High level processing scope in spoken sentence production

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Abstract

Five experiments investigate the scope of conceptual and grammatical encoding during spoken sentence production. An online picture description task is employed in which participants generate a variety of sentences in response to an array of moving pictured objects. Experiment 1, demonstrates longer onset latencies for single clause sentences beginning with a complex phrase (e.g. The dog and the kite move above the house) than for matched single clause sentences beginning with a simple phrase (e.g. The dog moves above the kite and the house). This finding suggests that more time is dedicated to the processing of the first phrase of an utterance than the remainder prior to speech onset. Experiments 2 and 3, compare the production of single and double clause sentences. The main effect of Experiment 1 is replicated. However, the data also suggest that some time is dedicated to the processing of elements within the second clause prior to speech onset. In Experiment 4, when participants are allowed to preview pictures prior to movement and timer onset the effect of initial phrase complexity is significantly reduced indicating that the latency effects observed previously primarily reflect lemma access. Finally, Experiment 5 demonstrates that this reduction is greater for nouns within the first phrase than for nouns beyond it. We conclude from these experiments that, prior to speech onset, lemma access is completed for the first phrase of an utterance and that high level processing is initiated but not completed for the remainder of a sentence beyond the first phrase.

Keywords: Processing scope; Spoken sentence production

1. Introduction

It has frequently been observed that at any given point in time during the production of a sentence a speaker will be actively generating not the smallest constituent
element at a given computational stage but rather a set of such elements. Thus, Garrett (1982) argues on the basis of word exchange errors that all of the lemmas within a clause are accessed simultaneously rather than individually at distinct points in time. Typically, researchers account for this fact by arguing that the selection of individual elements within a set is dependent upon and informed by the selection of the other elements within that set. Thus as Levelt (1992) argues, the collocational structure of a language entails that the selection of a lemma depends not only upon the conceptual structure underlying it but also upon the selection of neighbouring lemmas. Thus, to use Levelt’s example, whilst ‘to sink into oblivion’ and ‘to fall into disuse’ are natural in English, ‘to fall into oblivion’ and ‘to sink into disuse’ are not. Consequently, a speaker will need in these instances to check the selection of the verb and the noun against each other in order to produce natural English. Crucially, the quantity or scope of these dependently co-activated sets is amenable to investigation through online experiments because, as speech production researchers have frequently argued, if planning at the various high level processing stages does involve such sets then articulation should be initiated only when each high level processing stage has processed at least one such set and released it for further processing at the lower level stages. Thus Bock and Levelt (1994) (cf. also Garrett, 1982) argue that the assignment of nouns to functional roles is controlled by verbs. On such a view, the access of a noun in subject position in an English sentence cannot occur until the verb has also been accessed. Consequently, the articulation of the initial subject phrase should not occur until the dependent set of both the noun and the verb have been accessed (they cite Lindsley, 1975, in support of this).

Yet whilst it is generally assumed that the time to speech onset will be a product of the time taken to plan out at least one set of dependently co-activated elements at each stage of the speech production process, different models of speech production make different claims as to the scope of the dependently co-activated sets that arise at each processing stage. As a result, online sentence production experiments can provide a useful tool for determining the planning scope employed at the various stages of speech production and thus discriminating between the rival speech production models. In this article, we investigate the scope of high level processing achieved prior to speech onset via five online sentence production experiments. Before turning to these experiments, however, the relevant theoretical and empirical studies of high level processing scope are discussed.

2. High level processing scope: theoretical models

The first model of high level processing scope is that outlined by Wundt (1900) in his pioneering analysis of speech production ‘Die Sprache’ (1900 – cf. Blumenthal, 1970, for a detailed analysis of this aspect of Wundt’s work; also Levelt, 1989; MacPhail, 1998; Seuren, 1998). Wundt argued that at the conceptual planning level the various conceptual elements within a unit corresponding to the grammatical clause must be generated holistically and simultaneously before grammatical encoding can begin to convert this conceptual structure into the clause of a specific
language in piecemeal, phrasal chunks. Such a model clearly implies that prior to speech onset conceptual planning will be conducted for at least the first clause of a sentence and a phrasal unit will be planned out at the grammatical encoding level. A contemporary model similar to Wundt’s in terms of scope is Ward (1992) connectionist model of speech production, the flexible incremental generator (FIG). In the FIG, as in Wundt’s model, the conceptual structure underlying a clause must be generated before grammatical encoding can occur (cf. De Smedt, 1996). In contrast to Wundt, however, grammatical encoding occurs one word at a time rather than one phrase at a time. In Ward’s model, then, articulation is initiated when the conceptual planning for a clause but the grammatical encoding for only the first word of that clause has been executed.

Perhaps the most influential contemporary model of speech production is that developed by Garrett (1975, 1982). Garrett follows Fry (1969) in arguing that the processing of the whole of a sentence need not be completed at a given planning stage before that stage can release output to a subsequent planning stage (cf. Garrett, 1976, 234–236). One consequence of this is that, at any given point during sentence production, the various planning stages can be simultaneously active with different planning stages working on different parts of the sentence. However, Garrett also stresses that despite this flexibility there are systematic constraints on the minimum output that can be released from grammatical encoding stages to subsequent stages. He thus argues on the basis of exchange errors for a ‘functional’ planning stage at which the lemmas within a clause are simultaneously accessed and assigned to roles in a thematic plan before ‘positional’ stage processes are subsequently initiated which specify syntactic, morphological and phonological aspects of this clausal unit in successive phrasal chunks (cf. below for details). In some cases, Garrett (1982, page 66) argues, two such clausal units may be planned out simultaneously at the functional stage before being released for positional stage processing. It follows from such a model that functional level processes such as lemma access should be completed for at least the first clause of an utterance before positional level processing and consequently articulation can occur. In support of this, Garrett (1982, page 66) advances the view that the pauses that typically precede the articulation of a clause (cf. discussion below of Ford & Holmes, 1978; Ford, 1982) result from the execution of functional level processes such as lemma access and states that delays in the formulation of the clausal unit at the functional stage will give rise to delays in the articulation of a sentence’s initial phrase.

A further influential contemporary model of speech production is the incremental procedural grammar (IPG) developed by Kempen and Hoenkamp (1987) (cf. also De Smedt, 1996; De Smedt & Kempen, 1987). In this model processing is pipelined so that when output is released from one level to another the first level simply continues with the processing of the next fragment of the utterance and the two levels process in parallel (a feature known as ‘inter-component parallelism’). The IPG is also able to process multiple fragments simultaneously at a single processing stage (a feature known as ‘intra-component parallelism’) and this allows the conceptual planner to release successive fragments unimpeded by the fact that the grammatical encoder may not have yet completed its processing of prior conceptual
In this way, the conceptual planner in the IPG has always at any given point in time processed a greater proportion of the sentence than the grammatical encoder (until, of course, the grammatical encoder completes its processing of the sentence). However, the margin by which the conceptual planner runs ahead of the grammatical encoder is not fixed so that it is always a determinate number of fragments ahead of the grammatical encoder. Instead this margin varies according to how quickly processing proceeds individually at the two stages. This variation is further compounded by the fact that the size of the fragments released from each processing level is itself not fixed but subject to variation so that the conceptual planner may release fragments which correspond in size to lemmas or to clauses. As a consequence, the IPG allows for the possibility that the amount of conceptual planning (or indeed grammatical planning) achieved prior to speech onset will not always be a fixed amount but may instead be subject to variation. Also the IPG, in contrast to other models, allows for the possibility that an amount less than a clause may be conceptually planned prior to speech onset.

3. High level processing scope: off-line data

The scope of high level processing has been investigated in a number of off-line studies. Garrett, (1975, 1980, for instance, argues that speech errors demonstrate that two contrasting processing scopes are employed at two temporally distinct grammatical encoding stages. According to Garrett, ‘word exchange errors’ involving the exchange of lemmas in the same clause are evidence of an initial ‘functional’ stage at which the lemmas for at least the first clause of an utterance are accessed and assigned to thematic roles:

(1) This spring has a seat in it, (intended: seat has a spring).

For Garrett, the accessing of all of the lemmas within a clause occurs more or less simultaneously - obviously, word exchange errors could not take place if the words involved were not accessed at overlapping times. Garrett further argues that ‘sound exchange errors’ involving phonemes in the same phrase are evidence of a subsequent ‘positional’ stage employing a phrasal scope at which syntactic planning, morphological processing and some phonological processing is carried out:

(2) We have a lot of pons and pats to wash, (intended: pots and pans).

Crucially, for Garrett, positional level processing can only be initiated once a fragment is completed at and released from the functional level. In support of this, Garrett analyses errors in which lexical stems switch to incorrect positions leaving morphemes in their correct position:

(3)...a hole full of floors, (intended. floor full of holes).

Garrett argues that if the speaker had attached the morpheme ‘s’ to its intended stem ‘hole’ before the thematic role (and consequently syntactic position) of ‘hole’ had been determined then we should expect to see not (3) but rather the following:

(4)...a holes full of floor, (intended. floor full of holes).

For Garrett, then, the fact that errors such as (3) rather than (4) occur demonstrates that positional level processes such as morphology operate on fragments only after
they have been released from the functional stage. As the functional stage operates on clause sized fragments and the positional stage on phrase sized fragments, articulation in Garrett’s model can begin only when lemma access and thematic assignment have been completed for the first clause of an utterance and morphological and phonological processing have been completed for the first phrase. To reinforce the claim, moreover, that functional level processes such as lemma access are completed for at least the first clause of an utterance prior to speech onset, Garrett (1982, page 66) identifies functional level processing with the pauses which frequently precede the articulation of clauses in speech (i.e. Ford, 1982).

Unfortunately for Garrett, however, errors such as (4) in which both stems and morphemes occupy an incorrect syntactic slot do occur as the following example from Fromkin (1971) attests:

(5) examine the horse of the eyes, (intended: eyes of the horse).

Whilst such an error cannot be accounted for on the basis of Garrett’s two grammatical encoding stages, it could arise if we assume, contra Garrett, that errors can arise during conceptual planning (i.e. Harley, 1984). On such an assumption, the error could arise from the conceptual structure corresponding to the lemma ‘eyes’ being placed into the wrong thematic slot during conceptual planning. Subsequently, lemma access and morphological processing would then act only to reinforce this conceptual planning error thus leading to sentence (5). Yet if we concede that word exchange errors can arise during conceptual planning, it becomes possible to interpret Garrett’s speech error evidence not just in terms of two grammatical encoding stages but also in terms of a model in which a conceptual planning stage employing a clausal scope is followed by a single grammatical encoding stage employing a phrasal scope. On such a model, clausal word exchange errors (i.e. example 1) and errors in which both stem and morpheme occupy the incorrect slot (i.e. examples 4 and 5) would occur during conceptual planning whilst errors in which only the stem shifts to an incorrect thematic slot (i.e. example 3) would be attributed to an exchange of stems arising as lemma access and morphology occur simultaneously during a single grammatical encoding stage.

Garrett (1980) also attests to exchange errors involving elements from neighbouring clauses:

(6) watch the radio and listen to TV, (intended: listen to the radio and watch TV.)

(7) That wasn’t a tiger, that was a lion, (intended: a lion, that was a tiger).

Garrett notes that such multi-clausal exchanges always involve clauses which are ‘syntactically parallel’. Such exchanges also involve, however, clauses that are conceptually, as well as syntactically, similar. In example 1, for instance, both clauses describe a situation in which some form of media is being received. Why, then, should multi-clausal exchange errors arise only when the clauses involved are syntactically and conceptually similar? One possible explanation is that such errors might arise if a speaker generated a single underspecified conceptual representation which detailed only those aspects of the situation that the two clauses held in common and then attempted to formulate the two clauses on the basis of this shared representation. Such an approach would be economical in that it would allow for
multiple grammatical clauses to be extracted from a single rather than multiple conceptual structures yet it would also be error prone in that the underspecified conceptual structure would fail to safeguard against the selection of incompatible lemmas as in examples (2) and (3). Of course, this is no more than conjecture, however, as will be argued below, there is some evidence that a single conceptual representation can give rise to multiple clauses.

