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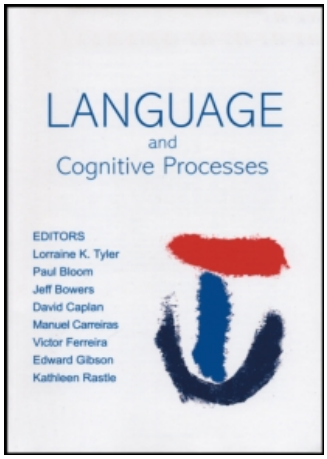

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Inhibitory form priming of spoken word production

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Inhibitory form priming of spoken word production

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Three experiments were designed to examine the effect on picture naming of the prior production of a word related in phonological form. In Experiment 1, the latency to produce Dutch words in response to pictures (e.g., *hoed*, hat) was longer following the production of a form-related word (e.g., *hond*, dog) in response to a definition on a preceding trial, than when the preceding definition elicited an unrelated word (e.g., *kerk*, church). Experiment 2 demonstrated that the inhibitory effect disappears when one unrelated word is produced intervening prime and target productions (e.g., *hond-kerk-hoed*). The size of the inhibitory effect was not significantly affected by the frequency of the prime words or the target picture names. In Experiment 3, facilitation was observed for word pairs that shared offset segments (e.g., *kurk-jurk*, cork-dress), whereas inhibition was observed for shared onset segments (e.g., *bloed-bloem*, blood-flower). However, no priming was observed for prime and target words with shared phonemes but no mismatching segments (e.g., *oom-boom*, uncle-tree; *hex-hexs*, fence-witch). These findings are consistent with a process of phoneme competition during phonological encoding.

INTRODUCTION

Each time we speak we must generate anew the sound form of every word we use. That we occasionally make errors in speaking that change or disorder the constituent sounds of words (e.g., *heft-lemisphere–left hemisphere*), demonstrates that the sound form of words are not retrieved from memory and produced as undifferentiated wholes. Instead, selection of the

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intended word triggers the construction of the form representations that are required to guide articulation—henceforth word form encoding. The complexity of this process is increased by the fact that the form encoding of most words occurs within a sea of activated alternative lexical items and their constituent sublexical representations. Some of this activation can come from external sources such as the speech of others and from written language (Harley, 1984). In addition, the fluency of normal speech production would not be possible without some advanced planning. This means that words that will occur later in an utterance must often be simultaneously active with those about to be articulated. Some advanced activation is essential for the generation of phonologically correct phonological words (Levelt, 1992; Wheeldon & Lahiri, 1997). Phoneme exchange errors, like the example given above, can only occur where there is simultaneous activation of at least adjacent words. Similarly, lexical or phonological representations also retain some activation for a period of time following articulation as evidenced by phoneme perseverations (cf. Dell, Burger, & Svec, 1997). There is also evidence for the activation of words that do not form part of the intended utterance but are related in sound form to a word to be produced. Malapropisms or form-related word substitutions (e.g., saying ''apartment'' when you intended to say ''appointment'') provide evidence of the multiple activation of words related in form to the target word. Further evidence for such multiple activation of form-related words comes from the study of word-finding difficulties in anomic speech and the tip-of-the-tongue (TOT) phenomena. In TOT states a word related in form to the target is frequently produced in its stead (Brown, 1991; Jones, 1989; Meyer & Bock, 1992).

Given this riot of background activation during the production of a given word, the speech production system must incorporate mechanisms that allow the intended word to be selected and produced in preference to other activated word forms. Most current models of word form encoding postulate inhibitory or competitive mechanisms at some stage during encoding to serve this purpose. However, the experimental evidence for inhibitory processes during word form encoding is limited. The aim of this research was to investigate the effect of form priming on spoken word production using a simple picture naming task and to provide evidence relevant to the locating of any effect to a particular component process of word form encoding.

Models of word form encoding

Many models of word production make similar suggestions as to the levels of representation and processes involved (Dell, 1986, 1988; Levelt, 1989, 1992; Levelt, Roelofs, & Meyer, 1999; Levelt & Wheeldon, 1994; Roelofs,

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1997; Shattuck-Hufnagel, 1987, 1992). First, the morphemic/lexical representation associated to the activated (or selected) semantic/syntactic representation is activated. Activation (or selection) of this representation makes available two further types of form information: (1) the word's constituent phonemes and (2) a frame for the shape of the word (but see Dell, Juliano, & Govindjee, 1993). A number of frame structures have been proposed: syllables (Dell, 1986), CVC slots (Dell, 1988), words (Shattuck-Hufnagel, 1987, 1992), phonological words (Levelt, 1992; Roelofs, 1997; Wheeldon & Lahiri, 1997). Whatever the proposed frame, a phonological encoding process is postulated which assigns the word's constituent phonemes to their positions in the frame. Various malfunctionings of this assignment process have been used to account for phonological speech errors (Dell, 1986; Dell & Reich, 1981; Shattuck-Hufnagel, 1979, 1987, 1992). Most models of speech production have been designed to explain how such errors occur. Less attention has been given to the problem of how a detailed phonetic representation is created which could be used as input to articulatory processes. Levelt (1989, 1992) postulates a prosody generatory that takes as input metrical information about the selected word including its number of syllables and their weight (as well as phrasal and syntactic information) and combines them into phonological words (see Levelt & Weeldon, 1994; Roelofs, 1997; Wheeldon & Lahiri, 1997, in press; Wheeldon & Levelt, 1995). The relevant segments are associated to these units in a left to right manner. As the segments for each syllable node are associated, they are used to retrieve stored, syllable-sized, articulatory routines (following Crompton, 1982). When the articulatory routines for the entire phonological word have been retrieved the phonetic plan is passed on to the articulators and is executed.

Facilitatory and inhibitory mechanisms of word form encoding

Most models of speech production postulate multiple activation of form related words through feedback activation from a phonological level of representation to a morphological level of representation (Dell & Reich, 1981; Dell, 1986, 1988; Levelt, 1989; Stemberger, 1985). Morphemes are connected to their constituent phonemes by bidirectional links. An activated morpheme node spreads activation to its constituent phonemes which in turn spread activation in reverse to all words that contain them. This secondary activation of phonologically similar words will sometimes result in a malapropism if the related word accrues more activation than the target.

Models differ, however, in how the appropriate (or inappropriate) word is selected from the activated pool of candidates. Stemberger (1985)

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postulates direct inhibitory links between activated nodes at a lexical level. Each activated node inhibits every other. The amount of inhibition a unit can impose is proportional to the strength of its activation, resulting in a ''rich get richer'' effect until one node suppresses its competitors and wins most of the activation. In Dell's (1986, 1988) model there are no lateral connections between morpheme nodes. Instead, after a certain number of time steps (determined by speech rate) the most highly activated node is selected. Stemberger's (1985) selection process is therefore competitive, as a node's activation level directly affects the activation of other nodes. In Dell's (1986, 1988) model the most strongly activated node is selected regardless of the activation levels of related nodes. Therefore, morphemes do not compete for production.

