Phrase Structure Priming Across Sentences: Facilitation or Reconfiguration?

Alexandra K. Frazer (akf207@lehigh.edu)
Department of Psychology, Lehigh University USA

Padraig G. O'Seaghdha (pat.oseaghdha@lehigh.edu)
Department of Psychology and Cognitive Science Program, Lehigh University, USA

Abstract

Structural priming, the tendency for speakers to reuse the structures of recent utterances (Bock, 1986) or to produce repeated structures more fluently, is well documented for structural selection, but less so for phrase structure generation. Priming of structural choices is long-lived, persisting across intervening utterances (Bock & Griffin, 2000), but priming of phrase structure does not survive even one intervening sentence (Wheeldon & Smith, 2003), suggesting that the processes may be different. Moreover, although Smith & Wheeldon (2001) found an initiation latency benefit of initial noun phrase priming, the main verb (*move/s*) was also constant. Here, we report a noun phrase structure repetition effect only when the entire verb phrase was also repeated. Because this effect is better accounted for as plan reconfiguration than as structural priming, previous reports of phrase level structural priming need to be reassessed.

Keywords: Language production; grammatical encoding; structural priming; lexical boost; planning scope

Structural Priming in Sentence Production

For a quarter of a century, structural priming has been one of the most researched topics in the field of language production. Structural priming is the tendency to echo the syntactic structures of recently produced utterances (Pickering & Ferreira, 2008) with potential gains in fluency. For example, after producing sentence (a), people would be more likely to generate (b) than (c) in a picture description task (example from Bock & Griffin, 2000, p. 178).

(a) The car's windshield was struck by a brick.
(b) The boy is being awakened by a noisy alarm.
(c) A noisy alarm awakened the boy.

In addition, production of (b) may be more fluent following (a) than following a non-passive precursor. Such effects are ubiquitous in production, occurring across languages (Loebell & Bock, 2003), in written and spoken production (Pickering & Branigan, 1998), between speakers (Bock, Dell, Chang & Onishi, 2007), in aphasic speakers (Hartsuiker & Kolk, 1998), and in children (Huttenlocher, Vasilyeva, & Shimpi, 2004) (for a recent comprehensive review see Pickering & Ferreira, 2008). Furthermore, structural priming is not easily explained by repetition of themes, lexical items, or metrical relationships between the prime and target utterances, and has been interpreted as evidence for an abstract or isolable representation of syntax (see Pickering & Ferreira, 2008).

Most models of sentence production make a distinction between functional and positional levels of grammatical encoding (Bock & Levelt, 1994; Garrett, 1976). During functional grammatical encoding, lexical items are selected with respect to grammatical roles, whereas during positional encoding words are linearized and linked to phonological information. One might expect structural priming to operate at both levels (Pickering & Ferreira, 2008). However, the available evidence suggests that the processes at the two levels may differ (Bock & Griffin, 2000; Smith & Wheeldon, 2001).

The bulk of structural priming research has considered functional level priming, using syntactic choice data to determine whether priming has occurred (Bock, 1986; Pickering & Ferreira, 2008). Functional level priming is long-lived, persisting over multiple intervening sentence productions, and so may reflect adjustments to the mappings between meanings and syntactic expressions rather than short term activation of lexical or syntactic options (Bock & Griffin, 2000; Chang, Dell & Bock, 2006). Such high level mappings, however, are not transparently relevant to positional level processes.

Positional level structural priming involves the linearization of words and may involve a phrasal planning scope. Thus, because they involve linearization of nouns (Bock & Warren, 1985), coordinate noun phrases are a good candidate for phrase structure priming. Smith and Wheeldon (2001) tested structural priming between both simple and compound noun phrases, reporting a benefit in initiation latency for primed compound phrases but no benefit for simple noun phrases. Importantly, the priming effect did not persist over even one intervening trial (Wheeldon & Smith, 2003). Wheeldon and Smith interpret this as evidence that positional level assembly processes facilitate the construction of a particular noun phrase structure, rather than reflecting the mappings from conceptual to grammatical representations that operate at the functional level. Thus, although functional and positional level priming may both be considered to be "structural", they also involve distinct processes.

