up, down, left or right. The four movements on both the target and prime trials were distributed so that subjects would see equal numbers of all movements. The order in which the movements were distributed was also pseudorandomized to ensure that subjects could not predict an upcoming movement type. The filler trials either featured three different pictures which appeared and remained stationary and would be described as 'The pictures do not move' or a blank screen which would be described as 'No pictures appear'. Decoy trials were also used to prevent subjects becoming aware that the experiment was structured into pairs of trials. These decoy trials would resemble either unrelated prime trials or target trials and would occur in single units sandwiched between filler trials.

7.1.2. Design

The four matched sets of 15 target triples were assigned to the four experimental target conditions. Over the course of the experiment, the four sets of 16 target picture triples were rotated so that each target picture triple occurred an equal number of times in all four conditions. The prime triples were also assigned to the trials preceding the four target trial conditions so as to ensure that all prime triples occurred an equal number of times prior to all four target trial types. The experiment consisted of six blocks of trials. The first of these was a demonstration block showing typical experimental and filler trials. This was followed by two practice blocks of 15 trials structured as in Experiment 1. Lastly, the subject was presented with three experimental blocks each consisting of 64 trials. In each block there were 40 experimental trials (consisting of 20 prime trials and 20 target trials) and 24 filler trials. There were five target trials for each of the four conditions in each block. There was also an equal number of trials featuring each movement category in each block and each condition within a block featured an equal number of trials of each movement category. The distribution of the experimental trials across the block was pseudorandomized. Also, the same picture never occurred in two consecutive trials. The distribution of the filler trials across a block was also randomized. Finally, the ordering of the blocks was systematically rotated across participants to ensure that each block occurred an equal number of times in each position in the experiment.

7.1.3. Procedure

The procedure was the same as in Experiment 2.

7.1.4. Participants

The participants were ten male and 14 female students from Birmingham University.

7.2. Results

Outliers and trials with technical problems were excluded from the analyses as in Experiment 1. This resulted in the loss of 1.5% of the data. Responses were categorized as errors as in Experiment 1 and were excluded. Mean latencies and percentage error rates are summarized in Table 15. Error rates were highest in the conditions with the longer production latencies, thus providing no evidence of a speed–accuracy trade-off. For the Complex-simple sentences, production latencies were a significant 42 ms longer for sentences in the unrelated condition than for sentences in the related condition ($F_1(1,23) = 21.1,\ P < 0.01,\ F_2(1,59) = 9.3,\ P < 0.01$). For the Simple-complex sentences, production latencies were a non-significant 10 ms longer to the unrelated sentences than to the related sentences ($F_1(1,23) = 1.5,\ P > 0.2,\ F_2(1,59) = 0.6,\ P > 0.4$). An ANOVA on latencies yielded a significant main effect of Sentence complexity ($F_1(1,23) = 112,\ P < 0.01,\ F_2(1,59) = 96,\ P < 0.01$). This reflected the 91 ms difference between mean latencies to Complex-simple sentences (883 ms) and Simple-complex sentences (792 ms). There was also a significant main effect of Prime ($F_1(1,23) = 20.7, P < 0.01, F_2(1,59) = 7.2, P < 0.01$) and an interaction between Sentence complexity and Prime ($F_1(1,23) = 5.8,\ P < 0.03,\ F_2(1,59) = 3.63,\ P = 0.06$). A similar ANOVA on the target sentence error rates approached significance over subjects but not items ($F_1(1,23) = 4.1,\ P < 0.06,\ F_2(1,31) = 3,\ P > 0.08$).

In order to test if performance differed over the three experimental blocks we conducted an ANOVA including the variable Experiment block. This ANOVA yielded an effect of Experiment block which was significant over items only ($F_1(2,46) = 1.9, P > 0.1, F_2(2,118) = 4.6, P < 0.05$). This reflected the progressive decrease in latencies over the course of the three blocks (848 versus 836 versus 822 ms). However, the pattern of results was similar across the three experimental blocks. The interaction of Experiment block, Sentence complexity and Prime proved

Table 15
Production latencies, sentence durations and error rates for target sentences in Experiment 6

	Complex-simple		Simple-complex	
	Latency (ms)	error rate (%)	Latency (ms)	error rate (%)
Primed	862	2.7	787	2.5
Unprimed	904	4.3	797	2.1
Difference	42	1.6	10	0.4

to be non-significant ($F_1(2,46) = 0.5$, $F_2(2,118) = 0.2$). A similar ANOVA performed on percentage error rates yielded no significant effects or interactions. The post-experimental interviews showed that participants were unaware of the experiment's design and thus that conscious strategies had not been employed.