Levelt, Roelofs, and Meyer (1999) Postulate no competitive selection process at the lexical level. Morphemes are selected if they are linked to the selected lemma node at the level above. There is also no feedback of activation from the phonemic to the lexical level. The relationship between phonemes and morphemes are explicitly encoded on the links between them and phonemes are selected following verification of their relationship to the selected morpheme. Thus, phoneme selection is independent of a phoneme's level of activation. In this model, competition during spoken word production is restricted to phonetic encoding processes. The model contains a phonetic syllabary (Levelt & Wheeldon, 1994). The phonetic syllables comprise packages of scores for the articulatory movements to be made. A syllable program is selected if its links to phoneme nodes match the syllable positions that were assigned during phonological encoding. However, the speed with which syllabary access takes place depends on the activation levels of other syllable motor programs. The probability of accessing a motor program is equal to the ratio of the node's level of activation and the sum of the activation levels of all syllable nodes in the network. Thus, different syllable programs compete for selection. However, this model predicts no inhibitory priming due to form overlap. Instead, prior activation of the target syllable's phonemes will speed encoding of the target by increasing the numerator of the access ratio for the target syllables compared with unrelated syllable programs.

Yet another approach has been taken by Peterson, Dell, and O'Seaghdha (1989) and O'Seaghdha, Dell, Peterson, and Juliano (1992). Their model was proposed to explain an effect of form-related inhibition of high frequency primes in a lexical decision task (Colombo, 1986; Lupker & Colombo, 1994). In the Peterson et al. (1989) model, facilitation is due to the activation of orthographically related words during prime processing, whereas inhibition arises due to competition between the phonological segments of the activated words. In particular, the activated phonemes of the prime word interfere with the specification of the target word's

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phonological form. In support of this claim, O'Seaghdha et al. (1992) tested homophones (e.g., hare-hair) and nonhomophones (e.g., hate-hair) in a word naming task. They found inhibition for the nonhomophones but facilitation from the homophones. Thus in absence of phonological competition, orthographic similarity caused facilitation.

A similar account was proposed by Sevald and Dell (1994) for the results of the speeded recitation task described in the next section. However, they amended the basic phoneme competition model to account for the different effects they observed for shared initial and final phonemes. They argued that the inhibition observed for syllable strings sharing word initial segments was due to the miscuing of the different possible coda phonemes during a left-to-right phoneme to frame association process. The activated mismatching syllable final segments would compete for association to the final slot in the syllable frame, thus slowing the phonological encoding process. No inhibition was observed for syllables that overlapped in final segments because nothing followed them to be miscued. In this condition only facilitation would be observed due to the priming of the shared phonemes.

In summary, three different inhibitory mechanisms have been proposed to occur during word form encoding processes. First, competition between form-related lexical representations due to facilitatory feedback from shared phonological segments (Stemberger, 1985). Second, competition between mismatching segments during a left-to-right assignment process of segments to frames (O'Seaghdha et al., 1992; Peterson et al., 1989; Sevald & Dell, 1994). Finally, competition between syllable motor programs during phonetic encoding (Levelt, Roelofs, & Meyer, 1999). As discussed above, only the first two of these options predict inhibitory priming from a form-related word.

Form priming effects in speech production

Recently, a number of different experimental techniques have been developed in order to investigate word form encoding processes. Unfortunately, the patterns of results derived from these experiments are almost as varied as the tasks used. In particular, both facilitatory and inhibitory effects of form priming have been demonstrated. In the picture word interference paradigm, participants must name a picture and ignore an auditorily or visually presented distracter word. This paradigm has consistently elicited facilitatory effects of form-related distracter words compared with unrelated distracter words. Facilitation was observed when a visually presented distracter word shared the first letter and phoneme with the picture (e.g., home-horse) and when a nonword string was a pseudohomophone of the picture name (e.g., hoars-horse) (Posnansky &

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Rayner, 1978; Rayner & Posnansky, 1978; Rayner & Springer, 1986). Using a similar technique Lupker (1982) demonstrated facilitation for rhyming words related in phonology but not orthography to the target picture (e.g., brain-plane). Lupker and Williams (1989) also demonstrated facilitation of picture naming due to a rhyming relationship when primes were presented 250 ms prior to picture presentation. Both word and picture primes yielded significant facilitation when they were named and categorised, although the effect for categorised primes was much smaller. These priming effects were explained as the result of lexical activation of the target word during prime processing via feedback from shared phoneme representations.

Meyer and Schriefers (1991) tested the production of picture names in the context of auditory interference, employing words which overlapped in onset phonemes (e.g., *boeg-boek*, bow-book) or rhyme phonemes (e.g., *doek-boek*, cloth-book). The overlapping part of the interfering words were presented auditorily at different SOAs relative to the onset of a picture. Although the presence of a distracter word tended to slow naming latencies, facilitation was observed for form-related distracters compared with unrelated distracters. In addition the time course of the facilitation effect differed between overlap conditions. For onset overlap, facilitation was observed at SOAs −150 to +150. The facilitatory effect of rhyming words was smaller than that for onsets and occurred at the later SOAs 0, +150. This difference in time course lead Meyer and Schriefers (1991) to locate their priming effects in a left-to-right phonological encoding process.

Meyer (1990, 1991) used an implicit production priming procedure to test the effect that prior knowledge of aspects of a word's form has on its production latency. In this paradigm participants learned sets of associated pairs of words so that, later, on presentation of one word (the prompt) they could produce the other (the target). A given word-pair association could be tested either in a ''homogeneous'' block in which all the target words shared certain form features or in a ''heterogeneous'' block in which there was no form relationship between the target words. Only certain kinds of form similarities resulted in a decrease in naming latencies for homogeneous blocks. Shared first syllables facilitated production but shared second syllables did not. For both monosyllabic and disyllabic words, shared onsets facilitated while shared rhymes did not (Meyer, 1991). These results were also attributed to a phonological encoding process involving the left-to-right assignment of phonemes to a frame.

Inhibitory effects of form priming have been observed in replanning studies in which participants prepare to say a target utterance in response to a cue but on a small number of critical trials the cue is an alternative utterance which they must produce instead. When the alternative

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utterance is form-related to the target, inhibitory effects are observed. Meyer and Gordon (1985) required participants to prepare to say a syllable pair (e.g., ub-ut). On a proportion of critical trials, participants were cued to produce the pair in reverse order (e.g., ut-ub). Latencies were longer and error rates were higher when the consonants of a syllable pair shared voicing or place of articulation than when they differered in these features. Yaniv, Meyer, Gordon, Huff, and Sevald (1990) used a similar technique to test effects of consonant and vowel similarity in the production of CVC syllables and again found inhibitory effects of similarity.