Further speech error evidence for the use of a clausal processing scope has been provided in a task by Bock and Cutting (1992); (cf. also Nicol, 1995; Vigliocco, Butterworth & Semenza, 1990) designed to elicit subject-verb agreement errors such as the following:

(8) *The slogan on the posters are really effective.
(9) *The boy that liked the snakes are really happy.

Sentences (8) and (9) are incorrect because the verb ‘are’ agrees in number with the plural noun (the ‘local noun’) rather than the singular subject noun, ‘slogan’ or ‘boy’. Crucially, Bock and Cutting found that such agreement errors are more likely to occur when the subject noun is modified by a prepositional phrase, as in (8), rather than a relative clause, as in (9), and thus that the local noun is more likely to interfere with the generation of agreement between subject and verb when it is in the same clause as the subject and verb than when it occupies a different clause to them. This suggests, then, that distinct clauses are processed separately and that this clause by clause partitioning is effected before syntactic processes such as number agreement are engaged in. It would seem, then, that sentence production ‘proceeds in hierarchical rather than sequential fashion, with the planning of clauses preceding the sequencing of words’ (Bock & Cutting, 1992, page 122).

Off-line data compatible with the use of a phrasal grammatical encoding scope has also been provided by Martin et al. (1998) in a study of a patient, ML, with a left frontal-parietal lesion. In an initial experiment, the ability to produce a single phrase involving a noun modified by an adjective (i.e. ‘the small leaf’) was tested in a task requiring the description of the highlighted picture in a contrasting pair (i.e. ‘small leaf’ vs. ‘big leaf’). In contrast to normals, ML performed extremely poorly on this task and tended to describe the object in two distinct clauses i.e. ‘it’s a leaf. It’s small’ (n.b. This is consistent with the view outlined above that a single shared representation can give rise to multiple clauses). In a second experiment, ML had to describe a scene via active and passive sentences containing relative clauses (i.e. ‘pick up the lion that kicked/was kicked by the frog’). Strikingly, patient ML scored very highly on this second task with an overall success rate of 87%. Clearly, if ML had employed a clausal grammatical encoding scope we would not expect superior performance on the second experiment since, taken in their entirety, the sentences featuring in this experiment are more complex lexically and syntactically than the noun phrases in Experiment 1. It is reasonable to expect such a pattern, however, on the assumption that ML had employed a phrasal grammatical encoding scope since the phrases ML was supposed to produce in Experiment 1 are, on an individual basis, more complex lexically and syntactically than those in the sentences in Experiment 2. Of course, evidence of phrasal grammatical encoding in patients does not by itself establish that grammatical encoding in normals has a phrasal scope. Nevertheless,
Martin, Katz and Freedman’s study provides evidence naturally compatible with such a view.

4. High level processing scope: on-line data

High level processing scope has also been examined in a number of on-line studies. Such studies have often investigated the distribution of the pauses that result from the planning of speech to determine how regularly speakers plan and thus how much they plan when they do (Butterworth, 1980; Goldman-Eisler, 1967). Such studies have typically found that pauses (typically defined as periods of silence over 200 ms in duration) tend to cluster at clause boundaries (Beattie, 1980; Pawley & Syder, 1983; Wijnen, 1990; Miller & Weinert, 1998 – for comprehension data cf. Gernsbacher, Hargreaves & Beeman, 1989; Stine, 1990; Gergely, 1997). This runs counter to models in which a phrasal processing scope is used at all high level processing stages since such models predict that pauses should be distributed evenly (or at least randomly) across phrasal junctures in speech. Instead such a result indicates that speakers employ a clausal scope at some point during speech production and that a phrasal scope is not employed at every speech planning stage.

Such findings have been extended by Ford and Holmes who have investigated the stage at which this clausal scope is employed. Ford and Holmes (1978), for instance, found that whilst subjects talked freely on a given subject their responses to an auditory signal were slower when the signal was presented near the end of a non-finite clause even when the end of that clause did not correspond to the end of a finite clause. Reinforcing this, a study of pausing in speech by Ford (1982) showed that pauses occur as frequently prior to non-finite clauses as to finite clauses and that the quantity of pausing that occurs prior to finite clauses is equivalent to that prior to non-finite clauses. Thus, Ford and Holmes’ work reveals that speakers plan their utterance a clause at a time and that non-finite and finite clauses necessitate equivalent amounts of planning. In English (the language used in the experiments), non-finite clauses are less complex grammatically than finite clauses but equally complex conceptually; we may not mark the subject of a non-finite clause grammatically but we must understand who the subject is. Ford and Holmes’ work suggests, then, that such pauses reflect the processing of clause-like units during conceptual rather than grammatical planning.

On-line data has also been used to support the view that grammatical encoding has a clausal scope. Thus in Meyer (1996), subjects were presented with pictures featuring two objects. They were instructed to describe the objects using either sentences (e.g. the arrow is next to the bag) or co-ordinated noun phrases (e.g. the arrow and the bag). On each trial an auditory distractor word was also presented which was often semantically related to one of the objects in the picture. Compared to unrelated distractor words, distractor words semantically related to the second word in both response types increased latencies. This was interpreted as evidence that the second word in both response types had been grammatically encoded prior to speech onset and thus that grammatical encoding has a clausal scope. However, latencies to the
co-ordinated noun phrases were on average 61 ms greater than sentence latencies. Meyer accounted for this by arguing that the co-ordinated noun phrase is more complex syntactically than the sentence and so requires more syntactic planning. Yet the claim that a noun phrase is more complex syntactically than a sentence is highly contentious and an interpretation of Meyer’s findings requiring no such assumption is possible. As Meyer concedes, it is possible that the semantic interference effects arise not from lemma access but from conceptual planning. The interference effects could thus have arisen if only the first phrase of an utterance is grammatically encoded whilst conceptual planning is carried out for the whole of the first clause. Such an account would also provide a simple explanation for the latency difference between the response types. Since the first phrase of the co-ordinated noun phrase (e.g. the arrow and the bag) is more complex lexically and syntactically than that of the sentence (e.g. the arrow) the difference could result from the extra grammatical encoding required for a co-ordinated noun phrase. Meyer’s findings are, then, consistent with either a phrasal or a clausal scope of grammatical encoding.

Contra Meyer, Lindsley (1975) argues that grammatical encoding is not completed for a single clause sentence prior to speech onset. Lindsley required participants to describe pictured scenes by producing either subject-verb sentences (e.g. the man is touching) or a verb describing the action (e.g. touching) and found that latencies were shorter for subject-verb than for verb-only responses. Based on this, Lindsley claimed that some, but not all, of the processing of the verb is carried out prior to speech onset. However, Lindsley’s design has serious flaws. For example, it is probably more natural to describe the pictures he used via a sentence than a verb. Also, there is an imbalance in that in the subject-verb condition, but not the verb condition, the first word of the sentence is supplied before each trial. Both of these factors may have caused the shorter latencies for the subject-verb responses. Finally, Lindsley’s experiments require subjects to repeatedly produce a set of only four semantically similar nouns (i.e. man, woman, girl, boy) and four verbs and it is not clear how such frequent repetition of such a limited set might affect the process of lemma access.

A stronger case for the claim that grammatical encoding has a phrasal rather than clausal scope has been made by Levelt and Maassen (1981). In this study, subjects took 59 ms longer to produce noun phrase conjunctives (i.e. ‘the circle and the square move up’) than sentence conjunctives (i.e. ‘the circle moves up and the square moves up’) in response to a moving visual array. Since the sentence conjunctives are lexically and syntactically more complex than the noun phrase conjunctives these results indicate that grammatical encoding has not been completed for the whole of both utterances prior to speech onset but for some portion of them only. Levelt and Maassen argue that this portion must be the phrase since the first phrase of the noun phrase conjunctives requires the retrieval of two nouns whereas the first phrase of the sentence conjunctives requires the retrieval of only one. However, the results are also consistent with a clausal grammatical encoding scope since the first clause of the noun phrase conjunctives (e.g. The circle and the square move up) also contains more lemmas than the first clause of the sentence conjunctives (e.g. the
circle moves up). The results can also be attributed to syntactic planning since the first phrase of the noun phrase conjunctives is syntactically more complex than that of the sentence conjunctives.

Finally, Ferreira (1991) has used a sentence recall paradigm to provide support for the claim that grammatical encoding is completed prior to speech onset for the whole of the first phrase of an utterance including the relative clause that modifies it. Subjects were required to memorise and reproduce sentences differing in the complexity of their initial segment (italicised in the following):

(10) the large and raging river empties into the bay,
(11) the river that stopped flooding empties into the bay.

Ferreira found that latencies were greater to sentences such as (11) than to sentences such as (10). In interpreting this result, Ferreira begins by arguing that the initial segment of sentence (11) involves only a single proposition (i.e. ‘the river stopped flooding’) and is, consequently, less complex conceptually than the initial segment of sentence (10) which involves two propositions (i.e. ‘the river is large’ and ‘the river is raging’). As Ferreira argues, it follows from this premise, that the greater latencies to sentence (11) cannot have resulted from conceptual planning and, consequently, must reflect the fact that the initial segment of sentence (11) is syntactically more complex than that of sentence (10) instead. On this basis, Ferreira is able to argue that syntactic planning is conducted for the whole of the first phrase including the relative clause that modifies it prior to speech onset. It can also be argued, however, that the initial segment of sentence (11) is conceptually more complex than that of sentence (10) and thus that the greater latencies to sentence (11) could also reflect conceptual planning. Thus according to Menaugh (1988) – cf. also Langacker, 1987), verb phrases represent the whole of an event as it unfolds continuously through time and as such are conceptually more complex than noun phrases which represent an object at a single point of time only. On such a view, the initial segment of sentence (11) since it contains both a verb and a noun phrase is more complex conceptually than that of sentence (10) which contains only a noun phrase. Similarly, Miller and Weinert (1998) claim that clauses denote situations suggests that sentence (11) is comprised of two discrete situations conceptually (i.e. ‘the river stopped flooding’ and ‘the river empties into the bay’) where sentence (10) is comprised of only one. However, it is difficult to be certain whether this alternative reading of Ferreira’s results is valid because, as Levelt (1989) has cautioned, there is no universally accepted method of quantifying the conceptual complexity of a sentence.

5. The present experiments

In summary, then, the literature on sentence production firmly supports the view that a clausal scope is employed at some point during the speech production process (Garrett, 1975; Ford & Holmes, 1978; Beattie, 1980; Ford, 1982; Pawley & Syder, 1983; Wijnen, 1990; Bock & Cutting, 1992; Meyer, 1996; Miller & Weinert, 1998). There is no study, moreover, which is incompatible with this view. There is also
some data consistent with the view that this clausal scope is employed at an early (possibly conceptual) planning stage (Ford & Holmes, 1978; Ford, 1982; Bock & Cutting, 1992). There is also evidence from aphasia consistent with the view that grammatical encoding has a phrasal scope (Martin et al., 1998). Moreover, the evidence cited in studies claiming that grammatical encoding employs a clausal scope (i.e. Garrett, 1976; Meyer, 1996) is ambiguous and seems also to be consistent with the view that it employs a phrasal scope. Overall, then, these studies are compatible with Wundt’s claim that conceptual planning employs a clausal scope whilst grammatical encoding employs a phrasal scope. They fail, however, to bear out the claim derived from the FIG (Ward, 1992) that grammatical encoding is executed one word at a time or Garrett’s claim that lemma access has a clausal scope (i.e. Martin et al., 1998). Moreover, whilst the IPG is not incompatible with these studies it does not motivate the finding that a clausal scope does seem to be employed at some point during the speech production process.

In the following study, five experiments are presented which yield unambiguous online data determining how much of a sentence aspects of grammatical encoding such as lemma access are completed for prior to speech onset and how much of a sentence at least some form of high level processing is conducted for prior to speech onset. To this end an online picture description task is employed in which subjects generate sentences in response to a visual array. In Experiment 1, latencies to single clause sentences indicate that more time is dedicated to the high level processing of the first phrase of an utterance than the remainder of the utterance prior to speech onset. In Experiments 2 and 3 latencies to single and double clause utterances demonstrate that some time has been dedicated to the processing of the second clause prior to speech onset. Experiment 4 indicates that when the time dedicated to lemma access is removed from latencies the previously observed effects of high level processing reduce to a non-significant amount and thus that these effects result from lemma access. Finally, in Experiment 5, latencies to single clause and relative clause sentences indicate that prior to speech onset lemma access is completed for elements within the first phrase but only initiated for elements beyond it. In the general discussion, it is argued that the results indicate that prior to speech onset grammatical encoding is completed for the first phrase of an utterance whilst high level processing is initiated but not completed for sentences up to two clauses in length.