7.3. Discussion

The results of Experiment 6 demonstrate that whilst latencies to Complex-simple target sentences are significantly shorter when preceded by a related than an unrelated prime there is no significant difference between latencies to Simple-complex target sentences in the related and unrelated conditions. Such a pattern of results has a number of implications. Firstly, as was argued above, if syntactic planning is carried out for the whole of the first clause prior to speech onset then the related Simple-complex prime should facilitate the Simple-complex target significantly more than the unrelated prime should because whilst the whole clause of the simple complex prime is syntactically similar to that of the Simple-complex target the unrelated prime lacks an object phrase and as such differs from the Simple-complex target over the span of the clause. Our failure to observe such a pattern indicates that syntactic priming does not facilitate the generation of the first clause of an utterance prior to speech onset. This offers further support for the view that syntactic planning is not completed for the whole of a clause prior to speech onset (Schriefers et al., 1999). It was also argued above that if priming facilitates the generation of only the first phrase of an utterance prior to speech onset, then there should be no significant difference in latencies to Simple-complex target sentences in the related and unrelated conditions since the first phrase of both the related and the unrelated prime matches the first phrase of the Simple-complex target in terms of syntactic complexity. The results, in demonstrating no significant difference between latencies to Simple-complex target sentences in the related and unrelated conditions, provide support for the view that only the generation of the first phrase of the Simple-complex sentence has been facilitated prior to speech onset. It was also argued above that since the first phrase of the Complex-simple related prime and target consists of a co-ordinated noun phrase whilst that of the unrelated prime features only a single noun, the related prime should facilitate the Complex-simple target significantly more than the unrelated prime if syntactic planning is facilitated for the first phrase of an utterance prior to speech onset. The fact that we observe shorter latencies to Complex-simple target sentences after related than after unrelated primes indicates that only the generation of the first phrase of the Simple-complex sentence is facilitated prior to speech onset.

This syntactic account of the facilitation effect is further reinforced by the fact that the results cannot be attributed to the priming of conceptual structure. Specifically, such a view is incompatible with the results from the Simple-complex condition. In this condition, target sentences are primed equally effectively by both the related prime and the unrelated prime. Whilst related primes are similar to target sentences in terms of overall conceptual complexity, unrelated primes are, however, highly dissimilar to them. Thus, both related primes and target sentences refer to three

different objects, whereas unrelated primes refer to three objects of the same type. Secondly, the thematic agent of both the related primes and target sentences is a single object, whereas it refers to multiple objects in the case of the unrelated primes. Thirdly, both the related prime and target sentence feature a direct object or recipient which the unrelated prime lacks. Finally, whereas the verb in the target sentences and related primes refers to a group of objects moving in an opposing direction to a second group of objects, that of the unrelated prime refers to a single group of objects moving in the same direction. Conceptually, the related prime is very similar to the target sentence, whereas in almost every part of the sentence the unrelated prime is conceptually dissimilar to the target sentence. The fact that the target sentence is primed equally effectively by both the related and unrelated prime clearly indicates that this priming is not conceptual in nature.

In summary, the results of Experiment 6 indicate that the 50 ms facilitation effect reflects the priming of the syntactic structure of the first phrase of an utterance prior to speech onset. This further indicates that the effect reflects the priming of the internal structure of the first phrase of an utterance and not the priming of syntax beyond the first phrase. The results are also compatible with the view that syntactic structure is planned for only the first phrase of an utterance prior to speech onset.

