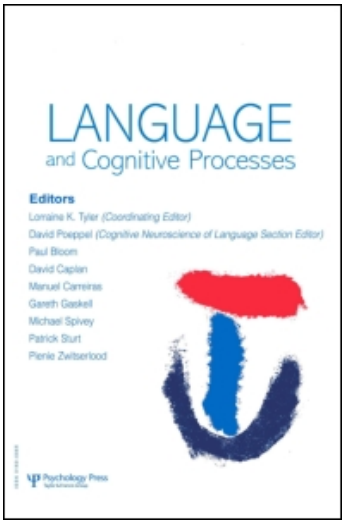

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Phrase structure priming: A short-lived effect

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Phrase structure priming: A short-lived effect

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Two experiments investigate the effect of phrase structure priming on sentence production latencies. Repetition priming of sentence initial noun phrase structure has been demonstrated in an on-line picture description task. Experiments 1 and 2 demonstrate this priming effect to be short lived. No priming survives the addition of one intervening unrelated trial. This finding contrasts with the more persistent effects recently demonstrated in off-line picture description tasks. This contrast is attributed to different loci for the two effects.

INTRODUCTION

A great deal of research has demonstrated a preference for the use of recently produced sentence structures in language production. In a seminal study, Bock (1986) used a picture description technique to demonstrate the priming of transitive and ditransitive sentences. For example, participants were more likely to describe a picture of lightning striking a church using the passive sentence, ''The church is being struck by lightning'' if they had just read a very different passive sentence such as, ''A passerby is being jostled by the drunk'' than if they had just read an active sentence. Recent research has expanded the range of experimental methodologies used. Priming effects have been demonstrated in sentence recall (Fox Tree & Meijer, 1999), written language production (Branigan, Pickering, Liversedge, Stewart, & Urbach, 1995; Pickering & Branigan, 1998, and between

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participants in experimentally controlled dialogues (Branigan, Pickering, & Cleland, 2000). This data has almost exclusively been collected in priming tasks in which the dependent variable is the percentage of a particular sentence type that is produced. A recent exception is a study by Smith and Wheeldon (2001) who developed a reaction time methodology to investigate sentence priming in spoken sentence production. The aim was to generate data relevant to the possible function of sentence-level priming effects. It had previously been claimed that repeated use of procedures or representations reduces processing costs and increases processing speed (Levelt & Kelter, 1982; Bock, 1986). Smith and Wheeldon (2001) provided the first direct evidence in support of this claim by demonstrating an effect of phrase structure priming on sentence production latencies.

Although sentence priming is clearly a robust effect, uncertainty remains as to the stage of language production at which it originates. Early claims located effects of sentence priming either during functional encoding when lemmas are retrieved and assigned grammatical roles such as subject and object or during positional encoding when constituent assembly processes are executed (Bock, 1986; Bock & Loebell, 1990; Bock, Loebell, & Morey, 1992). Bock and Loebell (1990) showed that dative sentences containing a location (e.g., ''The wealthy widow drove her Mercedes to the church'') primed dative sentences which did not contain a location (e.g., ''A rock star sold some cocaine to an undercover agent''). They therefore argued that this priming effect did not stem from the priming of thematic roles during the conceptual planning stage. In addition, Bock and Loebell (1990) observed that passive target sentences were more frequent after locative than after active primes. The passive and locative sentences shared constituent structure but differed in their thematic and grammatical role structure. Clearly, such a result could not be explained in terms of the priming of functional level processing. They therefore attributed the effect to the priming of constituent assembly processes at the positional level. However, in a later study, Bock et al. (1992) did attribute one sentence priming effect to the process of grammatical role assignment during functional encoding. They found that participants produced a higher proportion of active sentences with inanimate subjects following passive primes with inanimate subjects than following passive primes with animate subjects. They argued that such an effect is incompatible with the priming of thematic role assignment and interpreted the effect as the priming of the assignment of an animate lemma to a grammatical role.

More recently, however, a number of researchers have begun to argue that effects of sentence priming can indeed result from the priming of functional and conceptual structure (Chang, Dell, Bock, & Griffin, 2000; Hare & Goldberg, 1999; Hartsuiker, Kolk, & Huiskamp, 1999; Heydel,

Merino, & Murray, 1999; Heydel & Murray, 2000). Hare and Goldberg (1999) adapted the design of Bock and Loebell (1990) by having participants describe a picture using either a dative or ditransitive sentence after they had produced either a dative (3a), ditransitive (3b), or ''provide with'' sentence (3c).