O'Seaghdha et al. (1992) used a replanning task to examine the effects of form similarity on word production. Participants were presented with a word pair and instructed to prepare to say one of the words on cue. However, on one third of the trials a new word was presented instead of the cue and participants had to produce this word instead. They found that production latencies were slower when the new word shared initial sounds with the prepared word than when it was phonologically unrelated. In a second study, participants either produced a prepared sentence (e.g., *the hiker lifted the log or the log was lifted by the hiker*) or on critical trials they named a target word e.g., LOCK which was related in form to one of the words in the sentence. When the related word came at the beginning of the prepared sentence the effect on the production of the target word was inhibitory. When it came at the end of the prepared sentence the effect was facilitatory. The facilitation was attributed to lexical level activation whereas inhibitory priming was attributed to competition between the prime and target's phonemes during phonological encoding.

Inhibitory effects of form similarity have also been observed in tasks involving speeded recitation. Sevald and Dell (1994) required participants to produce sequences of four CVCs as quickly as possible in 8 s. The dependent variable was how many CVCs were correctly produced in that time. They varied the number of repetitions of consonants, onset CVs, and rhyme VCs. Compared with a condition with no repetition of consonants, repeated final consonants (e.g., PICK TUCK PUCK TICK) increased the number of correct repetitions, whereas repeated initial consonant or CV (e.g., PICK PUN PUCK PIN) reduced the number of correct repetitions. They accounted for these findings using an amended version of the phoneme competition account (O'Seaghdha et al., 1992).

The inhibitory priming effects summarised above are intriguing. However, both of the tasks used involve elements designed to create difficulty for participants. In the replanning task, participants must switch at speed from a planned utterance to an alternative. In the recitation task, participants must repeat short speech sequences at high speeds. Although both of these tasks must involve normal speech production processes it is unclear to what extent any inhibition could be attributed to the extra task-

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specific demands. However, examples of inhibitory form priming have been observed in more standard speech production tasks. Bock (1987) found that when participants produce declarative sentence descriptions of simple pictures, they placed form primed words later in the sentence and were less likely to use them at all. More recently, Sullivan and Riffel (1999) demonstrate an inhibitory effect of both onset and rhyme overlap in a picture naming task.

The present experiments

The aim of this research was to investigate form priming on spoken word production using a simple single word production task. Target words were produced in response to picture stimuli and prime words were produced in response to definitions. This paradigm has been shown to elicit facilitatory effects of repetition priming (Wheeldon & Monsell, 1994) and inhibitory effects of semantic competitor priming (Wheeldon & Monsell, 1994). Experiments 1 and 2 test for the inhibitory effect of form priming predicted by both the lexical and phonological competition models outlined above. To test for morpho/lexical level involvement in any priming, observed word form frequency was also manipulated (cf. Jescheniak & Levelt, 1994). To test for competition between mismatching segments during a left-to-right phonological encoding process (Sevald & Dell, 1994), Experiment 3 manipulated the nature of the form overlap between prime and target words as well as the presence of mismatching phonemes.

EXPERIMENT 1

The aim of this experiment was to look for an effect on word production of the prior production of a form-related word. In particular, to test if inhibitory form priming could be observed in a simple word production task involving no replanning of output or speeded recitation. The experiment used a cross-task priming methodology (Wheeldon & Monsell, 1992, 1994) in which the production of target words was elicited by pictures and prime words by definitions. The nature of the form overlap between prime and target words was similar to that found between the target and intruding words in malapropisms and TOT states: shared initial and final segments (Brown, 1991; Garnham, Shillcock, Brown, Mill, & Cutler, 1982). A second aim was to test whether any inhibition observed is a function of the frequency of occurrence of the prime words when target word frequency is kept constant. If inhibition is related to lexical level competition then a high-frequency related prime should be a stronger competitor than a low-frequency prime.

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Method

Materials. The experimental vocabulary comprised 36 pairs of phonologically related words, 28 monosyllabic word pairs and 8 disyllabic word pairs. Monosyllabic word pairs had (at least) the same initial and final phonemes and where possible differed only in the vowel (e.g., *blad-bloed*, leaf-blood). Each disyllabic pair also had (at least) the same initial and final phonemes and always had the same stress pattern (e.g., *vinger-vlinder*, finger-butterfly). One word in each pair was elicited by a picture (the target word) the other by a definition (the prime word). Two groups of 18 word pairs were constructed (see Appendix 1). Norming data for all the experimental stimuli were collected in a stimuli pretest which used the same experimental procedure described below. Twenty participants took part in the pretest, none of whom took part in the experiments described below. The groups of word pairs were matched on a number of variables (see Table 1).

Target words were matched for word frequency, number of phonemes, and number of phonemes shared with the prime word. The picture stimuli to elicit the target words were matched for naming latency, standard deviation of naming latency, and percentage error (taken from the norming experiment). The prime words in each group differed in their word frequency relative to that of their targets. In one group the frequency of all prime words was lower than the frequency of their related target (the Low prime frequency condition). In the other group the frequency of all prime words was higher than the frequency of their related targets (the High prime frequency condition). All low-frequency primes had a count per million of less than 15. All high-frequency primes had a count greater than 15. Frequency counts were taken from the CELEX Dutch lexicon comprising 42 million word tokens. The groups were matched for prime word length and the definition stimuli were matched for naming latency, standard deviation of naming latency, and percentage error rate.

TABLE 1
The two matched prime frequency groups of Experiment 1

	Log word freq.	*Median response time (ms)*	*S.D.*	*% errors*	*No. of phonemes*	*Phoneme overlap*
Low prime						
Picture target	3.1	707	145	3.6	4.5	2.6
Definition prime	1.8	1712	377	6.1	4.5	
High prime						
Picture target	2.7	716	147	4.2	4.4	2.7
Definition prime	4.0	1650	315	3.9	4.7	

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Finally, each prime frequency group was divided into two matched halves. Each half from the high-frequency prime group was recombined with one half of the low-frequency prime group to make two matched sets (see Table 2).

Design. Each target word was spoken in two conditions:

(1) Primed—following a phonologically related word.
(2) Unprimed—following a phonologically unrelated word.

Picture naming is subject to large and persistent repetition priming which could potentially drown smaller priming effects (Wheeldon & Monsell, 1992). Thus, in order to avoid repetition of pictures within participants the two matched sets detailed in Table 2 were assigned alternately to condition across participants such that each participant saw each target picture once only and that each target picture occurred in each condition an equal number of times.

The experiment consisted of seven blocks of 30 trials. Within a block, picture and definition trials alternated. Each block always began with a definition trial. The first block was a practice block containing only filler items. Blocks 2 to 7 were test blocks. Each test block contained six experimental pairs: three primed and three unprimed, three from each prime frequency set. Target pictures were assigned randomly to a position in a block with the constraint that experimental pairs never occurred consecutively. Filler pictures and definitions were assigned to the remaining trials. A high ratio of fillers to primed items was used in order to reduce participants' awareness of experimental trials and to prevent them from generating expectations about the upcoming items. Finally, the order of presentation of the experimental blocks was rotated across participants so that each target picture occurred in each condition in each block of the experiment an equal number of times.