8. General discussion

The current experiments were conducted with the aim of investigating syntactic persistence in an online setting. To achieve this aim we utilized a new online priming technique in which latencies to target sentences were recorded after participants had produced a prime sentence which either resembled or contrasted with the target sentence in terms of the complexity of its initial phrase. Experiment 1 demonstrated that participants are faster to produce a sentence by approximately 50 ms when it is preceded by the production of a syntactically similar sentence than when it is preceded by the production of a syntactically dissimilar sentence. The experiment's design, moreover, allowed us to rule out prosodic, visual and lexical similarities between prime and target trials as a possible source of the effect. The effect was then replicated in Experiment 2 whose design allowed us to rule out the possibility that the facilitation effect resulted from the target trial requiring the access of the same number of lemmas prior to speech onset as the related but not the unrelated prime trial. Experiment 2 also provided evidence in support of the claim that sentence durations reflect the rate at which the sentence is articulated and not the rate at which it is planned. The 50 ms effect was further replicated in Experiment 3 in which there was precisely the same relation between the movement of the picture array during the prime and target trials in both the related and unrelated conditions, allowing us to rule out with certainty the possibility that the effect reflected picture movement priming. This was further reinforced in Experiment 4 in which written sentences were used to stimulate the production of sentences during the prime trial, thereby ruling out similarities between the movement of pictures during the prime and target trials as a source of the facilitatory effect. Experiments 3 and 4 also

utilized single clause unrelated prime sentences and thus also allowed us to rule out the view that the 50 ms facilitation effect stemmed from the fact that in the previous experiments the related but not the unrelated prime sentence had featured the same number of clauses as the target sentence. In Experiment 5, the effect was found to disappear when participants named the picture movements but did not produce simple and conjoined noun phrases describing the pictures and this was interpreted as evidence against the view that the effect reflected the conceptualization of the picture movements rather than the formulation of the noun phrases. Finally, the results of Experiment 6 demonstrated that the facilitation effect was speeding the planning of only the first phrase of the target sentence prior to speech onset and provided further evidence against the view that the facilitation effect reflected the priming of conceptual planning. In short, these experiments repeatedly demonstrate a facilitation effect being obtained between syntactically related sentences and offer evidence against the view that this effect has its source in visual perception, conceptualization, lexical access and phonological planning. As such the experiments indicate that it is the priming of the syntactic planning of the target sentence which serves to give rise to the facilitatory effect. Moreover, in indicating that the facilitation effect had speeded the planning of only the first phrase of the utterance prior to speech onset, the experiments also indicated that the effect reflected the priming of the generation of the co-ordinate phrase of the target sentence. Taken together, the results of the six experiments indicate that the facilitation effect results from priming the grammatical formulation of the internal syntactic structure of the target sentence's initial phrase.

Such a pattern of results has a number of implications for speech production. Most obviously, the present results demonstrate that structural priming reduces the time dedicated to the generation of syntactic structure. As such the results provide confirmation of the Levelt and Kelter (1982) (cf. also Bock, 1986) 'effort reduction' theory of syntactic persistence in which it is argued that the function of syntactic persistence is to reduce the processing costs of the speaker and so to promote the fluency and rapidity of utterance generation. Of course, 50 ms might not seem like a tremendous reduction in processing cost. However, it must be remembered that such a figure represents the saving made for only the first phrase of an utterance prior to speech onset. Since, as Experiments 1 and 2 demonstrate, sentence durations reflect the time taken to articulate rather than plan a sentence, we cannot rule out the possibility that syntactic persistence enables further reductions in the planning of phrases beyond the initial phrase after speech onset. Certainly, it does seem likely that syntactic persistence does influence the generation of syntactic structure beyond the first phrase of an utterance given studies such as Bock and Loebell (1990) and Hare and Goldberg (1999) which demonstrate priming of phrases occurring after the verb phrase in English datives. If a sentence were to comprise four phrases each of which had their planning time reduced by 50 ms in line with the estimates obtained in the current study, this would represent a saving of approximately a fifth of a second per sentence as a result of the persistence of the constituent structure of phrases alone. Moreover, the current study restricted itself to the investigation of comparatively simple syntactic structures. It seems plausible that the figure of 50 ms

per phrase could rise as the complexity of the phrases themselves increases. Overall, the current study provides evidence in line with the view that syntactic persistence can provide for significant reductions in processing effort and thus supports Levelt and Kelter's hypothesis that the function of syntactic persistence in natural speech is to promote the fluency and rapidity of utterance generation.