(3) a. His editor promised the hot story to Bob.
b. His editor offered Bob the hot story.
c. His editor credited Bob with the hot story.

The ''provide with'' prime matches the dative sentence in terms of syntactic structure (i.e., they are both NP V NP PP) but does not match the ditransitive sentence (which has the structure NP V NP NP). In contrast, the ''provide with'' prime matches the ditransitive in terms of conceptual structure (i.e., they both place the recipient immediately after the verb) but does not match the dative (which places the theme immediately after the verb). Hare and Goldberg found that an equal proportion of ditransitive targets was produced after ditransitive and ''provide with'' primes and that this proportion was significantly higher than the proportion produced after dative primes. This finding suggests that the observed priming is influenced by the conceptual similarities between primes and targets.

Hartsuiker et al., (1999) also argue for an earlier locus for the priming effects observed by Bock et al. (1992). In the model of sentence production assumed by Bock, et al. (1992), the choice between active and passive sentences is determined during functional level processing. Consider, for example, the assignment of the lemma ''dog'' to a subject phrase and the lemma ''man'' to an object phrase in response to a picture of a man stroking a dog. Such functional level decisions will commit the participant to the production of a passive sentence (i.e., ''The dog is being stroked by the man''). Since the model also assumes a strictly feed forward information flow, it is not possible for positional level processes to revoke the commitments made during functional level processing. Consequently, priming of active and passive sentences cannot be attributed to positional level processes. Hartsuiker et al. (1999) therefore argue that such priming effects are better located in functional level processes. Moreover, they argue the animacy effects attributed by Bock et al. (1992) to the priming of functional level processing should be relocated to the conceptual level since animacy is an aspect of conceptual rather than a grammatical structure. Chang et al. (2000), also argue that such effects should be located in the mapping from conceptual to functional encoding.

However, it is of course possible that grammatical encoding can be independently facilitated by repetition at any of its constituent processing stages. Indeed, clear evidence remains that positional level processes can be primed. For example, Hartsuiker and Westenberg (2000) demonstrated

priming of the word order of auxiliary verb and past participle in Dutch subordinate clauses which varies freely and is not influenced by conceptual or functional factors. In this article we focus on another priming effect that has been attributed to phrase building processes at the level of positional encoding rather than early conceptual or functional processes. Smith and Wheeldon (2001) demonstrated an effect of phrase structure priming on sentence production latencies. In this study, participants saw linear arrays of moving pictures that they had to describe from left to right (e.g., *the spoon and the car move apart*). These descriptions were preceded by syntactically related picture descriptions (e.g., *the eye and the fish move up*) or by syntactically unrelated picture descriptions (e.g., *the eye moves up and the fish moves down*). These experiments, therefore, contrasted the structure of the sentence initial phrases because previous research using this paradigm demonstrated this to be the minimal chunk grammatically encoded prior to the onset of articulation (Smith and Wheeldon, 1999). Crucially, we contrasted the internal structure of noun phrases (coordinate or simple NPs) in which all nouns mapped to subject position, ensuring that the mapping from thematic to grammatical structures would play a minimal role. Syntactic relatedness speeded sentence production latencies by approximately 50 ms. Further experiments ruled out explanations in terms of lexical, visual, and conceptual similarity between prime and target sentences. The cost of lexical access was factored out by the previewing of pictures for 1500 ms prior to movement onset. Priming was still obtained, demonstrating that the effect was not a product of priming lexical access. Priming was also observed when related and unrelated prime trials featured the same picture display, therefore, the effect does not result from the visual perception of the picture movements. In addition, no priming was observed when participants described only the picture movements (i.e., apart, up, up–down) indicating that priming was not a function of the conceptual similarity between the picture movements in the target and related prime trials.

