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EVIDENCE OF FORM-RELATED INHIBITION IN THE PHONOLOGICAL ENCODING OF WORDS IN NORMAL SPOKEN WORD PRODUCTION

Paul ALLUM

In an experiment designed to investigate the processes involved in the phonological encoding of spoken words in normal speech production, evidence was found of form-related inhibitory processes. Such inhibition occurs when some phonological segments of a word are reused immediately in a subsequent word. It is greater than the inhibition normally found when any word is immediately preceded by another phonologically unrelated word. There is also some evidence to suggest that this effect is stronger with shared onsets than with shared offsets. This finding gives support to one of the basic findings in Wheeldon (submitted) that normal phonological encoding involves form-related inhibitory processes. It is an important finding because it challenges current models of word-form encoding. It cannot be explained by either Dell's (1986, 1988) or Roelofs' (1997; Roelofs & Meyer, 1998) models.

Key words: spoken word production, phonological encoding, form based inhibition

INTRODUCTION

Words are reconstructed every time we speak them. Models of this process envisage a hierarchy of representations from the conceptual level to the motor program level. Within this hierarchy, a semantic/syntactic abstract word representation, or lemma, which is phonologically unspecified, releases a set of specifications or instructions that enable a phonological representation to be created. This representation itself, or a modification of it, becomes the phonetic representation that allows appropriate selection of motor programs and production of the word. (See Figure 1)

The information released by the lemma is usually visualized in terms of a frame with segment slots, and a process for the retrieval of stored phonemic segments to fill them. The exact nature of either the frame or the retrieval and assignment process is not clear. The aim of this experiment is to investigate that process.

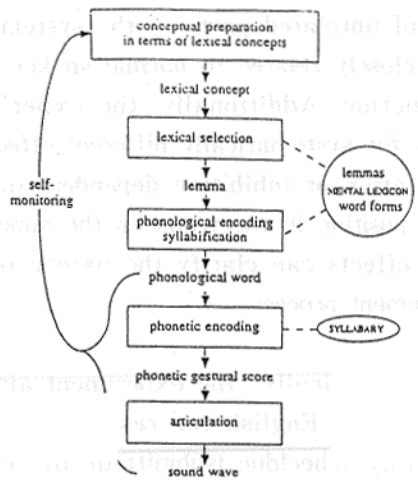

Figure 1. An Outline Model of Speech Production Taken from Levelt, & Meyer (unpublished manuscript)

The evidence of speech error data is taken to indicate that there is a process of selection from competing candidates. There is considerable experimental evidence to show that the current selection process is affected by immediate prior use of the system. These two observations have been partly accounted for by the incorporation of a process of activation into models. The effect of immediate prior use is realized through an increased level of activation that temporarily remains in the affected parts of the system. Experimentally this level is manipulated through priming.

In this experiment increased activation of specific elements through use of a phonological prime is used to investigate whether, and if so how, the segment selection process might involve inhibitory mechanisms. Such mechanisms have been posited but evidence is limited. The main question addressed here is whether prior activation of segments or plans needed in the phonological encoding of a current word can hinder the process of selection relative to prior activation of unrelated parts of the system in a task closely related to normal spoken word production. Additionally, the experiment looks for systematically different effects of facilitation or inhibition dependent on segment position in the frame in the hope that such effects can clarify the nature of the assignment process.

More specifically, the experiment aims to confirm for English the results found for Dutch by Wheeldon (submitted), by replication of part of her experiment. She found that the concept of phonological competition within a serial, left-to-right segment retrieval and assignment process proposed by Sevald and Dell (1994) was generally supported. Her conclusion was based on the finding that shared onsets for prime and target caused inhibition in the selection process while shared offsets facilitated it. Her experimental paradigm much more closely approximated normal speech production than that of Sevald and Dell (1994) or the limited number of previous experiments evidencing inhibition, and thus gave strong support for this view of segment assignation as part of normal speech production. Wheeldon's (submitted) result needs confirming because it provides a strong challenge to the two major current models of phonological encoding, those proposed by Dell (1986,88) and Roelofs (1997).