5.1. Experiment 1

The aim of Experiment 1 was to investigate the scope of high level processing in sentence production. Specifically, Experiment 1 was designed to test whether more time is dedicated to the conceptual and grammatical encoding of elements within the first phrase of an utterance than to elements in the remainder of the utterance prior to speech onset. In order to test for this, we adapted a picture description task from Le-velt and Maassen (1981). In the task, subjects were presented with three pictures arranged in a horizontal line across the centre of a computer screen (see Fig. 1).

As soon as the three pictures were presented they would begin to move either up
or down the screen. On the experimental trials, the three pictures would move in two opposing groups with either the left and middle picture moving in opposition to the right picture or the middle and right picture moving in opposition to the left picture. Participants were required to describe the pictures from left to right using a single clause sentence comprising a verb phrase, a ‘complex’ noun phrase featuring two nouns and a ‘simple’ noun phrase featuring a single noun. According to the movement of the pictures on a trial participants would, on experimental trials, produce one of the following sentences:

(1) Complex-simple sentence: the dog and the foot move above the kite.
(2) Simple-complex sentence: the dog moves above the foot and the kite.

The dependent variable of interest was latency to speech onset. In order to be able to attribute any differences in latencies observed to the two sentences to differences in grammatical and conceptual complexity and not to differences of low level processing, it was necessary to ensure that the sentences were matched in terms of low level processing. Care was thus taken in matching the prosodic structure of the sentences. Specifically, the experimental sentences were designed to ensure that the first phonological word (i.e. the smallest prosodic unit which is at least as large as a lexical item) was of equivalent complexity in the two experimental sentences. This was deemed to be important as recent research has suggested 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). The prosody of the sentences was also matched insofar as the two sentence types featured an equivalent number of phonological phrases (i.e. a stretch of speech defined around a single syntactic head of phrase) and also insofar as the two sentence types both featured a single intonational phrase (i.e. a stretch of speech over which a single intonational contour is planned). It has also been shown by Meyer (1996) that phonological processing is not carried out for the second noun of a complex noun phrase prior to speech onset. this indicates that any latency differences observed between complex-simple and simple-complex sentences should not be attributed to phonological processing because whilst the first phrase of the former is more complex phonologically than that of the latter, phonological processing, as Meyer’s results show, is carried out for the first noun only prior to speech onset and not for the whole of the phrase. Care was also taken to ensure that the movement of the pictures in the visual array were similar in terms of overall complexity. Thus, overall, the visual array on both types of trial comprised three pictures moving in
two opposing groups. Despite this matching, the visual arrays in the two conditions still differed in terms of the number of pictures featured in each of the two moving groups on a trial (i.e. the leftmost moving group in a complex-simple sentence trial featured two pictures whereas that in a simple-complex sentence trial featured only one). Later experiments (see Experiments 4 and 5), however, demonstrated that this contrast in visual display complexity gives rise to a small and non-significant latency effect, indicating that any differences observed in the current experiment were not attributable to differences in visual display complexity.

The sentences were also carefully matched in terms of overall syntactic complexity since they were both comprised overall of a verb phrase and two noun phrases, one of which conjoined two nouns and one of which featured a single noun. The sentences were also matched in terms of lexical complexity since both sentences featured nine lemmas. It was assumed that since the two sentences were, overall, of equivalent lexical and syntactic complexity they were also, overall, of a similar conceptual complexity. Certainly, there seemed to be no compelling argument as to why one of the sentences might be deemed more conceptually complex than the other. Yet as well as being matched in terms of overall complexity, the sentences also contrasted in terms of the complexity of their first phrase. Thus, the first phrase of the complex-simple sentence (‘the dog and the foot’) is more complex than that of the simple-complex sentence (‘the dog’) syntactically (since it conjoins two nouns), lexically (since it features five lemmas) and, presumably, conceptually.

It was assumed, then, that any latency differences should be attributed not to low level (i.e. prosodic or perceptual) processing but to high level (i.e. grammatical and conceptual) processing. In particular, it was reasoned that if more time is dedicated to the high level processing of elements within the first phrase of a sentence than to elements beyond the first phrase then latencies should be significantly greater to complex-simple than to simple-complex sentences since the first phrase of the former is conceptually and grammatically more complex than that of the latter. In contrast, if no significant differences were observed between latencies to complex-simple and simple-complex sentences then this would be consistent with the view that conceptual and grammatical encoding are completed for the whole of a single clause sentence prior to speech onset or for the first word only since over both of these distances the two sentence types are equally complex. Such a result would also be consistent with the view that prior to speech onset high level processing had been completed for the first word only and initiated but not completed for the remainder of the sentence.

5.2. Method

5.2.1. Materials

A set of 92 simple black and white line drawings of familiar objects were used. Forty eight of these were used in the experimental trials and 44 in the filler trials. The pictures were taken mostly from Snodgrass and Vandervart (1980) picture norms with the rest being free drawn in a similar size and style. All pictures had been extensively pretested 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 pretest (n.b. word frequencies were calculated by averaging the orthographic token and stem frequency count for noun uses in Kucera and Francis (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). Due to the complexity of the task it was important that subjects could identify and name all pictures quickly and easily. Therefore, all experimental pictures had a naming latency of less than 600 ms. Mean naming latency and standard deviation were 525 and 150 ms, respectively. All experimental pictures had a word frequency of more than 15 occurrences per million. Mean word frequency was 147 occurrences per million. Percentage error rates for experimental pictures were less than 4%. All pictures names were either one or two syllables in length. The set of 48 experimental pictures was used to generate 32 sets of three pictures (henceforth triples). In order to do this the 48 pictures were first divided into three sets of 16 pictures to occur in each of the three possible screen positions. These were matched, as Table 1 demonstrates, ensuring that pictures contributed equally to latencies for words at each screen position.

Pictures in these three sets were then combined in two different ways resulting in two experimental sets of sixteen triplets. The construction of these picture triplets was constrained in a number of ways. Care was taken to ensure that there was no phonological or conceptual similarity between the three pictures in a triple because such similarities might lead to lemma priming within a sentence. As far as possible, we ensured that each of the 48 experimental pictures was combined with different pictures on both of the two triples in which it occurred. This would prevent associations forming between pictures. We also ensured that each picture never occurred in the same screen position twice. Also, each experimental picture occurred once in both of the two sentence types to ensure that individual pictures contributed equally to latencies for each condition. Pictures could move either up, down, right or left but only up and down occurred in the experimental trials. The assignment of these movements to pictures within a phrase was varied to give the two movement types shown below:

1. Subject phrase UP – object phrase DOWN.
2. Subject phrase DOWN – object phrase UP.

The two movement types were distributed so that subjects would see equal numbers of all movements. The order in which the movements were distributed

<table>
<thead>
<tr>
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<td>Three matched sets of picture name materials for Experiment 1</td>
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was also pseudorandomised to ensure that subjects could not predict an upcoming movement type. In combination with the two experimental conditions there was a total of four different movements.

Filler triples were also constructed in order to minimise inter-trial priming. Four types of filler sentences were constructed which differed in syntactic structure to the experimental trials. In particular, we were concerned that the filler trials should not prime the syntax of the initial noun phrase of the experimental trials by featuring an initial noun phrase of the same syntactic type. Therefore, the four filler types featured movements designed to stimulate the following descriptions:

1. they all move apart, (three pictures move in different directions),
2. they both move up, down, right or left, (two pictures move in the same direction),
3. they all move up, down, right or left, (three pictures move in the same direction),

5.2.2. Design

The two sets of 16 triples were assigned to the two ‘complex-simple’ and ‘simple-complex’ experimental sentence conditions. The assignment of sets to conditions was rotated across subjects so that by the end of the experiment each triple had occurred in both conditions an equal number of times. The experiment consisted of ten blocks in all. The first two blocks were practice blocks of 18 trials each. The practice blocks were similar to the experimental blocks in terms of the sentences that were elicited. During the practice blocks, the participant encountered each of the forty-two experimental pictures once. This allowed us to check that the participant knew the correct name for each picture. For the purposes of the design, the eight experimental blocks were divided into four pairblocks. Each pairblock contained four trials from both sentence conditions as well as twenty filler trials. The distribution of these experimental trials across the pairblock was pseudorandomised with the aim of ensuring that sentences of the same syntactic type could not follow one another in consecutive trials in order to minimise inter-trial priming. For this reason we also ensured that the same picture never occurred in two consecutive trials. The distribution of the filler trials across a pair block was also randomised. Finally, the ordering of the pair blocks was rotated across participants to ensure that each pair block occurred an equal number of times in each position in the experiment.

5.2.3. Apparatus

Each participant was tested individually, seated in a sound attenuating booth facing the screen of a Dell monitor positioned approximately 80 cm away from him/her. Participants wore headphones with an attached microphone through which they would respond. The experimenter was seated outside of the booth out of sight of the subject in front of a monitor which displayed information on-line about the progress of the experiment. The experiments were run by a program run on a Dell computer in tandem with a Kay computerised speech laboratory.
5.2.4. Procedure

Prior to the experiment itself participants were informed as to what types of movements they would see and how these movements should be described. They were also requested to describe the pictures from left to right. The timing of each trial was as follows: each trial began with the appearance of a $19 \times 6.5$ cm rectangular frame centred across the screen. This black on white frame delimited the area in which the pictures would appear. The frame was displayed for $2$ s. At its offset, the pictures to be described were presented on the screen. As soon as the pictures appeared they began to move in one of the ways stipulated above. The whole movement covered $2.5$ cm of the screen and lasted $1500$ ms. Participants began to describe what they had seen as soon as they could. As soon as the voicekey was triggered by the participant’s response the pictures disappeared from the screen. An interval of $4$ s then preceded the onset of the next trial. Participants were encouraged to take a break between blocks. At the end of the experiment each participant was asked a number of questions to ascertain how aware they were of the purpose of the experiment and to gauge if they had developed any strategies in response to the experiment.

5.2.5. Participants

The participants were 32 undergraduate students from Birmingham University, 19 males and 13 females. All participants in this and in the following experiments were native speakers of English who were paid either in research participation credits or at the rate of £4 per h. Each participant took part in only one of the experiments we report.

5.3. Results

Responses with latencies less than $400$ ms and longer than $2$ s were regarded as outliers and excluded from the analyses as were trials on which technical errors occurred such as voice key failures. This resulted in the loss of $0.4\%$ of the data. Three types of response were categorised as errors: responses in which participants did not use the expected picture names; responses in which participants did not use the expected syntactic structure; and disfluent responses on which participants stuttered or repaired the utterance. Data from all of these trials were excluded from the analyses. Separate analyses were carried out with subjects and items as random variable, yielding $F_1$ and $F_2$ statistics, respectively. The units of analysis in the item analyses were picture triplets.

Mean latencies and percent error rates were as follows: complex-simple sentences, $1039$ ms, $4.1\%$; simple-complex sentences, $962$ ms, $3.3\%$. The $77$ ms difference was significant, $F_1(1,31) = 51.5$, $P < 0.001$, $F_2(1,31) = 43.9$, $P < 0.001$. The $0.8\%$ difference in error rate was not significant. To test if performance differed over the two halves of the experiment, an ANOVA including the variable Experiment half was conducted. This analysis yielded a significant main effect of Experiment half, $F_1(1,31) = 36.5$, $P < 0.001$, $F_2(1,31) = 15.3$, $P < 0.001$, but no significant interactions.
6. Discussion

Experiment 1 demonstrates that latencies to complex-simple sentences are greater (by 77 ms) than those to simple-complex sentences even though these two sentences are equally complex overall. Such a difference is consistent with the view that more time is dedicated to high level processing of elements within the first phrase of a sentence than to elements beyond the first phrase prior to speech onset. On this view, complex-simple sentences give rise to longer latencies than simple-complex sentences because their first phrase is conceptually and grammatically more complex than that of a simple-complex sentence. Moreover, the difference between complex-simple and simple-complex sentences rules out the view that both grammatical and conceptual planning are completed for the whole of a single clause sentence prior to speech onset or are conducted for the first content word only. Also, the difference cannot be attributed to the fact that the subject phrases of the complex-simple sentences are syntactically plural whereas those of the simple-complex sentences are syntactically singular because in Experiment 4 the complex-simple and simple-complex sentences differ in this respect without differing significantly in terms of latencies.