TABLE 2
The two matched sets of items assigned alternately across participants to the primed and unprimed conditions of Experiment 1

	Log word freq.	*Median response time (ms)*	*S.D.*	*% errors*	*No. of phonemes*	*Phoneme overlap*
Set 1						
Picture target	2.8	716	160	3.9	4.4	2.4
Definition prime	2.9	1685	365	4.4	4.3	
Set 2						
Picture target	2.9	707	134	3.9	4.5	2.9
Definition prime	2.8	1661	328	5.0	4.9	

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Apparatus. The experiment was controlled by a Hermac PC. Participants' responses were recorded by a Sony DTC-55 ES DAT-recorder. An analogue voice-key registered voice onset times during word production.

Procedure. Participants were tested individually in a sound-proof booth. They were seated in front of a window through which they could see a computer screen. Participants were told that they would see definitions and pictures on the screen and that their task was to produce the most obvious single word response to these stimuli. They were asked to respond as quickly as possible without making mistakes. Participants were allowed short breaks between blocks.

Events on each trial were as follows. A visual warning signal appeared centred on the screen for 500 ms. The warning signal was different for picture and definition trials. Picture trials were cued with square brackets (i.e., [ ] and definition trials were cued with a series of dashes (i.e., ---------- ---- ---- ------- -----); 500 ms after the offset of the warning signal, a picture or definition appeared centred on the screen. Participants' response latencies were measured from the onset of the visual stimulus using a voice key. The stimulus remained on the screen until a response was made. There was a 2-s interval between trials. An experimental session lasted approximately 40 min.

Participants. Twenty-four participants were tested. They were all native Dutch speakers who were members of the Max Planck subject pool. They were paid for their participation.

Results

Exclusion of data. All correct target responses following an error trial were removed from the analysis. All data points more than two standard deviations from the mean were also removed. This procedure resulted in the loss of 9.4% of the data. Missing data points were substituted by a weighted mean based on subject and item statistics calculated following Winer (1971, pp. 488). Separate analyses were conducted with means calculated by averaging over subjects (F_1) and over items (F_2). One word, *kroon* (crown) was also removed from the analysis due to a very long unprimed naming latency and high error rate (1308 ms, 17%).

Mean naming latencies and percentage error rate are shown in Table 3. As can be seen, priming slowed picture naming latencies in both prime frequency sets. This inhibitory effect of form priming (35 ms) was significant, $F_1(1,23) = 10.2$, $p < .01$, $F_2(1,33) = 7.4$, $p < .01$. Naming

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TABLE 3
Mean naming latencies, naming durations, and percentage error rates are shown for the two prime frequency groups in the two priming conditions of Experiment 1

Condition	*Naming latencies*	*% errors*
High prime frequency		
Unprimed	769	1.8
Primed	806	2.3
Priming (unprimed-primed)	−37	−0.5
Low prime frequency		
Unprimed	737	3.4
Primed	770	4.5
Priming (unprimed-primed)	−33	−1.1

latencies for the target pictures in the high-frequency prime set were slower than in the low-frequency prime set (787.8 ms and 753.8 ms respectively). This difference was significant by subjects, $F_1(1,23) = 9.4$, $p < .01$, $F_2(1,33) = 1.2$, and can be attributed to exclusion of one slow picture (*kroon*, crown) from the low prime frequency set. The inhibitory effect of priming was similar in size for both prime frequency groups and the interaction of priming with prime word frequency was insignificant, F_1 and $F_2 < 1$. A similar analysis was carried out on percentage error rates. However, differences were small and the analysis yielded no significant effects.

During post experimental questioning, all participants stated having noticed the occurrence of similar word pairs during the course of the experiment. Interestingly, all participants thought that the effect of the form similarity had been to speed their performance. Importantly, no participant claimed to have attempted to anticipate words based on form similarity. Nevertheless, it is possible that the inhibitory effect observed is related to participants' awareness of these similarities, and builds as participants become more aware as the experiment progresses. In order to test for such an effect, an analysis was conducted which examined priming effects over the six experimental blocks. The analysis was the same as those conducted above with the addition of the variable Block (1 to 6). Mean naming latencies did not differ markedly over the six blocks and the main effect of block was not significant, $F_1(5,115) = 1.3$, $F_2 < 1$. Importantly, inhibitory priming was observed across the experimental blocks and the interaction of block and priming was not significant, F_1 and $F_2 < 1$ as were all other interactions with the variable block.

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Discussion

This experiment demonstrated that picture naming is significantly slowed by the prior production of a form-related word in response to a definition: specifically a word similar in its onset and offset sounds. This inhibitory priming effect occurs in a simple word production task that does not involve replanning or speeded recitation. On the whole, participants' responses were fast and accurate throughout the experiment and they even reported feeling assisted by the form relationships they noticed. Despite participants' awareness of the occurrence of related words, inhibitory priming was observed across all experimental blocks. The inhibitory priming effect can not therefore be attributed to strategies based on participants' growing awareness of related trials as the experiment progressed. Finally, the size of the priming effects did not vary with prime word frequency. Prime words with a higher frequency than their related targets yielded a similar amount of inhibitory priming to prime words with a lower frequency than their related targets.

This pattern of results provides strong evidence that some form of competitive process occurs during the production of spoken words related in sound form. The lack of an interaction with prime word frequency is not consistent with a lexical locus for this effect. However, it is possible that lexical competition effects may be observed when frequency is varied to affect the speed of processing of the target word rather than the prime. The selection of low frequency targets should be slower, allowing more time for any effects of competition to accrue. This possibility is tested in Experiment 2. In addition, Experiment 2 tested the persistence of the priming effect. In particular, whether inhibitory priming survives the production of an intervening unrelated word.

EXPERIMENT 2

This experiment had three aims. The first was to replicate the inhibitory effect of form priming demonstrated in Experiment 1. The second was to test the persistence of the effect. Priming was compared at two lags: with prime and target words produced on consecutive trials (lag = 0), and with one trial intervening between prime and target word productions (lag = 1). Finally, in contrast to Experiment 1, target word frequency was manipulated while holding prime word frequency constant.

Method

Materials. The experimental vocabulary comprised the same 36 pairs of phonologically related words used in Experiment 1 with some minor changes (see Appendix 2). Word pairs were now divided into two groups

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based on the frequency of the picture name. Picture names were assigned to high- and low-frequency groups according to the same criteria used in Experiment 1. The groups were again matched for a number of variables. Target words were matched for number of phonemes, and number of phonemes shared with the prime word. The picture stimuli to elicit the target words were matched for naming latency, standard deviation of naming latency, and percentage error (taken from the norming pretest). This time the prime words were also matched for word frequency (see Table 4).

For this experiment, three matched sets of 12 word pairs were constructed (see Table 5). Each group contained six high-frequency picture names and six low-frequency picture names.