The two most clearly specified models of speech production, specific enough to be instantiated in computer models, are Dell's spreading activation model (Dell, 1986, 1988) (See Figure 2) and Roelofs' WEAVER (Word Encoding And VERification) model (Roelofs, 1997) (See Figure 3).

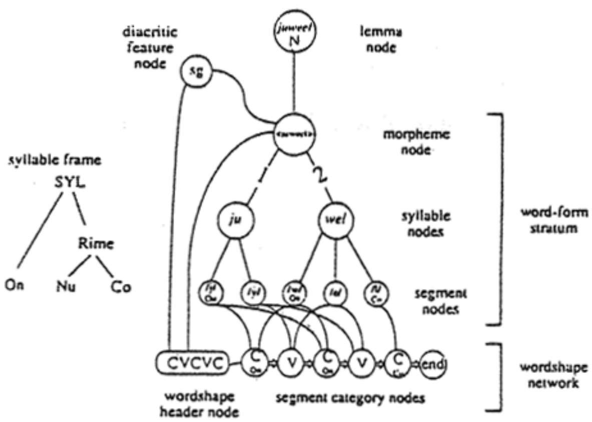

Figure 2. Dell's (1988) Model Taken from Roelofs (1997)

This latter is a refinement of Levelt's model (Levelt, 1989, 1992). The two models have been developed primarily to account for two different sets of speech production data. Dell's model can account for a considerable part of the speech error data, while Roelofs' accounts for some reaction time data, particularly for effects of facilitation.

Dell's (1986) model predicts neither facilitation nor inhibition from form-related priming in terms of reaction time. Selection of a segment is based on highest activation at a predetermined time. The most highly activated segment is chosen irrespective of the values of other segments. One segment has no connections to another, only to a higher or lower level. Neither is there any indirect way for activation of segments to influence reaction time, for example through inhibition at the lexical level.

Roelofs' (1997) model predicts facilitation from form-related primes, under specific conditions, and also predicts inhibition from unrelated primes relative to no prime. However, it does not predict inhibition from a form-related prime in relation to an unrelated prime. Neither of these two most highly-developed models of speech production predicts inhibition from form-related priming in contrast to unrelated priming during word-from encoding.

Peterson, Dell & O'Seaghdha (1989) and O' Seaghdha et al. (1992) developed a model