In providing support for the hypothesis that the function of syntactic persistence is to reduce the processing costs of the speaker, the current results also serve to emphasize that syntactic persistence rather than being an isolated or unique speech phenomenon has parallels with a number of other speech phenomena which serve to reduce the formulation costs of the speaker. Most obviously, the current research stresses the link between syntactic persistence and other forms of repetitious language which also serve to reduce the processing costs of the speaker – notably formulaic language, which as Kuiper (1996) has shown, facilitates unusually rapid and fluent speech. More generally, the current research offers further reinforcement for the view that all aspects of speech production, from the structuring of the lexicon around a few hundred core lexemes (Altenberg, 1990) to the reduction of utterance complexity via the use of ellipsis and semantic indeterminacy (Smith, 2000), are constructed so as to reduce the processing costs of the speaker. In providing support for the view that syntactic persistence functions to reduce the speaker's processing costs, the current research is also in line with the view of the growing consensus in the speech production literature that the primary concern of speakers is to reduce their own processing costs rather than to facilitate the comprehension of the utterance by the listener (Clark & Wasow, 1998; Keysar et al., 1999; Smith, 2000; Wasow, 1997). Of course, the current study has not directly addressed the issue of the effect of syntactic persistence on the listener and so it cannot be said to directly rule out the hypothesis advanced by Pawley and Syder (1983) that the function of repetitious language is, in part, to facilitate the comprehension of an utterance by a listener (cf. also Hawkins, 1994). Given the growing consensus in the speech production literature, however, that the primary concern of speakers is to reduce their own and not listener's processing costs and, in particular, given the prevalence of speech phenomena such as ellipsis and semantic indeterminacy which reduce the speaker's own processing costs even whilst they increase those of the listener, it seems inherently unlikely that the syntactic persistence arises in order to reduce the processing costs of the listener (Smith, 2000).

The results from the present experiments also provide evidence that the generation of the structure of an utterance is a process which costs time and thus effort. As such, the results run counter to that tradition in speech production research which emphasizes that syntactic planning is an automatic and non-costly process emerging as a by-product of other, costly processes such as lemma access or conceptual planning. The results also indicate why previous studies (Beattie, 1980; Butterworth, 1980; Goldman-Eisler, 1972) did not observe syntactic planning costs: since such hesitation studies typically considered pauses of only 200 ms or more they would be insensitive to planning costs in the region of 50 ms. As such the results indicate that Garrett (1982) was right to be sceptical of the view that such studies confirm that syntactic planning is a non-costly process. They also provide clear support for

Garrett's claim that the generation of syntax in speech is a process which incurs costs independently of those incurred by other non-syntactic processes (cf. also Braitenberg, 1998). Of course, it must be cautioned, however, that the present results, whilst demonstrating that syntactic planning is a costly process, do not demonstrate how costly a process it is since the estimate of 50 ms may reflect all or only some of the cost of generating the structure of the sentence's initial phrase. However, given the failure of hesitation studies to observe planning costs above 200 ms it seems reasonable to suppose that the true cost may be somewhere between 50 and 200 ms. Clearly, though, further experimentation is required in order to determine exactly what portion of the costs of syntactic planning this 50 ms reduction represents and thus to determine more generally what the total cost of syntactic planning is to a speaker. Also, it remains to be determined whether more complex syntactic structures do incur greater processing costs or whether there is a single invariant cost across a range of different syntactic structures (cf. Smith, 1998, for a preliminary investigation of this issue).