TABLE 4
The two matched target frequency groups of Experiment 2

	Log word freq.	*Median response time (ms)*	*S.D.*	*% errors*	*No. of phonemes*	*Phoneme overlap*
Low target						
Picture target	2.0	710	168	3.3	4.8	2.8
Related def. prime	2.5	1711	363	4.7	4.8	
High target						
Picture target	3.7	687	122	3.3	4.2	2.5
Related def. prime	3.2	1629	316	4.4	4.4	

TABLE 5
The three matched sets of items assigned in rotation across participants to the priming conditions of Experiment 2

	Log word freq.	*Median response time (ms)*	*S.D.*	*% errors*	*No. of phonemes*	*Phoneme overlap*
Set 1						
Picture target	3.0	701	131	3.7	4.7	2.9
Related prime	2.8	1702	356	4.6	4.7	
Unrelated prime		1700	377	5.7		
Set 2						
Picture target	2.8	702	151	2.5	4.2	2.3
Related prime	3.0	1636	319	5.0	4.5	
Unrelated prime		1612	340	3.7		
Set 3						
Picture target	2.9	692	152	3.7	4.7	2.7
Definition prime	2.8	1672	344	5.4	4.6	
Unrelated prime		1647	337	3.5		

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Design. Each target word occurred in three conditions:

(1) Unprimed—following a phonologically unrelated word.
(2) Lag = 0—following a phonologically related word.
(3) Lag = 1—following an unrelated word which is preceded by a phonologically related word.

The three matched word sets were rotated round these conditions across participants. The experiment consisted of seven blocks of 30 trials. Within a block, 15 definition and 15 pictures trials occurred in a random sequence except that the first trial was always a definition and that no more than four of the same stimulus type occurred on consecutive trials. The first block was a practice block containing filler stimuli. Each of the six experimental blocks contained two target pictures from each experimental condition; one target picture from each condition was assigned to the first and second half of each block. Filler items were assigned to the remaining trials.

Procedure. The procedure was exactly the same as in Experiment 1. There were 36 participants. As in Experiment 1, they were members of the Max Planck subject pool and were paid for their participation.

Results

Exclusion of data. Data points were excluded from the analysis following the same criteria used in Experiment 1. This procedure resulted in the loss of 8% of the data. In addition, one word, *boot* (boat) was removed from the analysis due to a very high percentage error rate (30%, next highest was 14%). The mean naming latency and percentage error rate in the three priming conditions are shown in Table 6.

For the naming latencies an inhibitory effect of form priming was only observed at lag = 0. The main effect of priming was significant, $F_1(2, 70) = 17.7, p < .001$, $F_2(2, 66) = 7.6, p < .001$. Post hoc comparisons showed that only the difference between unrelated and Lag = 0 conditions was significant ($p < .001$, by subjects and items). Mean naming latencies for high-frequency targets were 700 ms compared to 742 ms for low-frequency targets. The main effect of frequency was significant by subjects and marginally significant by items, $F_1(1, 35) = 38.8, p < .001$, $F_2(1, 33) = 3.44$, $p = .07$. Although low-frequency targets yielded a numerically larger effect of priming the interaction of frequency and priming was not significant, $F_1 = 1$, $F_2 < 1$.

The effect of priming on percentage error rates was small and non-significant, F_1 and $F_2 < 1$. However, the error analysis did yield a significant effect of frequency, $F_1(1, 35) = 9.3, p < .01$, $F_2(1, 33) = 4.0, p = .05$, as mean error rates were greater for low- than for high-frequency

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TABLE 6
Mean naming latencies, naming durations, and percentage error rates are shown for the two target frequency groups in the three priming conditions of Experiment 2

Condition	*Naming latencies*	*% errors*
High target frequency		
Unprimed	694	2.1
Lag = 0	719	0.5
Lag = 1	687	0.6
Priming (unprimed-primed)		
Lag = 0	−25	1.6
Lag = 1	7	1.5
Low target frequency		
Unprimed	723	1.4
Lag = 0	777	4.7
Lag = 1	727	3.3
Priming (unprimed-primed)		
Lag = 0	−54	−3.3
Lag = 1	−4	−1.9

targets (3.1% and 1.1% respectively). There was also a significant interaction between frequency and priming, $F_1(2, 70) = 3.2$, $p < .05$, $F_2(2, 66) = 4.5$, $p < .05$, due to a significant increase in error rates for low frequency targets at Lag = 0.

In response to the post experimental questions, all participants reported noticing sound similarities in words that occurred on consecutive trials but only one participant noticed similarities between words across an unrelated intervening trial. As in Experiment 1, no participant claimed to have attempted to anticipate words during the experiment. Once again, priming effects were examined across the six blocks of the experiment. Mean reaction times did not vary greatly across the experiment and the main effect of block was not significant, F_1 and $F_2 < 1$. There was also no significant variation in the size of the priming effect as the experiment progressed, F_1 and $F_2 < 1$.

Discussion

Experiment 2 again demonstrated a significant inhibitory effect of priming the production of a picture name with the production of a form-related word. Similar to Experiment 1 the effect on naming latencies was demonstrated to be independent of word frequency, in this case the frequency of occurrence of the target word form. However, a numerically

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larger inhibition effect was observed for low-frequency targets than high-frequency targets in the latency data. In addition, low-frequency targets were significantly more error prone than high-frequency targets following related primes. Finally, the inhibitory priming effect did not survive the encoding of an intervening unrelated word. Inhibition was observed only when the production of the prime word immediately preceded the production of the target word.

Taken together, the results of Experiment 1 and 2 provide strong support for the existence of a competitive mechanism during the generation of the sound form of spoken words. Two possible loci for such a mechanism have been proposed in the literature to date: the competitive activation of lexical form representations and competition between activated segments during phonological encoding. Although a numerically larger priming effect was observed for low-frequency target pictures than for high-frequency targets, this effect did not approach significance. Significant interactions with word frequency were limited to the error data. Jescheniak and Levelt (1994) have demonstrated a persistent effect of word frequency located in the process of accessing lexical form representations. Any competitive or inhibitory mechanism operating during the retrieval of lexical form should be affected by the frequency of lexical form representation such that higher frequency representations are better able to compete with or inhibit alternative candidates. That word frequency was not observed to interact with the inhibitory priming effect argues against locating the *bulk* of the effect at the level of activation/retrieval of lexical form representations. Experiment 3 was designed to test whether the observed inhibitory priming can be better attributed to segmental competition during phonological encoding.

EXPERIMENT 3

The aim of this experiment was to test Sevald and Dell's (1994) model of competition during phonological encoding. In their syllable recitation task (see introduction) they observed that performance was inhibited when syllable sets shared initial phonemes but facilitated when final phonemes were shared. Their explanation for these results was located at the level of phonological encoding, during a left-to-right assignment of phonemes to a syllable frame. They argued that the increased activation due to shared initial phonemes leads to a miscuing of the possible syllable final phonemes that then compete for selection. For syllables sharing final phonemes to miscuing is possible and only the facilitation due to the joint activation of phonemes is observed. Experiment 3 was designed to test this theory using the single word production task used in Experiment 1 and 2. Similar to Sevald and Dell (1994), this experiment manipulated the nature of the

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phoneme overlap between prime and target words. Overlap occurred either at the beginnings or the ends of words. In addition, however, the presence or absence of mismatching phonemes was manipulated. According to the Sevald and Dell (1994) model, inhibition should be observed for prime and target words sharing initial phonemes followed by mismatching phonemes (e.g., *bloed-bloem*, blood-flower) and facilitation should be observed when words share final phonemes (e.g., *kurk-jurk*, cork-dress). However, in the absence of mismatching phonemes, facilitation should be observed regardless of the nature of the overlap (e.g., *oom-boom*, uncle-tree; *hek-hexs*, fence-witch).