Verb Phrase Repetition and Priming

An important theoretical debate in the functional level literature concerns the potential role of lexical, and especially verb repetition in promoting structural persistence. Using measures of syntactic choice, Pickering and Branigan (1998) showed that when the verb was

repeated from prime to target, the amount of priming increased, and therefore proposed that verbs play a pivotal role in structural priming. Using the same materials as Pickering and Branigan (1998), and again varying whether or not the verb was repeated, Corley and Scheepers (2002) used both measures of syntactic choice and response latencies to measure priming. Only the same verb conditions resulted in significant structural priming measured by syntactic choice, and these conditions also showed a large initiation time advantage. However, Hartsuiker et al. (2008) showed that structural priming effects are distinct from the 'lexical boost' of verb repetition. They also showed that the lexical boost was a short-lived effect, occurring only from one sentence to the next, whereas structural priming effects were long-lived, persisting over multiple intervening sentences (see also Bock & Griffin, 2000).

Although it has not been explicitly addressed in the published literature, verb repetition may also be implicated in positional level processing. The Smith and Wheeldon (2001) studies employed a picture description task in which participants produced coordinate noun phrases prescribed by the movements of pictures on a screen. In these experiments, the specific movement of the pictures always varied between productions but the main verb always repeated from prime to target (e.g., MOVE/S up, down, together, apart). There was a small, but robust initiation time benefit of approximately 50ms across experiments, but only for complex initial noun phrases. Like the lexical boost of Hartsuiker et al. (2008), phrase structure priming was short-lived, occurring only between consecutive sentences (Wheeldon & Smith, 2003). This raises the question of whether phrase structure priming is a diminished structural priming effect (see Pickering & Ferreira, 2008), or whether it may be a different phenomenon.

Similar to Smith and Wheeldon, we have observed robust phrase structure priming among consecutively generated sentences when the prime and target sentences shared both structure and the verb phrase (Schuster & O'Seaghdha, 2005). This leaves open the possibility that the observed positional structural priming effects are contingent on or significantly enhanced by repetition of the verb. In a pilot study with no verb phrase repetition from primes to targets, we found no evidence of structural priming in measures of initiation time (Frazer, 2009). Thus, to our knowledge only studies of initiation time that have repeated some or all of the verb phrase show structural priming. If the repetition of the verb phrase is required for priming effects to be observed, this suggests the following interim conclusion: pure structural priming of the kind observed at the functional syntactic level may not occur at the level of phrase structure generation.

Current Study

We systematically manipulated structural repetition in conjunction with verb phrase repetition in order to examine whether structural priming effects at the positional level are in fact contingent on repetition of the verb phrase. The verb phrase was either the same in prime and target, different but in the same spatial dimension (horizontal or vertical), or different and in a different spatial dimension (see Figure 1). All the productions were functionally equivalent declaratives; only the positions of simple and complex noun phrases, and the spatial locations described in the verb phrases, varied.

We made two main predictions:

- Based on Smith & Wheeldon (2001), structural priming will only be observed for compound initial noun phrases.
- Structural priming effects will be robust when the verb phrase is repeated but reduced when it is not.

Method

Spatial Descriptions of Word Locations (SDWL) In this procedure, participants receive sets of four nouns followed by colored blocks that identify which words go together (same color) and where they feature in the sentence (green in NP1; red in NP2; see Figure 1). Thus participants are induced to prepare *Compound NP1 - VP - Short NP2* or *Short NP1 - VP - Compound NP2* sentences. Consecutive sentences share structure, spatial predicates, both, or neither. The spatial predicates are of the form *is/are left of/right of/above/below*. This procedure addresses our goal of examining positional level priming. Although the nouns in this task are fully prescribed, participants must engage the production processes of conceptualizing the spatial arrangement to be described, formulating the corresponding sentence, and linearizing the words for articulation.

Note that in this design, in the different structure condition, the final noun phrase in the prime matches the structure of the initial noun phrase of the target, raising the possibility of unwanted priming among these adjacent phrases. However, it is plausible that structural priming is regulated by the sentence hierarchy. On this basis, confirmed by the results of Smith and Wheeldon's (2001) Experiment 6, we assume that priming occurs between corresponding phrases in the same sentence positions**.**

Table 1: Experimental Design: Structural and Spatial Location Components Shared Between Prime and Target Sentences in Each Condition (all conditions include Compound and Short NP1 targets).