The present experiment indicates that, prior to speech onset, more time is dedicated to the high level processing of elements within the first phrase of a sentence than to elements beyond the first phrase and thus that conceptual and grammatical planning are not completed for the whole of a single clause sentence prior to speech onset or are conducted for the first content word only. Three distinct interpretations of such a pattern of data are possible. The results could mean that prior to speech onset conceptual and grammatical planning are completed for the first phrase only or are completed for the first phrase and only initiated for the remainder of the sentence or are completed for the first noun in a phrase and only initiated for the remainder of the phrase. Clearly, further experiments are needed to discriminate between these three interpretations.

7. Experiment 2

Experiment 2 is an attempt to replicate the finding that more time is dedicated to elements within the first phrase of an utterance than to elements beyond the first phrase prior to speech onset with a new set of sentences which are longer and more complex than those employed in Experiment 1. Also, Experiment 2 attempts to determine whether processing time is dedicated to the second clause of a sentence prior to speech onset. If this were so, it would be incompatible with the view that conceptual and grammatical planning are restricted to the first phrase of an utterance prior to speech onset and would instead indicate that at least some conceptual and/or grammatical processing is performed for elements beyond the first phrase prior to speech onset. Such evidence would also provide a test of whether processing scope could extend over two clauses prior to speech onset as ‘syntactic parallelism’ speech errors (Garrett, 1982) suggest.

To test these issues, Experiment 2 utilises a modified version of the experimental
design employed in Experiment 1. As before, subjects engage in a picture description task involving three pictures which are described from left to right as they move vertically across a computer screen. In contrast to Experiment 1, however, subjects are instructed to use double clause sentences to describe the movement of three pictures (as in sentences 1 and 2). Also, the current experiment contrasts with Experiment 1 in that subjects encounter trials in which only one or two pictures move. The subjects are instructed to describe these using single clause sentences which detail only the moving pictures (as in sentences 3 and 4). This design gives rise to four distinct sentence types:

1. complex-simple sentence: the dog and the foot move up and the kite moves down,
2. simple-complex sentence: the dog moves up and the foot and the kite move down,
3. complex sentence: the dog and the foot move up,
4. Simple sentence: the dog moves up.

As in Experiment 1, it was important to ensure that the sentences were matched as far as possible in terms of low level processing characteristics. Thus, as with Experiment 1, the experimental sentences were designed to ensure that the first phonological word was of equivalent complexity across the various experimental sentences. The prosody of the sentences was also matched insofar as the two sentence types featured an equivalent number of phonological phrases and also insofar as the two sentence types both featured a single intonational phrase. Care was also taken to ensure that the movement of the pictures in the visual array was similar in terms of overall complexity. Thus, the visual display for the double clause sentences was the same as that employed in Experiment 1 in featuring three pictures moving in two opposing groups. The number of moving pictures featured in the single clause sentences also matched the number of moving pictures in the first clause of the corresponding double clause sentence (i.e. the visual display for the complex sentence features two moving pictures matching the first clause of the complex-simple sentence which also features two moving pictures). This matching would allow greater latency differences between single clause sentences and their corresponding double clause sentences to be attributed to the visual, conceptual and grammatical processing of the second clause of the double clause sentences. In subsequent experiments (see Experiments 3–5) the relative contributions of visual, conceptual and grammatical planning to second clause processing prior to speech onset are teased apart indicating that the observed effects of second clause processing are not attributable to visual processing alone.

The sentences employed in Experiment 2 were also matched, as in Experiment 1, for overall lexical, syntactic and conceptual complexity. Thus, the double clause sentences were both comprised overall of two verb phrases and two noun phrases, one of which conjoined two nouns and one of which featured a single noun. In terms of lemmas, the double clause sentences were also similar overall since both sentences featured the same twelve lemmas. Again, it was assumed that since the two sentences were, overall, of equivalent lexical and syntactic complexity they were also, overall, of a similar conceptual complexity. The single clause sentences
also matched the first clause of their corresponding double clause sentences lexically, syntactically and conceptually (the complex sentence is, for instance, identical to the first clause of the complex-simple sentence). Again, though, despite this matching, the sentences contrasted in terms of the complexity of their first phrase. Thus, the first phrase of the complex-simple sentence is more complex lexically, syntactically and conceptually than that of Simple-complex sentence. Furthermore, the double clause sentences were clearly more complex lexically, syntactically and conceptually than the single clause sentences.

On this basis, it was reasoned that a comparison of latencies to the double clause sentences would again constitute a test of high level processing scope. As in Experiment 1, this comparison would test for whether more time is dedicated to the high level processing of elements within the first phrase of an utterance than to elements beyond it prior to speech onset but in relation to more complex sentences. Also, comparing latencies to single and double clause sentences would indicate whether any time had been dedicated to the processing of the second clause of an utterance prior to speech onset. If time is dedicated to either the visual, conceptual or grammatical processing of elements within the second clause prior to speech onset then latencies to single clause sentences should be significantly smaller than to their corresponding double clause sentences. Also, if the amount of processing dedicated to the second clause is dependent on its complexity then the difference between the double clause sentences should be smaller than the difference between the single clause sentences. This is because the simple second clause of the complex-simple sentence will require less processing than the complex second clause of the simple-complex sentence thus reducing the difference between the sentences due to first clause processing and rendering the difference between these two sentences less than that observed in the case of the single clause sentences. In summary, then, Experiment 2 constitutes a second test of the issues tested out in Experiment 1 with longer and more complex sentences. Experiment 2 also investigates, however, whether time is dedicated to the high level processing of the second clause of an utterance prior to speech onset and thus whether such processing extends beyond the first phrase prior to speech onset.

7.1. Method

7.1.1. Materials

The set of 48 experimental pictures used in Experiment 1 was used to generate 64 picture triples. These picture triples were built from the three matched sets of sixteen pictures employed in Experiment 1. The three sets were combined in four different ways to give four experimental sets of 16 triplets. The triplets were designed to avoid phonological or conceptual similarity between the three pictures and each of the 48 experimental pictures was combined with different pictures in each of the triples in which it occurred. Each picture never occurred in a screen position more than twice and each experimental picture occurred once in all four sets of 16 triples. During the experiment, pictures could move in five possible directions: up, down, right, left and no movement. Of these, only up, down and no movement occurred in the experi-
mental trials. The assignment of these movements to pictures within a clause was varied to give the four distinct movement types shown below.

1. Clause 1 UP ± clause 2 DOWN.
2. Clause 1 DOWN ± clause 2 UP.
3. Clause 1 UP ± clause 2 NO MOVEMENT.
4. Clause 1 DOWN ± clause 2 NO MOVEMENT.

The four movement types were distributed so that subjects saw equal numbers of the movements. The order in which the four movements were distributed was also pseudorandomised to ensure that subjects could not predict movement type. The fillers were constructed as in Experiment 1.

7.1.2. Design and procedure

The four sets of 16 triples were assigned to four experimental conditions:

1. complex-simple sentence: the dog and the foot move up and the kite moves down,
2. simple-complex sentence: the dog moves up and the foot and the kite move down,
3. complex sentence: the dog and the kite move up,
4. simple sentence: the dog moves up.

The assignment of sets to conditions was rotated across subjects so that each triple occurred in all four conditions an equal number of times. The experiment began with two practice blocks of 20 trials during which each experimental picture occurred once. These featured a similar distribution of sentences to the experimental blocks. There were eight experimental blocks from both sentence conditions as well as twenty filler trials. The trial order was pseudorandomised employing the constraints used in previous experiments. The order of pairblocks was rotated across participants.

The experiment began with two practice blocks of 20 trials during which each experimental picture occurred once. These featured a similar distribution of sentence types to the experimental blocks. There were eight experimental blocks of 20 trials. For the purposes of the design, these were combined to form four pairblocks. In each pairblock there were 16 experimental trials and twenty four filler trials. The sixteen experimental trials in each pair block consisted of four trials from each of the four sentence conditions. Each pairblock contained 4 trials from both sentence conditions as well as twenty filler trials. The order of trials was pseudorandomised employing the same constraints used in Experiment 1. The order of pairblocks was rotated across participants. The procedure was the same as in Experiment 1 except that participants were instructed to describe the visual array via the sentences given above. Thirty-two participants were tested, 15 females and 17 males.

7.2. Results

Outliers were excluded from the analyses following the same criteria used for Experiment 1 as were data from trials with technical problems. This resulted in the
loss of 1.4% of the data. Mean naming latencies and percentage error rates are shown in Table 2.

Error rates were highest in conditions with the longest latencies, thus providing no evidence of a speed-accuracy trade-off. An ANOVA including the variables sentence length (double versus single clause) and first clause complexity (complex versus simple noun phrase in the first clause) was conducted. A significant main effect of sentence length was observed, $F_1(1,31) = 75.2$, $P < 0.001$, $F_2(1,63) = 195.5$, $P < 0.001$. Latencies for the double clause sentences were, on average, 142 ms longer than for the single clause sentences. A significant main effect of first clause complexity was also observed, $F_1(1,31) = 147.5$, $P < 0.001$, $F_2(1,63) = 173$, $P < 0.001$. Sentences with complex first clauses were on average 137 ms longer than those with simple first clauses. The interaction between sentence length and first clause complexity was significant, $F_1(1,31) = 38.1$, $P < 0.001$, $F_2(1,63) = 23.5$, $P < 0.001$, as the effect of first clause complexity for the single clause sentences was more than twice that for the double clause sentences. A similar analysis of percent error rates yielded only a significant main effect of sentence length, $F_1(1,31) = 49.7$, $P < 0.001$, $F_2(1,63) = 56.1$, $P < 0.001$, and a significant interaction between Sentence length and First clause complexity, $F_1(1,31) = 6.71$, $P < 0.05$, $F_2(1,63) = 5.28$, $P < 0.05$. Latencies were significantly longer (by 78 ms) for the complex-simple sentences than for the simple-complex sentences, $F_1(1,31) = 35.6$, $P < 0.001$, $F_2(1,63) = 31$, $P < 0.001$. Latencies were significantly longer (by 195 ms) for the complex sentences than for the simple sentences, $F_1(1,31) = 135.8$, $P < 0.001$, $F_2(1,63) = 234.6$, $P < 0.001$. Similar analyses on the double clause sentence error rates proved to be non-significant, $F_1(1,31) = 0.2$, $P > 0.5$, $F_2(1,63) = 0.1$, $P > 0.5$, whilst analyses on the single clause sentence error rates proved to be significant, $F_1(1,31) = 13.8$, $P < 0.001$, $F_2(1,63) = 14.1$, $P < 0.001$.

To test if performance differed over the two halves of the experiment, an ANOVA including the variable Experiment half was run. This ANOVA yielded a significant main effect of Experiment half, $F_1(1,31) = 35.6$, $P < 0.001$, $F_2(1,63) = 94.6$, $P < 0.001$. Latencies were slower in the first half of the experiment than in the second half (1076 and 975 ms, respectively) but the pattern of results was similar across all pairblocks. The interaction of Experiment half and sentence length was not significant, $F_1(1,31) = 1.3$, $P > 0.2$, $F_2(1,63) = 0.4$, $P > 0.5$, as was the interac-

<table>
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tion of Experiment half and first clause complexity, $F_1(1, 31) = 0.77$, $P > 0.2$, $F_2(1, 63) = 0.01$, $P > 0.5$. The three way interaction only approached significance in the subjects analysis, $F_1(1, 31) = 4.7$, $P < 0.05$, $F_2(1, 63) = 1.1$, $P > 0.2$ and this was due to differences in the size rather than the direction of effects. An analysis of error rates yielded only a main effect of Experiment half significant by items only, $F_1(1, 31) = 3.6$, $P > 0.05$, $F_2(1, 63) = 7.7$, $P < 0.01$, and no significant interactions.