Method

Materials. The vocabulary comprised 56 pairs of monosyllabic words that were semantically and associatively unrelated but were similar to each other in sound form. There were four different groups of sound form similarity comprising 14 word-pairs each. The word pairs in these groups differed in phonemes that they shared (i.e., phonemes at the beginning or end of the words) and in whether or not they contained mismatching phonemes (see Appendix 3). The word groups and picture stimuli were matched for the same variables as in previous experiments. In addition, both picture names and prime words in each group were matched on word frequency (see Table 7). Each word group was divided into two matched groups of seven pairs (see Appendix 4).

Design. Each target picture could be named in one of two priming

TABLE 7
The four matched groups of Experiment 3

	Stimulus	*Log word freq.*	*Median response time (ms)*	*S.D.*	*% errors*	*No. of phonemes*	*Phoneme overlap*
Begin overlap (*paar—paard*)	Picture	2.9	756	149	4.7	4.2	3.2
	Definition	3.4	1538	330	5.0	3.2	
Begin overlap + mismatch (*bloed—bloem*)	Picture	2.9	748	155	3.2	4.0	3.0
	Definition	3.3	1499	3341	4.0	4.1	
End overlap (*oom—boom*)	Picture	2.6	756	153	2.8	4.2	3.1
	Definition	3.5	1428	280	4.6	3.2	
End overlap + mismatch (*kurk—jukr*)	Picture	3.0	744	154	2.6	4.1	3.0
	Definition	3.7	1473	296	4.2	4.0	

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conditions: primed or unprimed. In the unprimed conditions the related prime words in each seven-word group were reassigned to picture names to form the unrelated primes. The experiment consisted of eight blocks of 24 trials of alternating pictures and definitions. The first block was a practice block. The first trial of each block was always a filler definition. Two pictures from each of the four overlap conditions were assigned to a block; one from each subgroup. For a given participant, all words from subgroup A occurred in the primed condition and all words from subgroup B occurred in the unprimed condition, or vice versa. Each block also contained four filler pictures and four filler definitions. The procedure was identical to that of Experiments 1 and 2. Twenty-eight participants took part.

Results

Exclusion of data. Exclusion of data resulted in the loss of 10.6% of the data points. Two picture names were also excluded from the analysis due to a high percentage error rate (web 21%, zwaard 19%, all others words had an error rate less than 15%). Mean naming latencies and percentage error rates in each condition are given in Table 8. As can be seen, large effects of priming were observed in the mismatch conditions only. Interestingly however, the direction of the priming effect differs depending on the nature of the phonological prime. When initial phonemes were shared inhibitory priming is observed. When final phonemes were shared facilitatory priming is observed.

An ANOVA was performed including the variables relatedness (unrelated, related), overlap (begin, end), and mismatch (with, without). Mean unrelated and related naming latencies were 779 ms and 784 ms respectively. The main effect of relatedness was not significant, F_1 and F_2

TABLE 8
Mean naming latencies and percentage errors (in parentheses) for the four priming groups of Experiment 3

Condition	*Mismatch*	*Unrelated*	*Related*	*Priming*
paar—paard				
Begin overlap	no	807 (1.1)	807 (2.5)	0 (−1.4)
bloed—bloem				
Begin overlap	yes	748 (1.4)	772 (1.8)	−24 (−0.4)
oom—boom				
End overlap	no	781 (1.8)	773 (1.8)	+8 (0.0)
kurk—jurk				
End overlap	yes	799 (0.4)	766 (2.1)	+33 (−1.7)

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< 1. The main effect of overlap (begin, 783 ms, end, 780 ms) was also nonsignificant, F_1 and $F_2 < 1$. The main effect of mismatch (with, 771 ms, without 793 ms) was significant by subjects only, $F_1(1,27) = 9.4$, $p < .01$, $F_2 < 1$. The interaction of relatedness and mismatch was insignificant, F_1 and $F_2 < 1$. However, the relatedness by overlap interaction was significant, $F_1(1,27) = 5.6$, $p < .05$, $F_2(1,50) = 4.0$, $p < .052$. The three way interaction of relatedness by overlap by priming approached significance in the subjects analysis, $F_1(1,27) = 3.9$, $p = .058$, $F_2(1,50) = 1.9$.

Planned comparisons were performed comparing related and unrelated latencies in each condition. Only the mismatch conditions yielded significant effects. In the begin overlap with mismatch condition the inhibitory effect of relatedness was significant by subjects only, $F_1(1,27) = 5.2$, $p < .05$, $F_2(1,13) = 2.8$. In the end overlap with mismatch condition the facilitatory effect of relatedness was significant, $F_1(1,27) = 8.5$, $p < .01$, $F_2(1,13) = 4.5$, $p = .053$.

Percentage error rates were small and similar analyses yielded only a significant effect of relatedness in the subjects analysis, $F_1(1,27) = 4.3$, $p < .05$, $F_2(1,13) = 3.3$.

Finally, as with Experiments 1 and 2, an analysis was conducted including the variable block order. Once again the pattern of priming effects did not vary significantly across the seven blocks of the experiment. The main effect of block was not significant and there were no significant interactions with this variable.

Discussion

In this experiment inhibitory priming was observed in one condition only when prime and target words shared initial phonemes followed by mismatching final phonemes. In addition, facilitation was observed when prime and target words shared final phonemes preceded by mismatching initial phonemes. This aspect of the data is consistent with the Sevald and Dell (1994) model of phoneme competition.

However, in the two conditions where prime words contained no phonemes that mismatched with their targets, no priming was observed. This was despite the fact that prime and target words in these conditions shared as many (indeed slightly more) phonemes than in the mismatch conditions. According to Sevald and Dell (1994) the preactivation of shared phonemes should have facilitated the phonological encoding of the target in the absence of mismatching segments. Strong claims cannot be made based on this aspect of the data as word sets were small and the three-way interaction of overlap, mismatch, and priming failed to reach significance. However, one possible explanation for the lack of priming in

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the no-mismatch conditions involves the differences in syllable structure between prime and target words. In all priming conditions, primes and targets shared phonemes. However, in addition, word pairs in the mismatch conditions shared syllable structure (e.g., CVVC). In the no mismatch condition this was not the case. Prime words necessarily contained one less segment than their targets (e.g., CVVC targets might be primed by CVV or VVC primes). One possibility is that phoneme assignment is only facilitated when a primed phoneme is reassigned to the same syllable structure. Further experimentation is necessary to isolate any contribution of frame structure to the priming effects observed here.

Finally, this pattern of results also differs from the pattern observed by Sullivan and Riffel (1999) who primed onset and rimes in a simple picture naming task. They demonstrated inhibition for both kinds of overlap although the rime inhibition was smaller than the onset inhibition and was demonstrated by a smaller number of items. They attributed their inhibitory rime priming effect to lexical competition which occurs during an initial stage of parallel phoneme activation within the lexical network (as in Dell, 1988). This is followed by a sequential selection of phonemes for phonological encoding similar to that of Sevald and Dell (1994). Further research is required to reconcile these findings with those reported above.