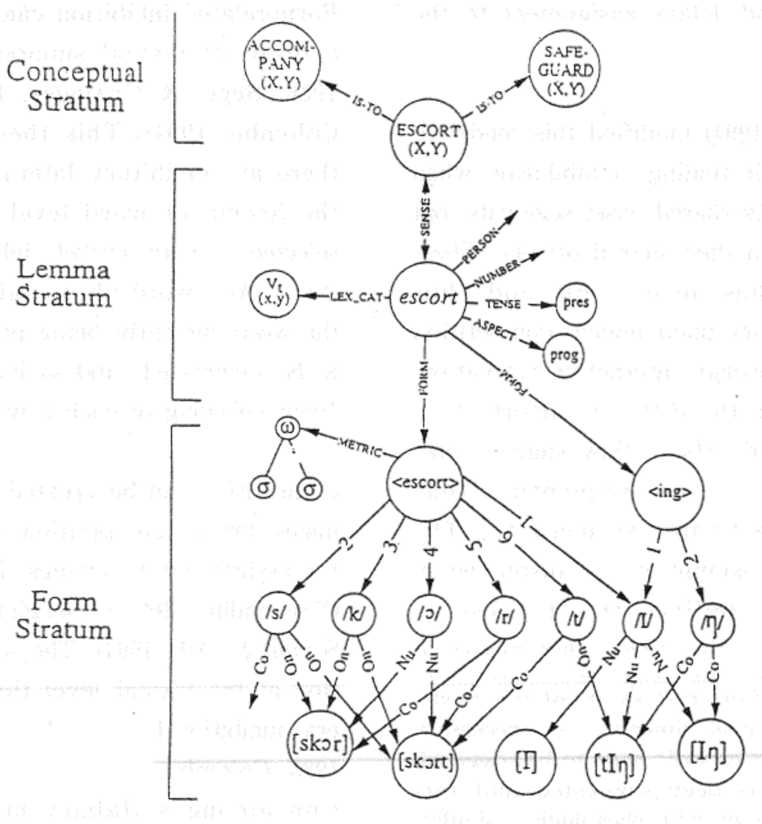

Figure 3. Roelofs (1997) Model Taken from Roelofs (1997)

that accounts for form-related inhibition for high frequency words but facilitation for low frequency words in lexical decision or naming (Colombo, 1986 ; Lupker & Williams, 1989). Facilitation occurs at the lemma level while inhibition occurs at the segmental level. Originally, this model depends on the concepts of an episodic node and phonological competition. In the event that a word similar in form (originally orthographic[1]) to the word held in the episodic memory is processed immediately after the earlier word, the episodic memory is triggered by awareness of the similarity. It then sends activation to the phonological segments in an attempt to specify itself phonologically again. This causes increased competition in the segmental selection process between the earlier and later words, and delays assignment to the frame.

Sevald & Dell (1994) modified this model to account for their finding of inhibition when repeated syllables shared onset segments, but facilitation when they shared offsets. Their modification has no episodic node but achieves inhibitory phonological competition in production through interactive activation. To account for the differential effect of shared onset and offset, they suggest that segmental retrieval is sequential, that phonemes are activated sequentially. The results of this assumption are displayed in Figure 4. They defined this process as 'sequential cuing'. This means that increased

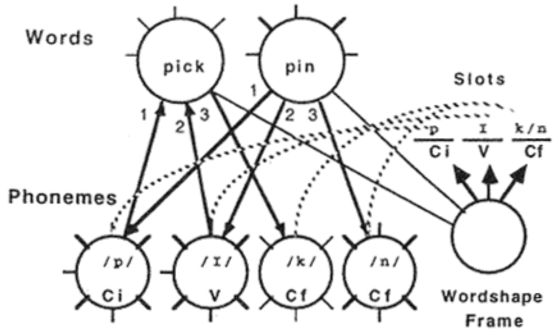

Fig. 4. Sequential cuing model. The effect of having just produced *PICK* on the production of *PIN*

Figure 4. Effects of Shared Priming
Taken from Sevald & Dell (1994)

competition occurs among the segments that follow repeated sounds thus resulting in greater inhibition for onsets. When the prime and target share the final consonant, but not the initial CIV, there is facilitation. Form-related inhibition can also be seen as a result of lexical suppression (Colombo, 1986 ; Segui & Grainger, 1990 ; Lupker & Colombo, 1994). This theory claims that there are inhibitory lateral connections at the lemma or word level. In order to be selected, a word actively inhibits all competitors. Any word phonologically related to the word currently being processed is likely to be suppressed, and so immediately subsequent encoding of such a word takes longer.

Competition can be created by three mechanisms. One is competition among phonemes for assignment to frames (Peterson, Dell & O'Seaghdha, 1989 ; O'Seaghdha et al., 1992 ; Sevald & Dell, 1994). The second is competition at the lexical level through direct lateral inhibition between lemmas (Stemberger, 1985 ; Colombo, 1986). The third is competition among syllabary motor programs (Roelofs, 1997). The first two could be trig-

[1] It is not clear from discussions of this model whether orthographic similarity is a necessary condition for the episodic node to be triggered. However, it has been suggested that this model could operate with phonological similarity as the trigger for the episodic node.)

gered by form-related priming. The first assumes interactive activation and selection of segments based on differentials in activation level. The second assumes interactive activation, inhibitory lateral connections at the lexical level, and a threshold or differential selective mechanism between lexical items. Only the modification of the first proposed by Sevald & Dell (1994) suggests differential effects for onset and offset form priming and dispenses with the need for awareness of the subject as a condition to trigger strong competition.