The results of the present study also extend the analysis of the phenomenon of syntactic persistence by demonstrating the priming of a new type of structure not previously tested in the literature, the co-ordinate noun phrase. Clearly, such a structure presents a strong contrast to the types of syntactic structures that have been primed previously in the speech production literature. Thus, as argued in Section 1, most studies of syntactic persistence have primed the generation of syntactic structures such as actives and passives or datives and ditransitives. Most accounts of the generation of such structures typically accord a critical role to the process of grammatical or thematic role assignment (cf. Bock, 1987; Fox-Tree & Meijer, 1999; Hare & Goldberg, 1999) which is in sharp contrast to accounts of the generation of co-ordinate noun phrase structures which tend to emphasize the role of linear ordering and constituent assembly processes (Bock & Warren, 1985). This contrast in theoretical treatment is also reinforced by studies emphasizing that whilst the generation of structures such as datives and passives is influenced by conceptual factors such as the concreteness and imageability of the nouns being assigned to phrases, the assignment of nouns to slots within a co-ordinate structure is not influenced by such factors (Bock & Warren, 1985). Clearly, the current results, in demonstrating that co-ordinate noun phrase structures are susceptible to structural priming just like other syntactic structures, serve to emphasize the similarity in the processing of co-ordinate noun phrase structures and other types of structures, in contrast to Branigan and Feleki (1999) who argue that the production of co-ordinate noun phrase structures is anomalous. In other accounts of speech production, moreover, the determination of the internal grammatical structure of a phrase necessary for the construction of a co-ordinate noun phrase is held to be a process which is both dissociable from and which occurs at a later stage than the process which assigns grammatical roles to the various phrases within a clause (for evidence in support of this view cf. Fox-Tree & Meijer, 1999). On such a view, the current study may be priming structure generation processes other than those tapped in studies such as Bock (1986) and thus may provide support for the view that syntactic persistence

can influence structure generation at a variety of different stages of the speech production process (Bock et al., 1992).

Finally, the current study has provided some evidence in Experiment 6 (and, indirectly, in Experiments 3 and 4) that syntactic persistence does not apply to the whole of the first clause of an utterance prior to speech onset but is restricted in its application to the sentence's initial phrase. As argued above, this finding is just what we would expect were syntactic planning itself to be restricted to the generation of the first phrase of an utterance only prior to speech onset. As such it provides further experimental data in line with the view that syntactic planning in particular and grammatical encoding in general employ a sub-clausal or phrasal processing scope (Schriefers & Teruel, 1999; Schriefers et al., 1999; Smith, 2000; Smith & Wheeldon, 1999a; Wasow, 1997). Such data are in line, moreover, with corpus linguistic observations of naturally occurring speech which provide evidence of the use of a phrasal grammatical encoding scope during speech production (Clark & Wasow, 1998; Garrett, 1975, 1976, 1980). Importantly, such a view of the scope of syntactic planning accords well with incremental models of speech production which have emphasized that speech production, rather than being holistic so that the grammatical structure of an entire sentence is generated simultaneously, is piecemeal so that the grammatical structure of a sentence is broken down into discrete phrasal chunks and formulated at successive points in time (De Smedt, 1994, 1996; Ferreira, 1996; Kempen, 1987; Kempen & Hoenkamp, 1987; Levelt, 1989; Ward, 1992; Wheeldon, Meyer, & Smith, in press; Wundt, 1900).

In short, the present study offers a first look at the phenomenon of syntactic persistence in the context of an online experimental design. The principal aim of looking at syntactic persistence from such a perspective was to test out Levelt and Kelter's effort reduction hypothesis of syntactic persistence. Further aims included the investigation of co-ordinate noun phrase structures in the context of a structural priming experiment and the analysis of more general issues of syntactic planning in speech production such as the scope and cost of syntactic structure generation. As a final remark, it is worth cautioning the reader that the present study constitutes only a preliminary and highly tentative glimpse of syntactic persistence in an online context. Further analyses of the phenomenon – and, in particular, replications of the basic effect in different paradigms such as recall experiments – are required before it can be regarded with anything like confidence.

Acknowledgements

The data reported in this article were presented at the 1999 meeting of the CUNY conference on sentence processing. Part of the data contributed to the first author's PhD degree. The research was supported by a Birmingham University School of Psychology Studentship awarded to the first author and by an ESRC research grant awarded to the two authors. The authors would like to thank Holly Branigan, Nik Hargaden, Glyn Humphreys and Antje Meyer for insightful discussion and Jan Zandhuis for unflagging technical support.

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