We concluded that there was an effect of syntactic priming on sentence production latencies and that it was due to the facilitation of the formulation of the syntactic structure of a sentence initial phrase. The experiments we report here investigate the persistence of the phrase structure priming effect. Our aim was to determine whether this effect differed in its persistence to the structural priming effects reviewed above. Structural priming has been demonstrated to be long lived. Using Bock's (1986) picture-naming task, Bock and Griffin (2000) demonstrated that priming of transitives and datives persisted over as much as ten intervening trials. Branigan, Pickering, Stewart, and McLean (2000) demonstrated that when participants were required to produce spoken sentence completions, a similar magnitude of syntactic priming was observed when the prime and

targets were adjacent and when they were separated by one intervening item. Also, a number of experiments have demonstrated persistent cumulative effects of structure priming due to the repeated exposure to primes over the course of an experiment (Hartsuiker & Kolk, 1998; Hartsuiker et al., 1999). If the phrase structure priming effect observed by Smith and Wheeldon (1999) is occurring at a late, positional, stage in grammatical encoding then it may have a different pattern of persistence to the effects reported by Bock and colleagues. We therefore compared priming from sentences which immediately preceded the target sentence to conditions in which the prime sentence was separated from the target sentence by an interval of three intervening trials (Experiment 1) or one intervening trial (Experiment 2).

EXPERIMENTS 1 AND 2

Method

Materials

The materials were the same 84 black and white line drawings used in Smith and Wheeldon (2001, Experiment 1). All picture names were monosyllabic. In order to construct the picture pairs for the target trials, a set of 24 pictures was divided into two matched sets of 12 pictures (see Table 1).[1] Pictures in these two sets were then combined to give four sets of 12 pairs. The 12 pictures occupying the left position in one set of pairs were matched with those occupying the right position and both positions were matched across all four sets of pairs. This ensured that individual

TABLE 1
Properties of the two matched sets of picture names for target and prime trials in Experiments 1 and 2

	Targets		*Primes*	
	Set 1	*Set 2*	*Set 1*	*Set 2*
Naming latency (ms)	534	536	556	564
Standard deviation (ms)	139	134	169	168
Number of syllables	1	1	1.8	1.9
Number of phonemes	3.2	2.9	4	3.8
Log frequency	4	4	2.7	3

[1] 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).

pictures made a balanced contribution to production latencies for words at both of the two screen positions. There was also no phonological or conceptual similarity between the two pictures in a pair. Finally, each picture occurred in both screen positions once. A similar procedure, using a different set of 24 pictures, was employed in order to generate the stimuli for the prime trials (see Table 1).

During the experiment pictures could move in four possible directions: up, down, right, and left. Participants were instructed to describe these pictures from left to right. Example experimental sentences are given under (1) below. On experimental trials, horizontal movements (apart/together) always followed vertical movements (up/down) or vice versa.

(1) Target: The spoon and the car move up/down/apart/together.
Related: The fish and the eye move apart/together/up/down.
Unrelated: The fish moves up/down and the eye moves down/up.

A final set of 36 stimuli were constructed for use on the filler trials inserted between prime and target trials and in the rest of the experiment. In contrast to the experimental trials, all filler trials involved either one or three moving pictures. All filler sentences comprised a single clause beginning with a simple noun phrase (see (2) below). Therefore, the structure of the initial phrase corresponded to that of the unrelated primes and would not activate the coordinate phrase structure of the target sentences.[2]

(2) a. The house moves up/down/right/left (one picture moves).
b. The pictures move up/down/right/left (three pictures move in the same direction).
c. The pictures don't move (three pictures remain stationary).

Design

Experiment 1 tested priming at lag = 0 (no intervening items) and lag = 3 (three intervening items). Experiment 2 tested priming at lag = 0 and lag = 1. The four matched stimulus sets were assigned to the four experimental target conditions in each experiment which were created by

[2] Our fillers differ to those of Brock and Griffin (2000) who used intransitive fillers that were neutral in structure with regard to their experimental transitive sentences. Such neutral fillers are of course crucial when the dependent variable is choice of sentence structure. In our task however, there is only one correct sentence structure for a given stimulus and our interest is in the speed with which it is generated. Crucially, our unrelated trials and filler sentences cannot be used to describe the target stimulus and will not reactivate the target sentence structure.

crossing lag and relatedness. For both target and prime trials the assignment of stimulus set to condition was rotated over participants.

The experiment consisted of seven blocks of trials. The first was a demonstration block of eight trials in which subjects were shown typical experimental and filler trials. This was followed by two practice blocks that were similar to the experimental blocks in terms of the sentences that were elicited. During the practice blocks, participants encountered each of the 24 experimental pictures once.