Inhibitory effects of form priming on speech production have been observed in picture naming (Wheeldon, submitted), in mediated picture naming (Jescheniak & Schriefers, 1998), in replanning studies (Meyer & Gordon, 1985 ; Yaniv et al., 1990 ; O'Seaghdha, Dell, Peterson & Juliano, 1992), in speeded recitation (Sevald & Dell, 1994) and in sentence production (Bock, 1987).

A wide range of paradigms are used, and it is hard to assess to what extent they represent normal speech production processes. One problem is to the unknown effects of recognition processes on production processes. (See Levelt et al. 1991 ; Jescheniak & Schriefers, 1998 ; Dell & O'Seaghdha, 1994; Zwitserloed, 1994). There is as yet no real model to account for theorized effects, and a lack of experimental evidence related specifically to this important problem. A second is the possibility of memory effects interpolating into the process and only limited use of higher level processing being involved. (e.g. Sevald & Dell ; 1994, Meyer & Gordon ; 1985). A third is possible effects of long SOA's and production preparation times with possible buffering effects. (e.g. O'Seaghdha et al. ;1992) An additional problem is that of strategy use, for example internal comparison or output editing. The longer the SOA, the more chance there is for processes other than the automatic encoding system to become involved.

Despite the above problems, overall the experiments provide considerable evidence for some kind of form-based inhibitory process in speech production. Shared onsets seem to be most strongly associated with inhibition (Wheeldon, (submitted) ; O'Seaghdha et al. (1992) ; Bock (1987) ; Sevald & Dell (1994). For onsets, the most common pattern was CiV[2] (Wheeldon, (submitted) ; O'Seaghdha et al. (1992) ; Bock (1987) and in the case of Sevald & Dell (1994) an increasing effect from Ci to CiV. Although Jescheniak & Schriefers (1998) indicate completion of phonological encoding in 300 milliseconds, Wheeldon (submitted) found an inhibitory effect at a very early SOA, over -2000 milliseconds, or Meyer & Gordon (1985) at an SOA of -4500 milliseconds, and an ISI of 2500 milliseconds. However, Wheeldon (submitted) found one intervening trial erased the strong effect she found. Thus, although form encoding is completed rapidly, the effects may remain in the production system for over 2000 milliseconds provided there is no intervening use of the system.

Facilitation has been more commonly found than inhibition in form priming experiments. Effects have been observed in the picture-

[2] Ci indicates initial consonant, while Cf indicates final consonant.

word interference paradigm using visual word primes (Posnansky & Rayner, 1978; Rayner & Posnansky, 1978 ; Rayner & Springer, 1986 ; Lupker, 1982 ; Lupker & Williams, 1989), and auditory word primes, (Schriefers, Meyer & Levelt, 1990; Meyer & Schriefers, 199 ; Zwitserloed, 1996 ; Jescheniak & Schriefers, 1998), and with definition primes (Wheeldon, submitted). They have also been found with an implicit priming paradigm (Meyer, 1990, 1991 ; Roelofs, 1997), speeded repetition (Sevald & Dell, 1994), and replanning (Meyer & Gordon, 1985; O'Seaghdha, Dell, Peterson, Juliano, 1992).

Facilitation effects are obtained with both onset and offset overlap. Onset facilitation has been found in picture naming with auditory and visual word priming, and in implicit priming. Offset facilitation has been found in picture naming with auditory, visual word and definition priming, replanning and speeded recitation. Effects are obtained at comparable SOA's in comparable paradigms to the inhibitory effects cited in the previous section..