7.3. Discussion

The principal finding of Experiment 2 is that latencies to double clause complex-simple sentences are significantly greater (by 78 ms) than to double clause Simple-complex sentences. This replicates the pattern of results observed in Experiment 1 (though note that latencies and error rates to complex-simple and simple-complex sentences are greater in Experiment 2 than in Experiment 1 which most probably reflects the fact that Experiment 2 with its four experimental conditions constitutes a more demanding task overall than Experiment 1) and is again consistent with view that more processing time is dedicated to the high level processing of elements within the first phrase of an utterance than elements beyond it prior to speech onset. The difference between the double clause sentences is also incompatible with the view that conceptual and grammatical encoding have been completed for the whole of the two clause utterance or for the first word only prior to speech onset.

Interestingly, however, two aspects of the results support the view that time has been dedicated to the second clause of the double clause utterances prior to speech onset. Firstly, latencies to single clause sentences are significantly less than to their corresponding double clause sentences. Thus, complex-simple sentences take 83 ms longer to onset than complex sentences whilst simple-complex sentences take 200 ms longer to onset than simple sentences. Secondly, the difference between the double clause sentences is significantly less than the difference between the single clause sentences. As argued above, we should expect that the simple second clause of the complex-simple sentence will require less processing than the complex second clause of the simple-complex sentence thus reducing the difference between the sentences due to first clause processing and rendering the difference between these two sentences less than that observed in the case of the single clause sentences. Crucially, however, the fact that latencies to complex-simple sentences remain greater than those to simple-complex sentences despite this suggests that second clause processing is less thorough than first clause processing. Nevertheless, such a finding is consistent with the claim (Garrett, 1980) that processing may extend up to a distance of two clauses.

The results observed in the present experiment also serve to reinforce the view that the latency difference observed has not arisen on the basis of phonological processing. As in Experiment 1, the present effects are of too great a magnitude to be attributable to phonological processing alone. Much the same argument can be applied to the contribution of the perceptual processing of the visual array. It is certainly the case that since fewer moving pictures featured in the visual array of the
single clause sentence trials than the double clause sentence trials we would expect at least some of the difference observed between latencies to single and double clause sentences to reflect visual processing. However, given the size of the differences involved (latencies to double clause sentences were on average 142 ms longer than to single clause sentences) it is unlikely that the differences between single and double clause sentences reflect the visual display processing alone especially given the estimate of an upper limit on the cost of visual display processing obtained in Experiment 4. (It is also the case that fewer moving pictures featured in the visual array of the complex sentences than the simple sentences. Again, though, given the 195 ms difference involved it is unlikely that this reflects visual display processing alone given Experiment 4.) It would seem, then, more reasonable to assume that time has been dedicated not only to the visual processing of the second clause prior to speech onset but also to some high level processing of the second clause prior to speech onset.

In sum, Experiment 2 is consistent with the view that more time is dedicated to the high level processing of elements within the first phrase of an utterance than to those beyond it prior to speech onset. The results also indicate that high level processing is initiated but not completed for elements beyond the first phrase prior to speech onset and may extend up to two clauses.

8. Experiment 3

Experiment 2 clearly demonstrated that some time may be dedicated to the processing of the second clause of an utterance prior to speech onset. Such processing may have been necessitated, however, by the fact that in Experiment 2 the pictures described during a trial were removed from the screen as soon as the voicekey was triggered by the participant’s response. Such a design feature necessitates the visual processing of second clause pictures by participants prior to speech onset and suggests that in the absence of such a feature participants might not after all engage in second clause processing. In Experiment 3, then, this design feature was changed so that the pictures were removed 500 ms after participants had completed their response. It was reasoned that if time was still dedicated to second clause processing with the new design then this would be incompatible with the claim that such processing is purely a strategic response to certain design features in Experiment 2.

8.1. Method

8.1.1. Procedure

The materials and procedure were the same as in Experiment 2, except that the pictures remained on the screen during each trial until 500 ms after voicekey offset. Participants were 32 native English speakers of whom 21 were female and 11 were male.
8.2. Results

Outliers were excluded from the analyses following the same criteria used for Experiment 1 resulting in the loss of 0.8% of the data. Mean naming latencies and error rates are shown in Table 3. An ANOVA performed on mean latencies yielded a significant main effect of sentence length, $F_1(1, 31) = 109.9, P < 0.001$, $F_2(1, 63) = 129.8, P < 0.001$, and of first clause complexity, $F_1(1, 31) = 185.4, P < 0.001$, $F_2(1, 63) = 276.8, P < 0.001$. The interaction between Sentence Length and First clause complexity, was also highly significant, $F_1(1, 31) = 46.7, P < 0.001$, $F_2(1, 63) = 24.8, P < 0.001$. Percentage error rates also yielded significant main effects of Sentence length, $F_1(1, 31) = 17.3, P < 0.001$, $F_2(1, 63) = 36.4, P < 0.001$, and first clause complexity, $F_1(1, 31) = 21.8, P < 0.001$, $F_2(1, 63) = 22.3, P < 0.001$, but no interaction of these variables, $F_1(1, 31) = 0.67, P > 0.2$, $F_2(1, 63) = 3.1, P > 0.05$. Latencies were significantly longer (by 92 ms) for the complex-simple sentences than for the simple-complex sentences, $F_1(1, 31) = 78.2, P < 0.001$, $F_2(1, 63) = 104.9, P < 0.001$. Latencies for the complex sentences were significantly longer (by 164 ms) than for the simple sentences, $F_1(1, 31) = 235.8, P < 0.001$, $F_2(1, 63) = 205.4, P < 0.001$. Similar analyses on percentage error rates showed the 1.9% difference between the double clause sentences was significant, $F_1(1, 31) = 15.6, P < 0.001$, $F_2(1, 63) = 12.1, P < 0.001$, as was the 2.1% difference between the single clause sentences, $F_1(1, 31) = 9.6, P < 0.01$, $F_2(1, 63) = 13.5, P < 0.001$.

In order to test if participants’ performance varied over the course of the experiment, we conducted an ANOVA including the variable Experiment half. As in Experiment 1, mean latencies were significantly slower in the first half of the experiment than in the second half (1035 and 978 ms, respectively), $F_1(1, 31) = 33.8, P < 0.001$, $F_2(1, 63) = 62.1, P < 0.001$. This analysis also yielded an interaction of Experiment half and first clause complexity that was significant by subjects, $F_1(1, 31) = 8.9, P < 0.01$, but not by items $F_2(1, 63) = 2.17, P > 0.1$. In the first half of the experiment, sentences with complex first clauses were 112 ms slower than sentences with simple first clauses. This difference increased to 146 ms in the second half of the experiment. No other interactions were significant. A similar analysis of percentage error rates yielded no significant effects.

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<td>Simple</td>
<td>880</td>
<td></td>
<td>0.4</td>
<td></td>
</tr>
</tbody>
</table>
8.2.1. Comparison of Experiments 2 and 3

The results of Experiments 2 and 3 are compared in Fig. 2. In order to test for significant differences in the results of Experiments 2 and 3, combined analyses of variance were conducted. Mean latencies for Experiments 2 and 3 were 1026 and 1005 ms, respectively. The main effect of Experiment was significant by items but not by subjects, $F_1(1, 62) = 0.51, P > 0.2, F_2(1, 63) = 13.5, P < 0.001$. Both experiments yielded similar effects of first clause complexity. An analysis of the two clause sentences showed no significant difference in the size of the effect across the two experiments and this was true also for the effect of first clause complexity for the single clause sentences. The interaction of Experiment and sentence length was significant, $F_1(1, 62) = 9.3, P < 0.01, F_2(1, 63) = 16.1, P < 0.001$, due to a decrease in the difference between double and single clause sentences in Experiment 3. This decrease resulted from faster mean latencies to double clause sentences in Experiment 3 (1049 ms) than in Experiment 2 (1097 ms). The interaction of Experiment and first clause complexity was non-significant, $F_1(1, 62) = 0.4, P > 0.5, F_2(1, 63) = 2.3, P > 0.1$ and the three way interaction between Experiment, sentence length and first clause complexity was significant by subjects, $F_1(1, 62) = 4.0, P < 0.05, F_2(1, 63) = 1.3, P > 0.2$.

Percentage error rates yielded a significant main effect of Experiment, $F_1(1, 62) = 4.6, P < 0.05, F_2(1, 63) = 22.5, P < 0.001$. There were interactions between Experiment and sentence length, $F_1(1, 62) = 4.2, P < 0.05, F_2(1, 63) = 10.6, P < 0.01$, and Experiment and first clause complexity, $F_1(1, 62) = 2.1, P < 0.2, F_2(1, 63) = 4, P < 0.05$. The three way interaction between Experiment, sentence length and first clause complexity was also significant, $F_1(1, 62) = 7.1, P < 0.01, F_2(1, 63) = 7.1, P < 0.01$. These interactions were due to larger decreases in error rates in Experiment 2 for double than single clause sentences and for sentences with complex rather than simple first clauses.

Fig. 2. A comparison between the latencies for the four sentence types of Experiments 2 and 3.
8.3. Discussion

Overall, the results of Experiment 3 are highly similar to those of Experiment 2. As with Experiment 2, latencies to complex-simple sentences are longer than to simple-complex sentences indicating again that prior to speech onset more time is dedicated to elements within the first phrase of an utterance than to elements beyond it. Moreover, Experiment 3 also resembles the previous experiment insofar as latencies to double clause sentences are significantly longer (by 128 ms on average) than to single clause sentences and insofar as the difference between double clause sentences is significantly smaller than between single clause sentences. This again indicates that some time is being dedicated to the processing of the second clause prior to speech onset in the present experiment. The fact, then, that participants still engage in second clause processing prior to speech onset even with the modified design employed in Experiment 3 indicates that such processing cannot be interpreted purely as a strategic response to the design features employed in Experiment 2.

However, Experiments 2 and 3 do differ insofar as latencies to double clause sentences are, on average, 48 ms shorter in Experiment 3 than in Experiment 2. In contrast, there is no significant difference between the two experiments in terms of latencies to single clause sentences. Such a contrast indicates that whilst time is dedicated to second clause processing prior to speech onset in Experiment 3 the amount of time is less than that dedicated to such processing in Experiment 2. Despite this reduction, however, the time dedicated to second clause processing in the present experiment remains substantial as the difference between latencies to single and double clause sentences indicates. Again, then, as with Experiment 2, it seems reasonable to argue that the effect of second clause processing should not be attributed to the processing of the visual display alone but, rather, indicates that at least some high level processing has been carried out for the second clause prior to speech onset – a claim which is further supported by the results of Experiments 4 and 5.

In sum, Experiment 3 demonstrates second clause processing despite its modified design indicating that such processing is not a strategic response to the design features of Experiment 2.

9. Experiment 4

Previous on-line studies of spoken sentence production have differed in attributing latency effects either to lemma access (Levelt & Maassen, 1981) or to syntactic planning (Meyer, 1996). The aim of Experiment 4 was to determine which of these two processes the latency effects obtained in the previous three experiments reflected. To do this, a picture previewing period was added to the picture description task employed in Experiment 2. In this previewing period all three pictures featuring in a trial are shown prior to the onset of the trial for a period of 2 s (it was reasoned that such a period would provide time for subjects to access the lemmas
corresponding to all three pictures given the median naming latencies of the pictures employed). This period should, then, remove the time dedicated to the entire process of lemma access (from conceptual planning to lemma access) from the overall sentence production latencies. Of course, the preview period also provides information about the order in which the lemmas will occur in an utterance since the left to right ordering of the pictures on the screen determines the order of the lemmas in the utterance. However, the syntactic structure of the utterance cannot be inferred from this ordering information since the same order occurs in each of the four sentence types which feature in the experiment. Thus, a subject will not know whether the middle picture on the screen will occur in the utterance’s first phrase (as with a complex-simple sentence), in the second clause of an utterance (as with a simple-complex sentence) or whether it will not feature at all (as with a simple sentence). The cost, therefore, of syntactic planning should still be reflected in latencies despite the previewing period.