	Structure Repetition	
Spatial Location	**Different**	**Same**
Same	*Location Only (A)*	*Structure and Location (D)*
Opposite	*VP Dimension (B)*	*Structure and VP Dimension (E)*
Other	*Unprimed (C)*	*Structure Only (F)*

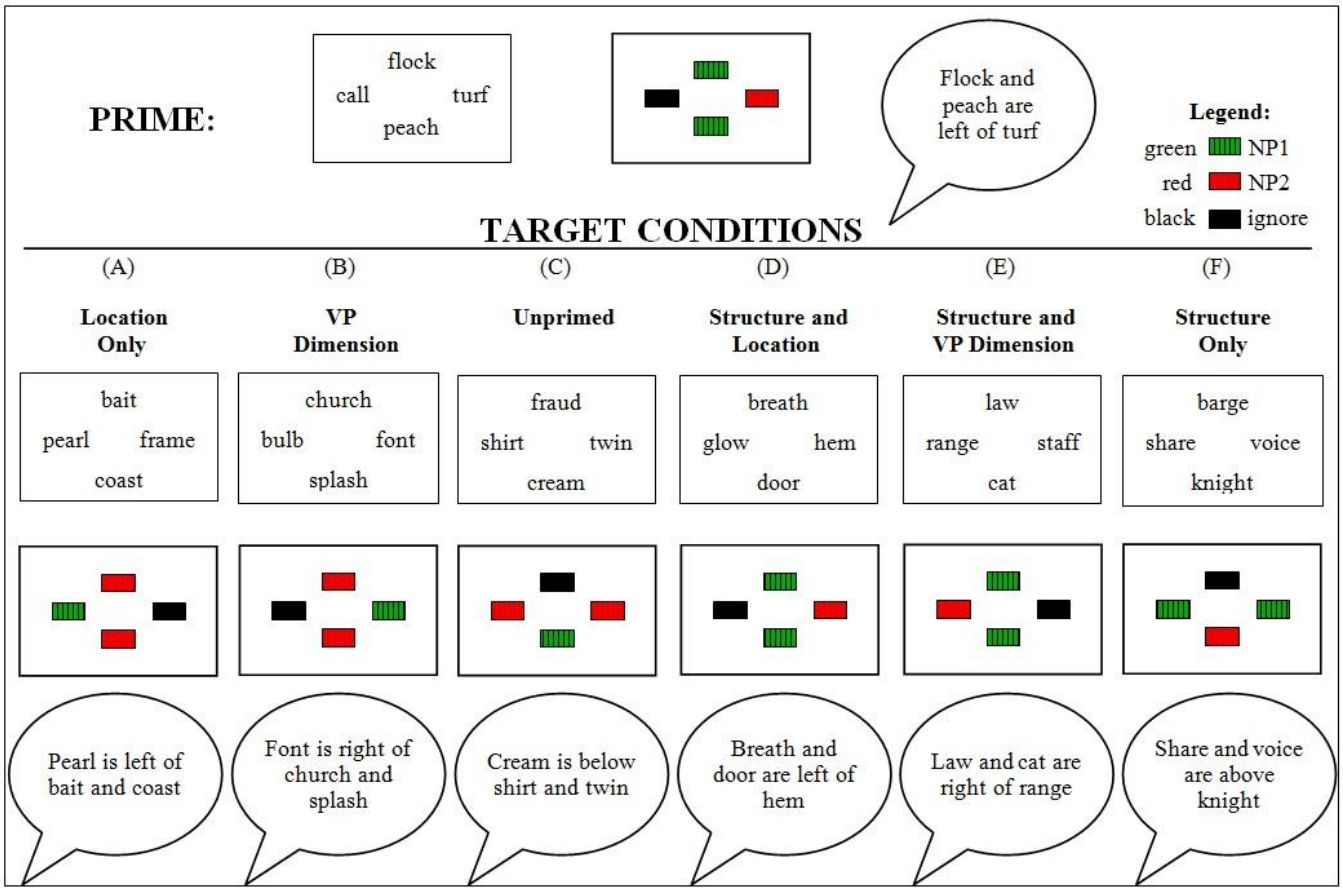

Figure 1: Spatial Descriptions of Word Locations Procedure: Target Conditions in Relation to a Preceding Prime Production

1. Participant receives and memorizes set of four words
2. Words are replaced by blocks which convey encoding requirements
   Words in GREEN locations are in the first NP; Words in RED locations are in the second NP. BLACK words are discarded.
3. Participant produces appropriate sentence of the form "X/ X and Y - is/are left of/right of/ above/ below - Y and Z/ Z]

Participants Thirty-six native English speaking Lehigh University undergraduates participated to fulfill a course requirement. The experiment took approximately one hour to complete.