These results of facilitation and inhibition are difficult to reconcile within current models of speech production. The results are contradictory, and there are suggestions that different paradigms may access different parts of the process (e.g. Roelofs, 1997), in which both facilitation and inhibition are involved (cf. Jescheniak & Levelt, 1998). It is also suggested that the results may derive from processes other than the automatic encoding of words, sometimes referred to as strategic effects (cf. O'Seaghdha & Marin, 1997). There is also the possibility of recognition effects confounding production effects, or the interaction not being well understood (cf. Levelt, 1991 ; O'Seaghdha et al, 1992). Finally, there seems to be a higher incidence of inhibition when the paradigm demands production of the prime compared to when it requires ignoring it.

Wheeldon's (submitted) paradigm comes closest to normal speech production. There is no recognition process of a word involved in the production of the prime or target, and a reasonable supposition that higher level processes will be used in the production of both. It's use in a semantic inhibition experiment (Wheeldon & Monsell, 1994) showed it reliably detects inhibitory effects, and perhaps because it involves higher level processes, more reliably than other paradigms. (Dell & O'Seaghdha, 1994 ; O'Seaghdha & Marin, 1997). For these reasons, it was chosen to replicate it here.

METHOD

Subjects

24 participants were tested. They were all native English speakers recruited from the students and administrative staff of Birmingham University. They all had normal or corrected-to-normal vision. They were paid £4.

Apparatus

The experiment was run using a CSL4300B Speech Lab under the control of a Dell computer. An analogue voice-key registered voice onset during word production. Subjects' responses were recorded on a Sony DAT recorder.

Material:

The experimental stimuli consisted of 48 pictures that subjects had to name. They were simple black and white line drawings based on Snodgrass & Vanderwaart (1980). The word representing the pictured object is referred to as the target. Each target was elicited in one of two basic conditions, following either a phonologically related word, or one with no phonological relationship. Spoken production of these primes, which immediately preceded the targets, was prompted by definitions. The definitions were either short well-known phrases or simple sentences, in which one word, to be spoken by the subject, was omitted, or they were short definitions such as one might find in a dictionary, to which the subject provided the defined word. (e.g. 'A head first plunge into water' for the target 'dive'). These words, when phonologically related, are referred to as related primes and when not, as unrelated primes.

Each target was paired with two primes for the two basic conditions, related and unrelated, as mentioned above. Further, two different phonologically related conditions were tested. Thus targets were sub-divided into two groups of 24. One group shared onset overlap with its related primes, the other shared offset overlap. Shared onset overlap consisted of initial consonant or consonant cluster and following vowel. Shared offset overlap was typically central vowel and final consonant or consonant cluster. Unrelated primes shared no phonemes with their targets. Examples of typical stimuli sets are shown in Table 1.

Potentially confounding variables were carefully controlled. The variables were number of syllables, semantic relatedness, naming or response latency, standard deviation of that latency, error rate, and word frequency. All items, both primes and targets were matched for number of syllables. All were monosyllables. No prime-target pair had any semantic relation. The targets of the onset and offset overlap sets were matched with each other on response latency, standard deviation of that latency, error rate, and word frequency. The four sets of primes, consisting of a related and unrelated set for both onset and offset overlap conditions, were also matched on the same basis. Both pictures and definitions had been normed for naming or response latency, standard deviation of that latency, and error rate in previous experiments. Frequency counts were taken from Francis & Kucera (1984). Such matching had to be the best possible within the limited choice of items normed for these

Table 1. Sample Stimuli Sets

Overlap	Prime Type	Prime Word - Definition	Target Word - Picture
Onset	Related	bell	bed
	Unrelated	stitch	
Offset	Related	cat	bat
	Unrelated	cup	

Table 2. Matching Variable Values for Each Condition

Overlap Set	Prime Type	Primes - Definitions				Targets - Pictures			
		%Er	Lat	SD	LgF	%Er	Lat	SD	LgF
Onset	**Related**	2.1	1533	438	3.5	1.9	672	228	3.2
	Unrelated	1.5	1542	420	3.5				
Offset	**Related**	1.7	1526	439	3.3	2.0	677	217	3.5
	Unrelated	1.5	1531	351	3.1				

Legend: %Er = percentage error rate, Lat = naming latency, SD = standard deviation of naming latency, LgF = log frequency. Lat & SD are measured in milliseconds.

variables. The average values of these criteria for the two sets are shown in Table 2.