In Experiment 1, participants were presented with four experimental blocks each consisting of 58 trials. Each block contained three target trials per condition. Blocks and conditions featured equal numbers of trials of each movement category. The distribution of the experimental and filler trials across the block was pseudorandomised. Each of the 24 experimental prime stimuli occurred only once in each block. The same pictured objects never occurred in two consecutive trials. Finally, the ordering of the blocks was rotated across participants to ensure that each block occurred an equal number of times in each position in the experiment. The design was the same as for Experiment 2 except that fewer fillers were required (for the lag = 1 condition) and participants were presented with four experimental blocks of 46 trials.

Apparatus

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

Procedure

Prior to the experiment, participants were instructed to describe the picture movements from left to right. In addition they were shown examples of each type of visual display that would occur and were given an example of the required response. Each trial began with the appearance of a 19 cm × 6.5 cm frame in the centre of the screen. This black on white frame delimited the area in which the pictures would appear and was displayed for 1500 ms. At its offset, the pictures were presented on the screen and immediately began to move. The movement covered 2.5 cm of the screen and lasted 1500 ms. Participants then began describing the movement as soon as they could and pictures were removed from the screen 500 ms after response completion. After a 2 s interval, the next trial

was initiated. After the experiment interviews were conducted to check participants' awareness of the experimental structure.

Participants

The participants were students from Birmingham University. All participants were monolingual native speakers of English who were paid in participation credits or at the rate of £5 per hour. A different group of 24 participants was tested for each experiment.

Results

Responses with latencies less than 400 ms and longer than 1750 ms were excluded from the analyses of both experiments as were trials on which technical errors occurred. Three further types of response were categorised as errors and excluded from the analyses: responses in which participants did not use correct picture names; responses in which participants used syntax that deviated in any way from the required structures; and dysfluent responses. Separate analyses were carried out with subjects and items as random variable, yielding F_1 and F_2 statistics.

Experiment 1

Exclusion of data resulted in the loss of 1.6% of the data in Experiment 1. Mean latencies and percentage error rates in each condition are given in Table 2.

An ANOVA on the latency data featuring the variables lag (No lag vs. Three trial lag) and prime (Related vs. unrelated) yielded a significant main effect on prime, $F_1\ (1,23) = 10.3$, $p < .01$, $F_2\ (1,47) = 9.3$, $p < .01$ but not of Lag, $F_1\ (1,23) = 0.6$, $F_2\ (1,47) = 0.7$. There was a significant interaction between lag and prime, $F_1\ (1,23) = 5.9$, $p < .03$, $F_2\ (1,47) = 4.5$, $p < .04$. Experiment 1 yielded a significant effect of priming at lag = 0,

TABLE 2
Production latencies and error rates for target sentences in the four priming conditions of Experiments 1 and 2

	Unrelated	*Related*	*Priming*
Experiment 1			
Lag = 0	1012 (0.8)	943 (0.5)	69 (−0.3)
Lag = 3	987 (0.7)	991 (0.8)	−4 (−0.1)
Experiment 2			
Lag = 0	977 (1.3)	911 (0.5)	66 (0.8)
Lag = 1	950 (0.5)	958 (0.8)	−8 (−0.3)

F_1 (1,23) = 20.6, $p < .001$, F_2 (1,47) = 12.8, $p < .01$. No priming was evident at lag = 3, F_1 and $F_2 < 1$. No significant effects on error rates were observed.

Experiment 2

Exclusion of data resulted in the loss of 1.1% of the data in Experiment 2. Mean latencies and percentage error rates in each condition are also given in Table 2.

Experiment 2 also yielded a significant main effect of prime, F_1 (1,23) = 9.3, $p < .01$, F_2 (1,47) = 4.4, $p < .05$, but not of lag, F_1 (1,23) = 0.9, $p < 0.04$, F_2 (1,47) = 0.7, $p > 0.3$. The lag and prime interaction was again significant, F_1 (1,23) = 7.7, $p < .02$, F_2 (1,47) = 6.7, $p < .02$. This experiment also yielded a significant effect of priming at lag = 0 of a similar magnitude to that observed in Experiment 1, F_1 (1,23) = 19.9, $p < .001$, F_2 (1,47) = 15.5, $p < .001$. Again, no priming was observed at lag = 1, F_1 and $F_2 < 1$. Percentage error rates again yielded no significant effects.

Experiment 1 and 2

An analysis of variance was performed which combined the data from both experiments. This analysis yielded no significant interactions with the experiment variable.