GENERAL DISCUSSION

The experiments reported in this article have demonstrated a robust inhibitory effect of form priming on picture naming latencies when a prime word is produced in response to a definition. This inhibition occurs when the prime word shares both onset and offset sounds with the target picture (Experiments 1 and 2). The size of the inhibitory priming effect observed is also not modified by manipulations of the frequency of prime (Experiment 1) nor the absolute frequency of the target picture name (Experiment 2). It is also a short-lived effect which disappears with the introduction of one intervening trial (Experiment 2). Finally, an examination of the respective contributions of initial and final form similarity to the inhibitory priming showed that similarity in initial segments of the prime and targets words is a necessary condition for inhibition to occur. Indeed, primes and targets with the same CVC structure and final phonemes but different onset phonemes yielded a facilitatory priming effect (Experiment 3).

The inhibitory form priming was observed in a simple word production task that involved no replanning or speeded recitation. Participants' responses to the picture stimuli were fast, accurate, and fluently articulated. Moreover, there was no evidence that the inhibition could be attributed to participant strategies as the pattern of inhibitory priming did not change as the experiments progressed. These experiments, therefore, provide strong

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evidence for the existence of an inhibitory or competitive mechanism operating during normal word form encoding processes.

In addition, these experiments provide some clues as to where the inhibitory process might be located. Two mechanisms have been proposed in the literature that would predict inhibitory form priming effects: inhibitory links between lexical representations (Stemberger, 1985) and competition between activated phonemes during phonological encoding (Peterson et al., 1989; O'Seaghdha et al., 1992; Sevald & Dell, 1994). The pattern of results reported here is more consistent with the second of these mechanisms.

As I have argued above, a model which postulates an inhibitory or competitive mechanism operating during the selection of lexical form representations would predict an interaction of inhibition with word frequency. No such interaction was observed despite a marginally significant main effect of target word frequency on picture naming latencies in Experiment 2. While it is still possible that an interaction could emerge with a stronger manipulation of target word frequency, this finding remains inconsistent with a *purely* lexical locus for the inhibition.

Another aspect of the data that seems suggestive of a later locus for the inhibition is the short-lived nature of the effect—no inhibition is observed following the production of one intervening unrelated word. Higher-level lexical effects might be expected to be more persistent than lower-level segmental effects. In particular, transient priming at the level of phonological encoding is most probably desirable. The on-line generation of phonological form requires rapid switching between different but frequently used phonemes and prosodic structures. Therefore, persistent activation of such structures would seriously inhibit rather than facilitate fluent speech production. However, no strong claims can be made based on observed transience of form priming. It is, as yet, unclear exactly what aspect of the lag between prime and targets is responsible for the dissipation of the inhibitory priming. First, there is the time lag of approximately 6 s between prime and target word productions. This lag might certainly be long enough to allow lexical activation to diminish. Second, there are the phonological processes involved in reading the intervening definition and in encoding the unrelated response word. Further experimentation is required to discover whether inhibitory priming dissipates over this time lag or whether the encoding of an unrelated word is necessary to remove the effect of a related prime.

The strongest argument against a lexical competition account of the inhibitory priming is based on the pattern of results from Experiment 3. Models of lexical competition claim that during the encoding of a word, its activated phonemes feed activation back to all words in which they occur and that these words then compete for selection. Such a mechanism cannot explain why *bloed* inhibits *bloem* but *hek* does not inhibit *heks*. This finding

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is best accounted for by Sevald and Dell's (1994) model of phoneme competition during the left-to-right association of phonemes to a word frame. According to this model, the prime word's lexical and phoneme representations remain active following its production. During the target picture naming trial, the encoding of the initial phonemes of the target leads to the miscuing of the word final phoneme of the prime, which then competes with the target final phoneme for association to the word frame. When the prime contains no phonemes that mismatch with the target, no competition can occur. The same mechanism accounts for the facilitation observed in the end overlap condition. *Kurk* facilitates the production of *jurk* because nothing follows the shared phonemes to be miscued. Instead facilitation occurs due to the priming of the shared phonemes. However, the Sevald and Dell (1994) model cannot explain why *oom* fails to facilitate boom, as these words also share phonemes and miscue no mismatching phoneme. However, these words do differ in their CVC structure. A possible explanation was offered above which involves only a small elaboration of this model. Facilitation cannot be attributed to the speeded *selection* of the target's phonemes due to prime activation. Instead, the assignment of target phonemes to a word frame is facilitated due to the encoding of the same phonemes during prime word production. If it is also the case that phonological encoding is only facilitated when a phoneme is reassigned to the same place in the *same frame structure* then no priming would be predicted in the no mismatch conditions of Experiment 3.

As mentioned in the introduction, Roelofs' (1997) WEAVER model provides no account for inhibitory form priming effects. This model was designed primarily to account for the facilitatory effects of form priming observed in the picture-word interference task (Meyer & Schriefers, 1991; Schriefers, Meyer & Levelt, 1990). Thus, a central aim of the model was to show how the activation of form-related prime words could result in the correct and speeded encoding of a target word. To do this Roelofs (1997) divorced the process of assigning phonemes to positions in a word frame from their level of activation. According to WEAVER, phonological encoding occurs following the verification of a phoneme's link to the selected morpheme. In addition, the order of assignment of phonemes to frame is determined by numbering the phoneme to morpheme links. In most models of form priming, selection of phonemes for association to frames is determined by the activation levels of the phoneme nodes (Dell, 1986, 1988; O'Seaghdha et al., 1992; Sevald & Dell, 1994). These models cannot explain the picture-word interference data as activation of alternative words leads necessarily to competition or errors in selection.

None of the models of word form encoding discussed, can account for the facilitatory effects of form overlap in the picture word interference task and the inhibitory form priming effects reported here. However,

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WEAVER does include a competitive process that could, in principle, account for inhibitory form priming effects. According to WEAVER competition occurs at the level of selection of syllable motor programs which are activated by their goodness of fit to the phonological syllables generated at the level above. Nevertheless, in its present formulation, WEAVER predicts only facilitation from form-related primes compared with unrelated primes. It remains to be seen whether a future formulation of WEAVER can model the results of both tasks with equal success. A crucial difference between these tasks may be the modality of presentation of the prime word. To date, inhibitory effects of form priming on spoken word production have only been observed when the prime words must also be produced or prepared for production (O'Seaghdha et al., 1992; Sevald & Dell, 1994). In the picture word interference task participants are required to ignore the auditorily presented distracter. It is possible that the production system is able to differentiate between activation from different sources (i.e., external or internal) or with different goals (i.e., comprehension or production). Indeed, given that we can successfully generate fluent speech whilst simultaneously comprehending the speech of others, some separation of codes must be possible. Current models of spoken word production, however, provide no mechanisms for the differentiation of activation from different sources.