The syllable is recognized as a basic unit of planning in phonological encoding. Words of different numbers of syllables were avoided in order to ensure that any outcomes were not a result of differing frame or plan effects, in terms of syllable or syllable constituent, between prime and target, or target and target. The single syllable word is the simplest unit, and the one least liable to confounding effects of this nature. Semantic priming effects have been found experimentally in production experiments and it is a potentially confounding variable. Frequency is a variable known to affect reaction times in word recognition tasks and production tasks. Error percentage can be seen as a measure of encoding difficulty, and is taken as such in experimental paradigms. By controlling for error rate, words of excessively different difficulty in encoding are avoided. Such difficulty could affect reaction times, and, naturally, error rates, which are a measure in this experiment. Naming latency is the central measure, and it is matched in order to avoid any effects of greater fatigue of the system in one set as compared to the other. Further, there is evidence that the size of priming effects is related to the naming latency, the longer the latency, the greater the priming effect.

Further matching was applied to the related primes and their respective targets. Their CV pattern was matched as closely as possible. In this case, the CV pattern refers to the phonological consonant-vowel pattern, not the orthographic one. For the onset overlap condition 20 out of 24 pairs matched exactly, 17 with a CVC pattern,3 with a CCVC pattern. The remaining 4 four differed by one consonant. For the offset overlap condition, 17 out of 24 pairs matched with a CVC pattern, 3 with a CV pattern and 1 with a CVCC pattern. The remaining three differed by one consonant. The overlap in either case was initial consonant(s) and vowel for onset, and vowel and final consonant(s) for offset except for the three offset CV pairs where the shared offset was the final vowel.(e.g. dive/DICE, glue/SCREW, Snail/SNAKE).

CVC pattern is a possible planning unit. Effects from the replanning of this unit were avoided, giving the effects of relatedness of segments the best chance to appear. Further, this kept the number of phonological segments equal, avoiding possible effects based on the processing of different numbers of segments.

Spoken word repetition is subject to powerful and long-lasting effects (Wheeldon & Monsell, 1992) that could obscure the weaker effects of partial overlap priming. To avoid this, and still have each target spoken in the two basic conditions, primed or unprimed, the materials were organized as follows. The stimuli for the two overlap target sets, onset and offset, were divided into two groups. Care was taken that the targets of the four overlap subsets thus created matched each other on the criteria mentioned above. Each of the targets in these four sets was paired with a related and an unrelated prime. The related and unrelated prime sets for any one of the four target subsets were matched with each other. Also the sets of related and unrelated primes for each of these subsets were matched with each other. All were matched on the criteria mentioned above. The appropriate related and unrelated primes were then alternately assigned to each of these four sets, to make two full sets of stimuli. Table 3 shows the actual values for these sets.

These sets were assigned alternately to subjects. Thus one pair of subjects provided one full target set of 48 items spoken under the two main conditions. The two sets of stimuli were made as near equivalent as possible on the criteria already discussed, thus avoiding possible differential effects of these variables. In brief, targets that were similar in key respects were processed in conditions that were similar in key respects. Because no subject saw the same target twice, repetition within subjects was avoided.