Participant strategies

To test if performance differed across the two halves of the experiments, we conducted ANOVAs including the variables experiment half (first half vs. second half), lag, and prime. Both experiments yielded significant main effects of experiment half as latencies were slower in the first than in the second half of the experiment: Experiment 1: 1039 ms vs. 929 ms, F_1 (1,23) = 40.7, $p < .001$, F_2 (1,47) = 63.2, $p < .001$; Experiment 2: 988 ms vs. 906 ms, F_1 (1,23) = 27.5, $p < .001$, F_2 (1,47) = 25, $p < .001$. However, for both experiments the pattern of results was similar across both halves and there were no significant interactions with this variable. The post-experimental interviews showed that participants were unaware of the experimental design and had not used conscious strategies.

DISCUSSION

Experiments 1 and 2 clearly demonstrate that the effect of phrase structure priming on sentence production latency reported by Smith and Wheeldon (2001) is relatively short lived: the generation of a particular noun phrase structure speeds only its immediate re-use. This finding contrasts with the experiments reported by Bock and Griffin (2000) in which priming

persisted over 10 intervening trials. Our task has many features in common with Bock and colleagues' picture description task with two main differences. First, as our critical pictures are always agents and grammatical subjects, our stimuli do not strongly contrast the mapping from conceptual to syntactic structure. Second, our dependent variable is speed of sentence production rather than choice of sentence structure. We discuss each of these differences in turn.

Bock and Griffin's (2000) persistent priming effect has been modelled as a form of implicit learning which affects the process of mapping from conceptual to syntactic structure. Prior experience of producing a given syntactic structure in response to a particular conceptual structure alters the weight on the link between these two levels of representation such that reactivation of the latter results in a speeded activation of the former (Chang et al., 2000). Other persistent repetition priming effects have been reported in speech production research. Wheeldon and Monsell (1992) demonstrated a facilitatory effect of spoken word repetition that remained significant after 100 intervening word productions—a time lag of approximately 8 mins. They also attributed this effect to changes in the weight of links between two levels of representation: in this case between lexical semantic and form representations.

Clearly, however, such a mechanism does not provide a satisfactory explanation for our priming effect. Thus, the fact that Bock and Griffin's (2000) priming effect persisted over 10 intervening trials whereas our priming effect failed to persist over a single intervening trial suggests that the two effects are tapping into distinct language production processes. Moreover, because our stimuli do not strongly contrast the mapping from thematic to grammatical roles, our effect cannot arise during the mapping from conceptual to functional processing (see also Smith & Wheeldon, 2001). Instead we suggest that the priming effect observed in the current study reflects the priming of constituent assembly processes at the positional level. Specifically, we propose that the effect is best explained in terms of the facilitated generation of a particular noun phrase structure due to residual activation following its generation. Short-term priming effects can be better modelled in terms of residual node activation, which in most spreading activation models must decay quickly or be actively suppressed in order to avoid the immediate reselection of linguistic units.

It is most probably desirable that priming at the level of phrase structure building should be transient. The on-line generation of surface syntactic structure requires rapid switching between different but frequently used phrase structures. It is possible, therefore, that persistent activation of such structures could inhibit rather than facilitate fluent speech production. In contrast, it is clear how the persistent reactivation of the mapping between thematic and grammatical structures could contribute to the fluency with

which speech is produced. It would serve to speed the choice between possible grammatical structures leading to faster production, and indeed faster comprehension, during the course of a conversation.

However, the sentence structures tested by Bock and colleagues have not yet been primed in an on-line speech production task (but see Corely and Scheepers (2002) for a typed sentence output task). We therefore do not know exactly how the different dependent variables of sentence choice and production speed relate to each other. The possibility therefore remains that the same underlying mechanism could generate different patterns of persistence in off-line and on-line tasks. In other words, weight changes large enough to influence a participant's choice of a particular syntactic structure at long lags might not be sufficient to speed the generation of that sentence. There is some evidence of long-term priming of choice of word order. Hartsuiker and Westenberg (2000) demonstrated an overall increase in the production of the least preferred ordering of auxiliary verb and past participle at the end of their experiment. They attributed this increase to a long-term rise in the resting level activation of a particular syntactic structure due to its repeated production over the course of the experiment. In contrast, however, our on-line phrase priming effects have never significantly varied over the course of an experiment. The exact relationship between the choice of a particular syntactic structure and its speed of production remains an issue for future research.

In summary, this research has replicated the on-line phrase structure priming effect demonstrated by Smith and Wheeldon (2001). In addition, the experiments reported have shown that priming of the later process of phrase structure generation is relatively transient.

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