It was reasoned, then, that if the picture previewing period does remove the time dedicated to lemma access then latencies in the present experiment should be significantly shorter than in Experiment 2. If this is so, moreover, the difference between latencies to double clause sentences in the present experiment and Experiment 2 should also be greater than the difference between latencies to single clause sentences in the present experiment and Experiment 2 as three lemmas are processed in the case of the double clause sentences prior to speech onset but only one or two are in the case of the single clause sentences. Furthermore, if the time dedicated to lemma access is removed by the previewing period, it may also affect the difference observed between latencies to sentences within the present experiment. Levelt and Maassen (1981), for instance, attribute the 59 ms difference between noun phrase conjunctives (i.e. single clause sentences featuring an initial complex noun phrase) and sentence conjunctives (i.e. double clause sentences each clause of which features a simple noun phrase) that they observe to lemma access. On such an account, latencies to Complex-simple sentences are longer in Experiment 2 than those to simple-complex sentences because they involve the thorough processing of two lemma and the less thorough processing of one whereas the latter involve only the thorough processing of one lemma and the less thorough processing of two. If this is so, then the differences observed between sentences should be reduced to a non-significant amount in the present experiment. In contrast, Meyer (1996) attributes the difference observed in her study to syntactic planning. On such a view, the latency difference between double clause sentences observed in Experiment 2 results from the fact that the first phrase of the complex-simple sentence is syntactically more complex that that of the simple-complex sentence. If this is so, the differences observed in Experiment 2 should remain in the present experiment and not be significantly affected by the previewing period. The latency differences Experiment 4 should also give an estimate of the contribution of visual array movement processing to the differences observed in Experiment 2. Any differences observed in the present experiment will reflect a combination of the costs of syntactic and visual array processing and will thus constitute an upper limit on the cost of the processing of the visual array. If these differences are small it will indicate that
the processing of the movement of the visual display has not made a significant
contribution to the differences observed in Experiment 2.

9.1. Method

9.1.1. Procedure

The materials and method were the same as for Experiment 2 except for a change
made to the sequence of events on each trial. As with Experiment 2, each trial began
with the appearance of a 19 × 6.5 cm frame which was displayed for 2 s. Given that
the experimental pictures had a mean naming latency of less than 600 ms this was
judged to provide enough time for all three picture names to be retrieved. Inside the
frame the three pictures featuring in the trial were displayed. Participants were
instructed to spend this 2 s previewing period retrieving the picture names. At the
end of this period the frame was removed and the pictures moved across the screen.
Participants responded as soon as they could and latencies were measured from
movement onset. As soon as the voicekey was triggered, the pictures disappeared.
An interval of 4 s then preceded the onset of the next trial. There were 32 partici-
pants, 14 females and 18 males.

9.2. Results

Exclusion of data resulted in the loss of only 0.3% of the data. Mean naming
latencies and percentage error rates are shown in Table 4.

An ANOVA on latencies yielded significant main effects of Sentence length,
$F_1(1, 31) = 61.6, \; P < 0.001, \; F_2(1, 63) = 72.6, \; P < 0.001,$ and first clause
complexity, $F_1(1, 31) = 20.4, \; P < 0.001, \; F_2(1, 63) = 25.6, \; P < 0.001.$ The inter-
action of length and complexity was significant by subjects, $F_1(1, 31) = 11.1, \; P < 0.01,$
and approached significance by item, $F_2(1, 63) = 3.04, \; P < 0.09.$ The same
ANOVA on error rates yielded a main effect of sentence length, $F_1(1, 31) = 14.6, \; P < 0.001, \; F_2(1, 63) = 56.1, \; P < 0.001,$ and an interaction
between sentence length and first clause complexity, $F_1(1, 31) = 5.4, \; P < 0.05, \; F_2(1, 63) = 5.1, \; P < 0.05.$ Latencies were 23 ms longer for the complex-simple
sentences than for the simple-complex sentences. This was significant by subjects
(just) but not by items, $F_1(1, 31) = 4.4, \; P < 0.05, \; F_2(1, 63) = 1.3, \; P > 0.2.$ There
was no significant difference in error rates for the double clause sentences,

Table 4

<table>
<thead>
<tr>
<th>Sentence type</th>
<th>Naming latency (ms)</th>
<th>% Error rate</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complex-simple</td>
<td>879</td>
<td>5.4</td>
<td>23</td>
</tr>
<tr>
<td>Simple-complex</td>
<td>856</td>
<td>4.6</td>
<td></td>
</tr>
<tr>
<td>Complex</td>
<td>808</td>
<td>3.1</td>
<td>67</td>
</tr>
<tr>
<td>Simple</td>
<td>741</td>
<td>1.6</td>
<td></td>
</tr>
</tbody>
</table>
Latencies for the complex sentences were a significant 67 ms longer than for the simple sentences, $F_1(1, 31) = 26.5, P < 0.001, F_2(1, 63) = 25.3, P < 0.001$, and 1.5% more error prone, $F_1(1, 31) = 4.5, P < 0.05, F_2(1, 63) = 13.5, P < 0.001$. The analysis including Experiment half yielded only a significant main effect of Experiment half, $F_1(1, 31) = 63.3, P < 0.001, F_2(1, 63) = 158.9, P < 0.001$, due to a 87 ms decrease in latencies as the experiment progressed. Error rates yielded a main effect of Experiment half, $F_1(1, 31) = 4.3, P < 0.05, F_2(1, 63) = 10.3, P < 0.01$ and an interaction between Experiment half, sentence length and first clause complexity, $F_1(1, 31) = 5.2, P < 0.05, F_2(1, 63) = 2.4, P > 0.1$.

10. Comparison of Experiments 2 and 4

The results of Experiments 2 and 4 are compared in Fig. 3. Mean latencies in Experiment 2 and Experiment 4 were 1026 and 821 ms, respectively. This 205 ms difference was significant, $F_1(1, 62) = 35.6, P < 0.001, F_2(1, 63) = 662.1, P < 0.001$. The reduction in the difference between the double clause sentences from 78 ms in Experiment 2 to 23 ms in Experiment 4 was significant, $F_1(1, 62) = 10.6, P < 0.01, F_2(1, 63) = 12.6, P < 0.001$, as was the reduction in the difference between the single clause sentences from 195 ms in Experiment 2 to 67 ms in Experiment 4, $F_1(1, 62) = 37.3, P < 0.001, F_2(1, 63) = 47.4, P < 0.001$. An analysis of the double clause sentence percent error rates yielded a significant main effect of Experiment, $F_1(1, 62) = 9.1, P < 0.01, F_2(1, 63) = 37.5, P < 0.001$, but no significant interactions between Experiment and other variables were observed. An analysis of the single clause sentence percent error rates yielded a

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**Fig. 3.** A comparison between the latencies for the four sentence types of Experiments 2 and 4.
significant main effect of first clause complexity, $F(1, 62) = 17.5$, $P < 0.001$, $F(2, 63) = 18.4$, $P < 0.001$, but there were no significant interactions between first clause complexity and other variables. The interaction of experiment and sentence length was significant, $F(1, 62) = 5.93$, $P < 0.05$, $F(2, 63) = 14.9$, $P < 0.001$. The difference in latencies between double and single clause sentences reduced from 142 ms in Experiment 2 to 94 ms in Experiment 4. The interaction of experiment and first clause complexity was also significant, $F(1, 62) = 37.5$, $P < 0.001$, $F(2, 63) = 58.2$, $P < 0.001$. The effect of complexity reduced from 112 ms in Experiment 2 to 46 ms in Experiment 4. The three way interaction of experiment, length and complexity was significant by subjects only, $F(1, 62) = 9.5$, $P < 0.01$, $F(2, 63) = 3$, $P < 0.1$. Error rates yielded a main effect of experiment, $F(1, 62) = 9.1$, $P < 0.1$, $F(2, 63) = 40.1$, $P < 0.001$, and an interaction between experiment and sentence length, $F(1, 62) = 5.1$, $P < 0.05$, $F(2, 63) = 16.3$, $P < 0.001$.

10.1. Discussion

The pattern of results in Experiment 4 differs markedly from that observed in Experiment 2. Firstly, responses in Experiment 4 were significantly faster and less error prone than in Experiment 2 suggesting that picture names were, indeed, retrieved during the previewing period. This view is reinforced by the amount latencies were reduced by for each of the four sentence types. Consider first the single clause sentences. Compared to Experiment 2, picture preview reduced latencies to complex sentences approximately twice as much as latencies to produce simple sentences (245 and 118 ms, respectively. It is important to note that such figures make an interesting comparison to Levelt, Praamstra, Meyer, Helenius and Salmelin, 1999, who estimate that the lemma selection phase in picture naming has a duration of between 115 and 125 ms). This makes sense given that the complex sentences require the retrieval of two picture names whereas simple sentences require the retrieval of only one picture name. For the two clause sentences, the reduction in complex-simple naming latencies was greater than the reduction in simple-complex naming latencies (257 and 202 ms, respectively). This again makes sense as the former represents the time taken to access two picture names but to perform a visual/conceptual processing of only one whilst the latter represents the time taken to access one picture name but to perform a visual/conceptual processing of two. It seems then that the preview procedure has successfully removed picture name retrieval processes from sentence latencies.

The second effect of picture preview was to significantly reduce both the difference between double clause sentences and the difference between single clause sentences. Indeed, for the double clause sentences, this effect was only marginally significant in the subject analysis. Thus, it seems that the bulk of the difference observed between double clause sentences and between single clause sentences in Experiments 2 and 3 can be attributed to lemma access processes as claimed by Levelt and Maassen (1981). Yet whilst the 23 ms difference between latencies to the double clause sentences was only marginally significant the 67 ms difference
between the single clause sentences was significant indicating some processing other than that involved in lemma access was occurring. Certainly, it is possible that these differences could reflect syntactic planning. A further possibility however, is that these figures reflect differences in picture movement complexity. Thus the 67 ms difference may in part stem from the fact that the visual array for the complex sentences involves two moving pictures whereas that for the simple sentence involves only one. It is unlikely, therefore, that this 67 ms difference can be wholly attributed to syntactic planning. The figure of 23 ms obtained in the case of the double clause sentences is more likely to offer a truer estimate of syntactic planning cost as the double clause sentences trials always featured three moving pictures and so the figure is less likely to reflect picture movement processing. These figures moreover also suggest an upper limit on the cost of processing incurred by differences in picture movements. Thus it is unlikely that much more than 23 ms of the 77 ms difference observed between double clause sentences in Experiment 2 arose from differences in the visual display. The present results, then, indicate the effects observed previously reflect high level rather than visual display processing.

In conclusion, the results of Experiment 4 support the view that the latency differences observed in previous experiments are largely due to lemma access processes (Levelt & Maassen, 1981) rather than syntactic planning or the visual processing of the picture array.

11. Experiment 5

Experiments 2–4 had demonstrated that time is dedicated to the processing of elements beyond the first phrase of an utterance prior to speech onset. It was argued, moreover, that this time is unlikely to be wholly dedicated to the processing of the movement of the visual display given the size of the estimates for second clause processing obtained in Experiments 2 and 3 and the upper limits on the estimates of such visual processing obtained in Experiment 4. However, whilst the previous experiments had rendered a visual processing account unlikely they did not rule out this possibility. As a consequence, the final experiment in this section was constructed with the aim of testing for second clause processing prior to speech onset in an experimental paradigm in which the effects observed could not be attributed to processing of the movement of the visual display. The second aim of Experiment 5 is to obtain a more direct estimate of the amount of processing time dedicated to elements within the first phrase and elements beyond the first phrase prior to speech onset. This should allow us also to determine directly whether any time is dedicated to the high level processing of elements beyond the first phrase prior to speech onset and to gauge whether this time is less than that dedicated to elements within the first phrase prior to speech onset.