A second difference between the picture-word interference task and the word production task used here involves the lag between prime and target presentation. In the picture word interference task, the prime word is presented close to or simultaneously with the presentation of the target picture. In the experiments reported above, there was a lag of 2 s between the production of the prime word and the onset of the target picture. It is possible, therefore, that differences in the time course of the activation of the prime word, rather than differences in its modality of presentation, may account for the different patterns of effects observed. Experiments are currently underway to provide answers to these questions.

In summary, this paper has provided a clear demonstration of the inhibition of spoken word production due to the prior production of a single form-related word. No current model of word form encoding provides a complete account of the pattern of results observed. However, the data are more consistent with a process of competition between phonemes during phonological encoding than with a process of competition between lexical representations.

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APPENDIX 1

Experimental vocabulary for Experiment 1.

High prime		*Low prime*	
Picture target	**Definition prime**	**Picture target**	**Definition prime**
bank (bank)	boek (book)	beer (beer)	boor (drill)
blad (leaf)	bloed (blood)	bloem (flower)	blaam (blame)
bom (bomb)	boom (tree)	boot (boat)	bord (plate)
bot (bone)	bad (bath)	bril (glasses)	bijl (axe)
bus (bus)	bos (wood/bunch)	brood (bread)	breed (broad)
fles (bottle)	vlees (meat)	kaas (cheese)	kas (greenhouse)
fluit (flute)	fruit (fruit)	kroon (crown)	kraan (tap)
hoed (hat)	hond (dog)	mes (knife)	mus (sparrow)
kaars (candle)	koers (course)	muis (mouse)	maas (corn)
schoen (shoe)	schoon (clean)	pijl (arrow)	pool (pool)
tas (bag)	thuis (home)	pijp (pipe)	piep (squeak)
vaas (vase)	vis (fish)	ster (star)	schaar (scissors)
vork (fork)	volk (people)	tent (tent)	tand (tooth)
zon (sun)	zoon (son)	voet (foot)	vet (fat)
gitaar (guitar)	gebaar (gesture)	appel (apple)	angel (angle)
kannon (cannot)	karton (carton)	kasteel (castle)	kameel (camel)
snavel (beak)	spiegel (mirror)	spijker (nail)	stekker (plug)
trompet (trompet)	tapijt (carpet)	vinger (finger)	vlinder (butterfly)

APPENDIX 2

Experimental vocabulary for Experiment 2.

High target		*Low target*	
Picture	**Definition**	**Picture**	**Definition**
bank	boek	beer	boor
boot	bord	bloem	blaam
blad	bloed	bom	boom
brood	breed	bot	bad
bril	bijl	fluit	fruit
bus	bos	kaars	koers
hoed	hond	muis	maas
kaas	kas	pijl	pool
mes	mus	vaas	vis
pijp	piep	vork	volk
tas	thuis	schoen	schoon
tent	tand	ster	schaar
fles	vlees	appel	angel
voet	vet	gitaar	gebaar
zon	zoon	kannon	karton
kasteel	kameel	schommel	spiegel
sleutel	snavel	spijker	stekker
vinger	vlinder	trompet	tapijt

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APPENDIX 3

Experimental vocabulary for Experiment 3.

Begin overlap			
Group 1		**Group 2**	
boek (book)	boe (booth)	bank (bank)	bang (afraid)
paard (horse)	paar (pair)	clown (clown)	klauw (claw)
heks (witch)	hek (fence)	hoed (hat)	hoe (how)
rits (zip)	rit (journey)	Helm (helmet)	hel (hell)
uil (owl)	ui (onion)	kast (cupboard)	kas (greenhouse)
wiel (wheel)	wie (who)	lamp (lamp)	lam (lam)
zwaard (sword)	zwaar (heavy)	wolk (cloud)	wol (wool)
Begin overlap with mismatch			
Group 1		**Group 2**	
bom (bomb)	bord (plate)	bloem (flower)	bloed (blood)
broek (trousers)	broer (brother)	glas (glass)	glad (smooth)
kam (comb)	kas (greenhouse)	harp (harp)	hard (hard)
kok (cook)	kom (bowl)	kerk (church)	kern (core)
pijp (pipe)	pijl (arrow)	tol (barrel)	tong (tongue)
schaar (scissors)	schaal (dish)	stoel (chair)	stoep (pavement)
ster (star)	step (scooter)	vlag (flag)	vlam (flame)
End overlap			
Group 1		**Group 2**	
brood (bread)	rood (red)	boom (tree)	oom (uncle)
beer (beer)	eer (honour)	fiets (bicycle)	iets (something)
draak (dragon)	raak (hit)	schaap (sheep)	aap (ape)
fles (bottle)	les (lesson)	slak (snail)	lak (varnish)
hark (rake)	ark (ark)	taart (cake)	aard (nature)
leeuw (lion)	eeuw (century)	tas (bag)	as (ash)
slang (snake)	lang (long)	web (web)	eb (eb)
End overlap with mismatch			
Group 1		**Group 2**	
bot (bone)	lot (lottery ticket)	fluit (flute)	huid (skin)
deur (door)	geur (smell)	jurk (dress)	kurk (cork)
klok (clock)	slok (gulp)	kaars (candle)	laars (boot)
muis (mouse)	huis (house)	mond (mouth)	hond (dog)
vaas (vase)	kaas (cheese)	muur (wall)	vuur (fire)
veer (spring)	weer (weather)	noot (nut)	rood (red)
voet (foot)	roet (soot)	pauw (peacock)	lauw (luke)

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APPENDIX 4

The two matched sets within the four condition groups of Experiment 3.

	Stimulus	*Log word freq.*	*Median response time (ms)*	*S.D.*	*% errors*	*No. of phonemes*	*Phoneme overlap*
Set 1							
Begin overlap (*paar—paard*)	Picture	2.8	756	152	5.2	4.3	3.3
	Definition	3.6	1540	324	2.0	3.3	
Begin overlap + mismatch (*bloed—bloem*)	Picture	2.6	752	171	3.4	3.9	2.9
	Definition	3.0	1517	339	4.7	4.0	
End overlap (*oom—boom*)	Picture	2.6	756	155	2.8	4.3	3.3
	Definition	3.6	1405	266	4.3	3.3	
End overlap + mismatch (*kurk—jukr*)	Picture	3.1	741	146	1.7	3.8	2.9
	Definition	4.1	1496	310	2.3	3.8	
Set 2							
Begin overlap (*paar—paard*)	Picture	3.0	756	145	4.2	4.1	3.1
	Definition	3.2	1538	336	7.5	3.1	
Begin overlap + mismatch (*bloed—bloem*)	Picture	3.1	744	152	2.9	4.1	3.1
	Definition	3.6	1481	343	3.3	4.1	
End overlap (*oom—boom*)	Picture	2.6	757	151	2.7	3.0	2.9
	Definition	3.4	1451	294	5.0	3.0	
End overlap + mismatch (*kurk—jukr*)	Picture	3.1	744	163	3.7	4.3	3.1
	Definition	3.2	1497	300	5.0	4.1	