Materials Words were selected based on a direct measure of lexical accessibility, the naming latencies of singular monosyllabic nouns in the English Lexicon Project database (Balota, et al., 2007). Selected items were within one half standard deviation of the mean naming latency [Range: 591 ms to 653 ms]. Item selection also took into account concreteness and unambiguous pronunciation.

Items were first assigned to prime or target groupings of four such that all words were used only once. The words were then rotated across Conditions and Target Structures in 16 versions of the experiment so that there were no systematic bindings of words to conditions. This elaborate counterbalancing meant that there were no stable sentence-level items and so no analysis by items is warranted.

Each version of the experiment contained 64 prime-target combinations for a total of 128 productions. For each Target Structure in both the Primed and Unprimed conditions there were 4 targets where the spatial description was the same as in the prime, 4 where the location was in the same dimension but opposite, and 8 where the location was in one or the other pole of a different dimension.

Design We manipulated Target Structure (Compound NP1 or Short NP1), Structure Repetition from the preceding sentence (Same of Different), and the Spatial Location described in the verb phrase (Same, Opposite, Other). See Table 1.

Procedure Sentences were produced according to the Spatial Descriptions of Word Locations procedure (Figure 1). First, four words appeared on screen. Participants read each word aloud, paying attention to its location. When they were ready, they pressed a key to continue, or the

experiment continued automatically after 10 seconds. Next, the colored blocks replaced the words. These blocks indicated how the words should be spatially described (see Figure 1). Participants were asked to produce the ingredients of the compound noun phrases in a natural order, top-to-bottom or left-to-right.

Participants were asked to produce the sentences as quickly and accurately as possible. They were shown four examples before proceeding to a practice section of 12 productions. During the practice trials the experimenter corrected any errors and clarified the procedure as necessary.

The sentences were organized in prime-target pairs but presented in a continuous stream. The sequence of sentence pairs was fully randomized. The experiment was broken into two sections, with the opportunity for a break between sections. The session was recorded for later coding.

Results

Data Scoring and Errors Any trial where speech did not begin within 5 seconds of the appearance of the colored blocks was discarded. Errors were defined as productions in which the wrong words were produced, the words were produced in the wrong order within a Compound NP or in the wrong NP, the spatial description was incorrect, or the production was incomplete. An error in the prime meant that the prime-target pair was removed even if there was no error on the target.

Six participants were excluded from the analysis for having error rates over 50%. This left 30 participants who had an average error rate of 29%. This rate is consistent with previous work using this paradigm (Frazer, 2009; Schuster & O'Seaghdha, 2005) and reflects both the intrinsic difficulty of the task and the need to exclude targets if there was an error on the preceding prime.

Analysis The results of an initial overall analysis of variance are summarized in Figure 2. There are two notable findings. First, sentences beginning with a short noun phrase (Short NP1) were actually produced more slowly (1635ms) than those beginning with a compound noun phrase (1381ms). This suggests that the short NPs, which were produced as bare nouns, were planned in conjunction with the following verb phrases, whereas compound noun phrases were not (see Wagner, Jescheniak, & Schriefers, 2010, for a recent discussion of flexibility in the scope of planning). This effect of Target Structure was significant, F (1, 29) = 39.78, $p < .001$.