To test for this, a picture description task is employed in the present experiment similar to that of previous experiments. In Experiment 5, however, the visual array presented to subjects features only two pictures the movements of which are designed to stimulate the production of the complex sentences (i.e. ‘the dog and
the kite move up’) and relative clause sentences (i.e. ‘the dog which is next to the kite moves up’). A further distinctive feature of Experiment 5 is the introduction of a picture previewing period into half of the experimental trials. During this previewing period, subjects see the picture corresponding to the second noun of the target utterance (i.e. ‘kite’ in the above examples) for 1 s prior to trial onset. The subjects are instructed to use this previewing period to access the word corresponding to the picture. In this way the previewing period removes the time taken to access the second noun from the overall latencies. Comparing latencies to sentences with a previewing period to sentences without a previewing period thus provides an estimate of the time dedicated to the processing of the second noun prior to speech onset in the case of both the complex and relative clause sentences and allows us to determine whether more processing time is dedicated to elements within the first phrase of an utterance than to elements beyond the first phrase prior to speech onset1. Moreover, this design acts to eliminate the time dedicated to movement processing also. Whilst the picture movements that give rise to the two sentence types are different the estimates of the time dedicated to second noun processing are not obtained by comparing these two different movement types. In the case of the complex sentence, for instance, the estimate of second noun processing is obtained by comparing one type of complex sentence trial with another. Since these two complex sentence trials feature exactly the same movement the estimate of second noun processing in no way reflects movement processing. The estimate of second noun processing in the case of the relative clause sentences is likewise uncontaminated by picture movement processing. As a consequence the comparison of the estimates of second noun processing for these two sentence types constitutes a test of whether high level processing extends beyond the first phrase prior to speech onset which is unconfounded by picture movement processing. This design also prevents phonological processing from contributing to the differences observed. As argued above, only the first phonological word is processed prior to speech onset. The estimates of processing in both the complex and relative clause sentence conditions are obtained, however, by comparing identical sentences whose first phonological word is the same in both cases thus ruling out phonological planning as a source for any latency differences.

11.1. Method

11.1.1. Materials

From the set of 92 drawings used in previous experiments 80 were selected to be used in Experiment 5. Of these, 36 were used on the experimental trials whilst 44 were used on the filler trials. The set of 36 experimental pictures was used to

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1 Whilst linguists tend to describe both the set of ‘head’ nouns and the relative clause modifying them as a single phrase we will adopt here a convention of characterising the noun in a relative clause modifier as being ‘beyond the first phrase’ since it allows us to distinguish between the ‘head’ nouns and their relative clause modifier and because it accords with psycholinguistic work which, contrary to linguistic theory, emphasizes the disjunction between the head noun and its relative clause modifier i.e. Bock & Cutting, 1992; Stine, 1990.
generate 72 sets of picture doubles. These picture doubles were built from two matched sets of eighteen pictures (see Table 5). These two sets were then combined, using the criteria adopted in previously, in four different ways to give four experimental sets of sixteen doubles. In this experiment six different movements were used (up, down, left, right, apart and no movement). Only four of these, up, down, apart and no movement appeared in the experimental trials. The up and apart movements were used to elicit the complex sentences. the relative clause sentences were elicited using up, down and no movement. This gave rise to four experimental sentences each associated with a distinct movement type:

1. the X and the Y move up, (both pictures move up),
2. the X and the Y move apart, (X moves left and Y moves right),
3. the X which is next to the Y moves up, (X moves up, Y remains stationary),
4. the X which is next to the Y moves down, (X moves down, Y remains stationary).

Fillers were similar to those in previous experiments except there were now no two picture trials.

11.1.2. Design and procedure

Seventy two two-picture trials occurred in four experimental conditions:
(1) complex sentence: no picture preview,
(2) complex sentence: second noun previewed,
(3) relative clause sentence: no picture preview,
(4) relative clause sentence: second noun previewed.

The assignment of picture sets to conditions was rotated across participants so that by the end of the experiment each picture double had occurred in all four conditions an equal number of times. The experiment consisted of eight blocks of 28 trials the first two of which were practice blocks. The six experimental blocks were combined into three pair blocks each comprising six trials from each of the four conditions and 32 filler trials. Half of the filler trials also featured preview pictures. The distribution of these experimental trials across the pairblock was pseudorandomised. Randomisation was constrained to ensure that sentences of the same syntactic type could not occur in consecutive trials in order to minimise inter-trial priming. For this reason, we also ensured that the same picture never occurred in two consecutive trials. Finally, the ordering of the pair blocks was systematically rotated across participants to ensure that each pair block occurred an equal number of times in each position in

Table 5
Matching of two sets of picture name materials for Experiment 5

<table>
<thead>
<tr>
<th></th>
<th>Set 1</th>
<th>Set 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naming latency (ms)</td>
<td>524</td>
<td>523</td>
</tr>
<tr>
<td>Standard deviation (ms)</td>
<td>127</td>
<td>133</td>
</tr>
<tr>
<td>No. of syllables</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>No. of phonemes</td>
<td>3.1</td>
<td>2.9</td>
</tr>
<tr>
<td>Log frequency</td>
<td>3.7</td>
<td>3.6</td>
</tr>
</tbody>
</table>
the experiment. The procedure was the same as in Experiment 1 except that on half of the experimental trials a picture previewing period was employed. During this period a frame was displayed for 2 s and during the 1st s of this period the picture corresponding to the second noun was displayed in the centre of the frame. Having been displayed for 1 s the picture was then removed and the frame was left blank for 1 s. The frame was then removed and the trial commenced. In trials without a picture previewing period trials were preceded by the display of a blank frame for 2 s. There were 24 participants, 15 females and 9 males.

11.2. Results

Exclusion of data resulted in the loss of 0.2% of the data. Mean naming latencies and percentage error rates for each condition are shown in Table 6.

For the complex sentences, latencies in the condition without a picture preview were 110 ms greater than those in the condition where the second noun was previewed. For the relative clause sentences, picture preview reduced latencies by 64 ms. An ANOVA featuring the variable sentence type (complex sentence with no preview, complex sentence with preview, Relative clause sentence with no preview, Relative clause sentence with preview) was run and this yielded a significant main effect of sentence type, \( F_1(3, 69) = 59.5, \quad P < 0.001, \quad F_2(3, 213) = 103.4, \quad P < 0.001. \) Posthoc pairwise analyses in the form of Scheffes tests were then applied to this ANOVA. These revealed a significant effect of preview. Thus the 110 ms difference between the complex sentence with no picture preview and the complex sentence with the second noun previewed was significant (\( P < 0.01 \) for both subjects and items). A significant effect of sentence complexity was also revealed. Thus the 168 ms difference between the complex sentence with no picture preview and the Relative clause sentence with no picture preview was significant (\( P < 0.01 \) for both subjects and items) as was the 132 ms difference between the complex sentence with the second noun previewed and the Relative clause sentence with the second noun previewed (\( P < 0.01 \) for both subjects and items). An error rate ANOVA yielded a main effect of sentence type, \( F_1(3, 69) = 23, \quad P < 0.001, \quad F_2(3, 213) = 25.9, \quad P < 0.001. \) Scheffes tests applied to this ANOVA showed the 2.3% difference between the complex sentence error

<table>
<thead>
<tr>
<th>Sentence type</th>
<th>Naming latency (ms)</th>
<th>Difference</th>
<th>% error rate</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complex unpreviewed</td>
<td>1119</td>
<td>110</td>
<td>4.2</td>
<td>2.3</td>
</tr>
<tr>
<td>Complex previewed</td>
<td>1009</td>
<td></td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>Relative unpreviewed</td>
<td>951</td>
<td>64</td>
<td>0.9</td>
<td>0.1</td>
</tr>
<tr>
<td>Relative previewed</td>
<td>887</td>
<td></td>
<td>0.8</td>
<td></td>
</tr>
</tbody>
</table>
rates was significant ($P < 0.01$ for subjects and items) as was the 3.3% difference between the error rates for the complex sentence with no preview and the relative clause sentence with no preview ($P < 0.01$ for subjects and items).

A second ANOVA on latencies included the variables sentence complexity (complex vs. relative clause sentences) and preview (no picture preview vs. second noun picture preview). This analysis yielded significant main effects of sentence complexity, $F_{1}(1, 23) = 56.7$, $P < 0.001$, $F_{2}(1, 71) = 269.4$, $P < 0.001$, and preview, $F_{1}(1, 23) = 127.6$, $P < 0.001$, $F_{2}(1, 71) = 101.3$, $P < 0.001$. The interaction between sentence complexity and preview was also significant, $F_{1}(1, 23) = 8.8$, $P < 0.01$, $F_{2}(1, 71) = 5.9$, $P < 0.05$. Error rates also yielded main effects of sentence complexity, $F_{1}(1, 23) = 49.5$, $P < 0.001$, $F_{2}(1, 71) = 50.3$, $P < 0.001$, and preview, $F_{1}(1, 23) = 5.6$, $P < 0.05$, $F_{2}(1, 71) = 13.4$, $P < 0.001$, and an interaction between sentence complexity and preview, $F_{1}(1, 23) = 5.5$, $P < 0.05$, $F_{2}(1, 71) = 9.9$, $P < 0.01$. An ANOVA was conducted to test if performance varied over the three pairblocks of the experiment but yielded only a significant main effect of pairblock, $F_{1}(2, 46) = 46.37$, $P < 0.001$, $F_{2}(2, 142) = 74.17$, $P < 0.001$. An error rate ANOVA yielded no significant effects.

11.3. Discussion

The aim of Experiment 5 was to investigate how much time is dedicated to the non-visual processing of elements beyond the first phrase of an utterance prior to speech onset. The results show that latencies to Relative clause sentences in a non-picture preview condition are significantly longer (by 64 ms) than those to relative clause sentences in a picture preview condition. This is consistent with the view that the latency difference represents the time dedicated to the processing of elements beyond the first phrase prior to speech onset (in this case to the noun in the relative clause). Since the latency difference does not, as argued above, reflect low level processing, it must demonstrate that some high level processing is conducted for elements beyond the first phrase prior to speech onset. Experiment 5 also demonstrates, however, that latencies to complex sentences in a non-picture preview condition are significantly longer (by 110 ms) than those to Complex sentences in a picture preview condition. Clearly, such a finding indicates that substantial time has been dedicated to the processing of the second noun within a complex sentence prior to speech onset. Moreover, as this figure of 110 ms is significantly greater than that observed in the relative clause sentence condition it indicates that elements within the first phrase of an utterance are processed significantly more thoroughly than elements beyond the first phrase of an utterance prior to speech onset (it also agrees with other work such as Stine (1990); Bock and Cutting (1992) in emphasizing a disjunction between the processing of the ‘head’ noun in a noun phrase and the relative clause modifying it). This is further supported by the fact that in the non-preview conditions latencies to the complex sentences were significantly longer (by 168 ms) than those to relative clause sentences. This is predicted if the bulk of processing time is allocated to the initial phrase prior to speech onset because the complex phrase sentences comprised two nouns whereas the initial phrase of the
relative clause sentences comprised only one noun. These results are in line with Experiments 2–4 which also indicated that whilst processing is performed for elements beyond the first phrase of an utterance prior to speech onset such processing is significantly less thorough than that for elements in the first phrase.

Also, the results of Experiment 5 further confirm the estimate of the time dedicated to the processing of a noun in the first phrase prior to speech onset obtained in Experiment 4. In Experiment 4 an estimate of 118 ms was obtained for the time dedicated to the processing of the noun in a simple sentence prior to speech onset. A further estimate of 245 ms was obtained for the time dedicated to the processing of the two nouns in a complex sentence prior to speech onset. The estimate of 110 ms observed in the present experiment for the processing of the second noun within a complex sentence is in accordance with these figures. Moreover, this figure indicates that similar amounts of processing time are dedicated to the second noun in a complex noun phrase and the noun in a simple sentence prior to speech onset and thus that the two are equally thoroughly processed prior to speech onset. Clearly, the noun within a simple sentence must be grammatically encoded prior to speech onset since it is impossible to articulate a noun without first having grammatically encoded it. It follows, then, that grammatical encoding is also completed for the second noun within a complex simple sentence prior to speech onset since such a noun is as thoroughly processed prior to speech onset as the noun within a simple sentence. This also indicates that grammatical encoding is not completed for elements beyond the first phrase of an utterance prior to speech onset since significantly less time is dedicated to such elements than those within the first phrase of an utterance prior to speech onset.

In summary, Experiment 5 indicates that, prior to speech onset, grammatical encoding is completed for the first phrase of an utterance and initiated for elements beyond the first phrase.