Overall, targets preceded by a same structure prime were initiated more quickly (1472ms) than those preceded by a different structure prime (1544ms), F (1, 29) = 5.85, p = .022. This does not indicate across the board structure priming however, because it is qualified by a complex pattern of interaction. As predicted, priming is largely confined to the conditions with compound initial noun phrases (see Figure 2). Among Compound NP1s, the effect of structure repetition is further limited to sentences with the

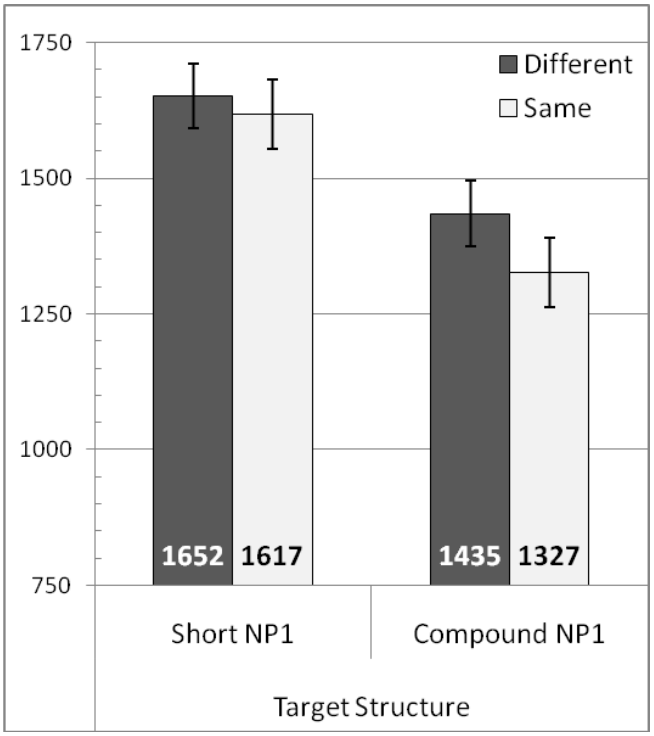

Figure 2: Mean Initiation Times with Standard Errors as a Function of Structure Repetition (Same or Different) and Target NP1 Structure

Same Spatial Location in prime and target (see Figure 3). The three-way interaction, reflecting an effect of Structure Repetition concentrated in the Same Spatial Location and only in the Compound NP1 Target Structure was significant, F (2, 58) = 5.18, p = .009.

A separate analysis of the Short NP1 sentences confirmed that there was no effect of Structure Repetition, F (1, 29) < 1, or of Spatial Location, F (2, 58) = 1.01, and no relationship of the two, F (2, 58) < 1. This is consistent with previous results with initial noun phrases containing single monosyllabic nouns (Smith & Wheeldon, 2001). Smith and Wheeldon suggested one explanation of this outcome, that short initial NPs are primed in all conditions. This is complicated in our case by the evidence that short noun phrases may be planned with the following verb phrase. But in any case, the short noun phrase data by themselves do not show any priming and will not be considered further.

Turning to the Compound NP1 productions, we found a benefit of Structure Repetition, F (1, 29) = 12.07, p = .002, as we did in the overall analysis. There was no main effect of Spatial Location, F (2, 58) = 1.78, p = .181, but the effect of Structure Repetition is clearly concentrated in the Same Spatial Location condition [Interaction: F (2, 58) = 7.36, p = .001; see Figure 3]. One could interpret this as a benefit of verb phrase repetition or as a structural benefit contingent on verb phrase repetition, except that the effect appears to reflect a cost in the Location Only condition rather than a clear benefit in the Structure and Location

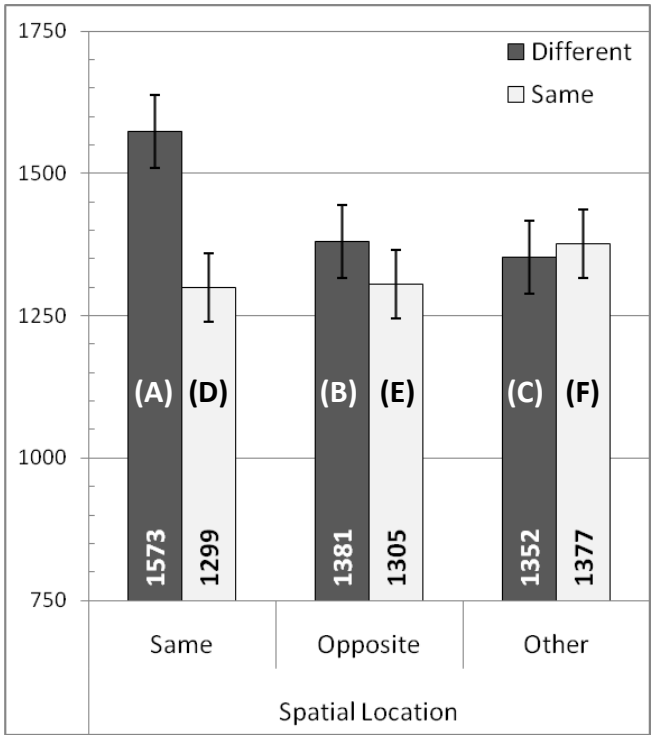

Figure 3: Mean Initiation Times for Compound NP1s with Standard Error Bars as a Function of Structure Repetition (Same or Different) and Spatial Location (Letters refer to conditions in Figure 1).

condition. The mean initiation time for the Location Only condition is substantially slower than for any other condition in Figure 3. The priming effect in the Opposite Spatial Location conditions is much smaller and nonsignificant, and in the Other Spatial Location conditions there is no priming.

Why is there a cost to compound initial noun phrase production following a simple initial noun phrase that used the same conceptual configuration and predicate? One explanation may lie in the planning scope of the Short NP1 prime sentence which, as discussed earlier, may be included with the verb phrase in a larger unit. Because the Compound NP1 is not typically included in a larger planning unit, there may be difficulty in moving from a short to a long noun phrase when the verb phrase is repeated. This could happen in two related ways. There may be a tendency to bind the compound noun phrase to the repeated predicate, that is, to repeat the NP-VP planning scope, or there may be difficulty in adopting the simpler NP planning scope in this condition. The larger planning scope, or reconfiguration to the default shorter planning scope for a compound noun phrase, can account for the reaction time pattern. In either case, the apparently large priming effect in the Structure and Location repetition condition is not convincing evidence for phrase structure priming, but may instead involve reconfiguration in the different structure condition.

Discussion and Conclusions

Our study brings into question previous findings of structural priming at the level of phrase structure. Previous research has suggested that priming occurs but only for relatively complex phrases. In this experiment, we saw only a non-significant trend toward structural priming in conditions where the entire verb phrase following a complex initial noun phrase was not repeated. However, it remains possible that structural priming occurs when there is a "foothold" available in planning beyond the primed component. This was available in the Smith and Wheeldon (2001) experiments in the form of the main verb "move". This constant and dependable planning component contiguous to the noun phrase may allow for expression of a fragile priming effect. It may also be that the more direct picture movement description task of Smith and Wheeldon is more sensitive than our rather demanding spatial description task. Thus the jury is out on the question of whether structural priming extends to the level of phrase structure.

A second challenge to existing findings is presented by our Same Location observation of a cost to structure shifting rather than a benefit to structure repetition. Specifically, initiation of sentences beginning with a compound noun phrase was slower following a similar spatial configuration but different structure prime. Previous studies such as Smith and Wheeldon (2001), which did not vary verb phrase congruity, do not distinguish between costs and benefits and so their small priming effects may reflect either or both.

Related to the cost-benefit determination, we also found a counterintuitive difference in planning scope between sentences beginning with short and long noun phrases such that short noun phrases were slower to initiate. We suggest that this is because they are planned with the following verb phrase. This outcome may be specific to bare monosyllabic noun production, which is natural in our Spatial Descriptions of Word Locations procedure though not in picture naming. Smith and Wheeldon (2001) elicited sentences with pictures, for which speakers produced a definite article before the nouns (e.g. "the eye"), and latencies were shorter for short NPs in their study. Consistent with our findings here, previous research using the SDWL procedure with monosyllable nouns has shown longer latencies for short NPs (Frazer, 2009). However, short noun phrases were faster when the nouns were disyllables (Schuster & O'Seaghdha, 2005), suggesting that speakers prefer an NP planning scope provided that the phrase contains more than one stress unit. Caution in drawing strong conclusions about the status of phrase structure priming is appropriate in light of these planning scope considerations. Nonetheless, our findings suggest that phrase structure priming may be even more evanescent than previous work has suggested (Wheeldon & Smith, 2003), or may not explain significant variance at all. Because phrase structure generation occurs at a different level than the structure selection that is the focus of most structural priming research, the fate of phrase structure priming does

not diminish the theoretical interest of the larger field of structural priming. However, it is important to determine the true status of phrase structure priming in future research because it speaks to the pervasiveness of structural persistence in the syntactic system.

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