12. General discussion

The experiments have given rise to three principal findings. Firstly, the data from the five experiments demonstrate repeatedly that grammatical encoding is not completed for the whole of a sentence prior to speech onset. In Experiment 1 this was demonstrated in relation to single clause sentences. Thus, in this experiment, latencies to complex-simple sentences were significantly greater than to simple-complex sentences – a result incompatible with the view that grammatical encoding is completed for the whole of a sentence (or indeed for its first clause) prior to speech onset. This finding was subsequently replicated with double clause sentences in Experiments 2 and 3 and with relative clause sentences in Experiment 5. Experiment 5 also allowed us to demonstrate specifically that lemma access is not completed for the whole of a sentence prior to speech onset since in this experiment we found that significantly less time is dedicated to the processing of a noun beyond the first phrase than to a noun within the first phrase prior to speech onset.

Secondly, the results, even whilst affirming that grammatical encoding is not
completed for the whole of the first clause of an utterance prior to speech onset, also
serve to affirm that grammatical encoding is completed for the first phrase of an
utterance prior to speech onset. Such a claim would lead us to expect the result,
obtained across all five experiments, that production latencies are greater to
sentences with more complex initial phrases. Thus complex-simple sentences take
longer to initiate than simple-complex sentences in Experiments 1–3 whilst complex
sentences take longer to initiate than simple sentences in Experiments 2–4 and
relative clause sentences in Experiment 5. The claim is further reinforced by the
comparison of Experiments 2 and 4 which shows that twice as much time prior to
speech onset is dedicated to the processing of the two nouns in a complex sentence
as to the processing of the single noun in a simple sentence. This result demonstrates
that the second noun in an initial co-ordinated noun phrase has as much time
dedicated to its processing prior to speech onset as the first noun and thus that its
access is, like that of the first noun, completed prior to speech onset. Such a claim is
reinforced by Experiment 5 which gives a direct estimate of the processing cost of
the second noun within a complex phrase prior to speech onset which matches that
obtained for the first noun in the simple sentence in Experiment 4.

Thirdly, the results whilst indicating that grammatical encoding is not completed
for the first clause of an utterance prior to speech onset but only for its first phrase do
not indicate that high level processing is confined to the first phrase of an utterance
prior to speech onset. Indeed, the results clearly and repeatedly show that some form
of high level processing is conducted for elements beyond the first phrase of an
utterance prior to speech onset. Moreover, the results demonstrate that this proces-
sing extends, prior to speech onset, far beyond the first phrase of an utterance to
cover elements even within the second clause of a two clause sentence. In line with
this, it was observed in Experiments 2 and 3 that the difference in latencies to
simple-complex and complex-simple sentences is smaller than the difference in
latencies to simple and complex sentences. As argued above, such a result arises
because the simple second clause of the complex-simple sentence requires less
processing than the complex second clause of the simple-complex sentence and
thus reduces the difference resulting from the processing of the first clause of
these sentences. This reduction consequently renders the difference between these
two sentences less than that observed in the case of the single clause sentences. Also,
the claim that high level processing, whilst not completed, is at least initiated for
elements beyond the first phrase of an utterance prior to speech onset is consistent
with the results from Experiment 5. These results indicate that some time is dedi-
cated to the processing of a noun beyond the first phrase prior to speech onset
although it is significantly less than the time dedicated to the processing of nouns
within the first phrase prior to speech onset.

Importantly, these findings are in accord with data from previous studies of
spoken sentence production. Thus the finding that lemma access is completed
only for the first phrase of an utterance prior to speech onset offers online reinforce-
ment for Martin et al. (1998) offline study indicating the use of a phrasal grammati-
cal planning scope by an aphasic patient. Such a finding also strengthens the view
that Levett and Maassen (1981) pattern of data is most likely to have resulted from
the accessing of lemmas within the first phrase rather than the first clause of an utterance prior to speech onset. The finding that some form of high level processing is conducted for the elements of a sentence beyond the first phrase of an utterance prior to speech onset is clearly consistent with the data from Meyer, (1996) indicating that some processing of a sentence final phrase occurs prior to speech onset. However, the finding that grammatical encoding and lemma access in particular are not completed prior to speech onset suggest that Meyer’s data should not be interpreted as indicating that lemma access is completed for the whole of a single clause sentence prior to speech onset. The finding that more time is dedicated prior to speech onset to the processing of a noun within the initial subject phrase of an utterance than to that of a noun within a relative clause modifying it is also compatible with the view proposed above in relation to Ferreira (1991) study that prior to speech onset conceptual but not grammatical planning is completed for a relative clause modifying the initial subject phrase. However, since our results bear on lemma access rather than syntactic planning they do not rule out Ferreira’s claim that syntactic planning will be conducted for a relative clause modifying an initial subject phrase prior to speech onset. Also the finding that some form of high level processing extends far beyond the first phrase of an utterance prior to speech onset to include elements within the second clause of an utterance is compatible with those pausing studies indicating that speakers at some point during high level processing employ a large, clausal processing scope boundaries (Ford & Holmes, 1978; Beattie, 1980; Ford, 1982; Pawley & Syder, 1983; Stine, 1990; Wijnen, 1990; Miller & Weinert, 1998). This finding is also compatible with the view (i.e. Ford, 1982; Ford & Holmes, 1978) that this clausal scope is employed prior to the planning of the surface grammatical structure particularly as in our study this clausal scope did not necessitate the completion of lemma access. Also, the data, in suggesting the action of two scopes – a phrasal scope with which lemma access is completed and a clausal or sentential scope with which some form of high level processing prior to the completion of lemma access is carried out - is compatible with the study by (Bock & Cutting, 1992) arguing for an initial high level processing stage employing a clausal scope and a subsequent grammatical planning stage. Overall, then, the data in our experiments are in line with the data from previous studies of high level processing scope.

Perhaps the study whose data gives the most striking fit with that of the current study, however, is the analysis of speech errors developed by Garrett (1975, 1982). Like Bock and Cutting (1992), Garrett provides evidence of two discrete high level processing stages the first of which employs a clausal processing scope. He also provides speech error evidence, however, showing that the subsequent high level processing stage employs a phrasal scope. Clearly, the data from the current study, if interpreted in terms of an initial high level processing stage employing a clausal scope and a subsequent high level processing stage employing a phrasal scope, matches Garrett’s data extremely well. Despite this, however, there is a conflict between one aspect of our data and Garrett’s interpretation of his own data. As outlined above, Garrett interpreted his evidence for an initial clausal processing scope as evidence that lemma access is carried out simultaneously for all of the
lemmas within a clause before phrasal syntactic planning and articulation were subsequently initiated. In contrast, we have found that lemma access is not completed for the first clause of an utterance prior to speech onset but only for the first phrase. Yet if lemmas need be accessed only for a phrase before being released for processing at later stages, then this suggests that it is not the initial stage employing a clausal scope but rather the second stage employing a phrasal scope which should be identified with the operation of lemma access processes. Of course, whilst such a view is in conflict with Garrett’s interpretation of the speech error data, it is not, however, in conflict with the data itself. As argued in the introduction, an alternative reading of Garrett’s data in terms of an initial conceptual planning stage employing a clausal scope and a subsequent grammatical planning stage at which lemma access is carried out for successive phrasal chunks is as plausible, even preferable, to Garrett’s own. Crucially, this alternative reading can account not only for the speech error data but also, since it claims that lemma access has a phrasal scope, for the data obtained in the current study.

A further model of speech production that the current findings have implications for is the FIG developed by Ward (1992). The finding that some high level processing is conducted for elements up to and including those within the second clause of utterance prior to speech onset is compatible with the claim made by the FIG that the conceptual structure underlying a sentence is generated before grammatical encoding and articulation are initiated. However, the finding that lemma access is completed for the whole of the first phrase of an utterance prior to speech onset cannot be reconciled with the FIG which predicts that articulation is initiated with only the first lemma of an utterance accessed. The findings also bear on a further incremental model of speech production, the IPG (Kempen & Hoenkamp, 1987) though in a somewhat less clearcut manner. Whilst an IPG system is capable of processing varying quantities of information at the various computational stages prior to speech onset the current experiments do not provide any evidence of such variation. In fact, in fitting so well with the data from previous observational and experimental studies the current findings compound the view that there are determinate processing scopes which apply consistently across a wide variety of speaking situations. As argued above, the IPG is also capable of conceptually planning a unit smaller than a clause prior to speech onset but again the current findings offer no direct evidence of this and show rather that some form of high level processing (it seems reasonable to infer that this includes conceptual planning) extends even into the second clause of an utterance prior to speech onset. It must be cautioned though that whilst failing to confirm the IPG the present results offer no direct evidence against it either. Given the flexibility of the IPG with regard to scope, it is entirely possible that the IPG could complete lemma access for the first phrase of an utterance and some form of high level processing such as message level planning for elements beyond the first phrase before articulation was initiated. However, in providing further data compatible with the view that high level processing employs a clausal scope at some point the current experiments underline the fact that the IPG does not motivate the widespread finding that a clausal scope is systematically employed during the production of speech.
The results from the experiments also bear on Wundt’s claims that grammatical encoding is executed in successive phrasal chunks only after the conceptual structure underlying a sentence has been generated holistically. Crucially, Wundt’s claims with regard to scope are inflexible and thus easy to falsify. Thus, for instance, if we had found that no high level processing is carried out for elements beyond the first phrase prior to speech onset or that grammatical encoding is completed for the whole of a sentence prior to speech onset or that grammatical encoding is not completed for the whole of the initial phrase prior to speech onset then our results would have been incompatible with Wundt’s claims. In fact, we failed to falsify Wundt’s claims on any of these three counts. Instead, we found that high level processing is initiated but not completed for elements within the second clause of a sentence prior to speech onset – a finding compatible with Wundt’s view that the conceptual structure of a sentence is generated prior to grammatical encoding and thus articulation. Also, we found that lemma access is completed for only the first phrase of an utterance prior to speech onset - a finding compatible with Wundt’s view that grammatical encoding occurs in piecemeal phrasal chunks. Overall, then, our data fits as neatly with Wundt’s claims regarding high level processing scope as that from previous studies of speech production.

It seems reasonable, then, to interpret the current findings in terms of a speech production model in which conceptual planning is executed in holistic clausal or sentential chunks whilst grammatical encoding is carried out for successive phrases especially given the wide variety of empirical studies also consistent with this model. However, it must be remembered that the current data is ambiguous with respect to a number of issues. Most importantly, the current experiments do not determine precisely what kind of high level processing is conducted for elements beyond the first phrase prior to speech onset. Although the experiments indicate that high level processing is not completed for elements beyond the first phrase prior to speech onset this may mean either that such processing involves only conceptual planning or that it involves both conceptual planning and some limited, incomplete grammatical encoding. This latter interpretation of the results suggests that whilst grammatical encoding is primarily focused on a single phrasal chunk it nevertheless extends beyond this phrase to achieve some limited grammatical encoding of neighbouring phrases. It is possible that such an approach is demanded by the fact that to successfully formulate a single phrase it is often necessary to engage in ‘lookahead’ to take account of the grammatical characteristics of neighbouring phrases (Dell, Burger & Svec, 1997). As Bock and Cutting (1992) have shown, for instance, errors may arise if a speaker fails to consider grammatical features of neighbouring phrases such as number. Such a pattern of processing might also result if grammatical encoding were conducted in bursts determined by a fixed processing capacity and this capacity allowed for the complete processing of one phrase and the partial processing of some other phrases. Ultimately, of course, such interpretations of the data are not incompatible with Wundt’s model and it seems reasonable to suppose that the findings of the present experiments may result from a speech production system combining both the clausal and phrasal scope of Wundt’s model and the multi-phrasal grammatical ‘lookahead’ of the other.
In conclusion, then, the current experiments provide online support for three findings. Firstly, the experiments show that grammatical encoding is not completed for the whole of a single or double clause sentence prior to speech onset. Secondly, they show that grammatical encoding and in particular, lemma access, is completed for the first phrase of an utterance prior to speech onset. Finally, they also indicate that some form of high level processing is conducted for elements up to and including the second clause of an utterance prior to speech onset. Whilst such findings are entirely consistent with the data from previous studies of high level processing scope they pose problems for a number of contemporary models of speech production (Garrett, 1982; Ward, 1992). The current data (and that of previous empirical studies) are, however, fully consistent with Wundt’s two stage model of high level processing scope in which grammatical encoding is executed in successive phrasal chunks only after the conceptual structure underlying a sentence has been generated holistically. Further experimentation is required to tease apart a number of possible variants of this model.

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