Procedures

The experiment consisted of 14 blocks of 18 trials. Within a block, definition (prime) and picture (target) items alternated. Each block began with a definition. The first two blocks were practice blocks containing only filler items. Blocks 3 to 14 were test blocks. Each test block contained 4 experimental pairs, representing each of the four conditions. The items were randomly assigned to block and position in block with the constraint that no experimental pairs appeared consecutively nor as the first item in a block. Filler pictures and definitions were assigned to the remaining trials. The use of a relatively high ratio of fillers to test

Table 3. Matching Variable Values for Balanced Stimuli Sets

Overlap	Items	Prime	Definitions				Pictures			
			%Er	Lat	SD	LgF	%Er	Lat	SD	LgF
SET 1										
Onset	12	Related	1.7	1544	349	3.4	1.7	673	222	3.5
	12	Unrelated	1.3	1526	382	3.5	2.0	671	235	2.9
Offset	12	Related	2.1	1524	408	3.1	1.8	677	198	3.5
	12	Unrelated	1.3	1540	343	3.4	2.2	677	237	3.5
SET 2										
Onset	12	Related	2.6	1522	527	3.5	2.0	671	235	2.9
	12	Unrelated	1.8	1553	458	3.6	1.7	673	222	3.5
Offset	12	Related	1.4	1528	469	3.4	2.2	677	237	3.5
	12	Unrelated	1.6	1521	359	2.8	1.8	677	198	3.5

items, and the fact that no two items of the same condition appeared in any one block, was intended to reduce subjects' awareness of patterns. The aim was to reduce the likelihood of the use of strategies that might render the results less representative of the basic system of phonological encoding. Strategic effects have been cited as possible explanations of various anomalies. The order of presentation of the blocks was rotated across subject pairs, so that each target occurred in each condition in each block of the experiment an equal number of times. This allows possible effects of prac tice or fatigue to be spread equally over items.

The experimental procedure was explained to each participant in terms of the order of events. Printed sample pictures and definitions were shown to them. They were instructed to respond as quickly as they could without making errors. The feedback displayed at the end of each block was explained. This indicated average reaction time, number of correct items and a score that combined these two. Subjects were told to try and keep the score as low as possible. The aim was to sample automatic processing devoid of strategic intervention.

Participants were tested individually in a sound-proof booth. They were seated at a comfortable distance from a computer monitor, on which the stimuli appeared, and wore a headset with earphones and a microphone. A short break was allowed between blocks and subjects could communicate via their microphone with the experimenter.

The progress of the experiment was as follows. An auditory warning signal was heard, a tone, and a visual warning signal, a large plus sign for both definitions and pictures appeared in the middle of the screen for 500 milliseconds. After the offset of the signal, a further 500 milliseconds of blank screen intervened before the appearance of the trial item. Participants' response latencies were measured from the onset of the visual stimulus using a voice key. The stimulus remained on the screen until there was a response or the trial was timed out at 5000 milliseconds. There was a 2000 millisecond interval between trials. Thus stimulus onset asynchrony was 3000 milliseconds as was inter-stimulus interval. At the end of each block, subjects saw their results in terms of average response time, number of errors and a score. One session lasted approximately 40 minutes.

Responses were monitored over earphones by the experimenter, and coded correct or otherwise. Besides wrong word responses, any item that showed effects of false starting, self-correction, or pre-onset vocal tract noise was coded wrong, as were items that were timed out. Coding was different according to the type of error.

At the end of the experiment, subjects were asked a few simple questions to ascertain whether they had been using any strategies during the procedure.

RESULTS

All correct target responses following a prime error and all incorrect target responses were removed from the data set. Outliers, targets with response times of

Table 4. Means of Naming Latencies for Each Condition

	Related	Unrelated	Priming Effect
All Items	777	751	- 26
Onset Overlap (bell/BED)	785 (5.7)	748 (4.5)	- 37 (-1.2)
Offset Overlap (cat/BAT)	768 (8.7)	754 (9.1)	- 14 (+0.4)

Note: All measurements are in milliseconds. Figures in brackets show error rates as a percentage

more than 2000 milliseconds, were also removed. The longer time would indicate processes other than those involved in first pass 'automatic' lexical access. Five items with losses in excess of 30% were removed from the analysis entirely. Targets excluded as outliers or as errors were replaced with the mean for items in that condition. Replaced items accounted for 7.4% of the original data set

Mean latencies for primed and unprimed items are given in Table 4.

Form priming slowed naming latency overall, and in each condition.
Analysis was performed through the General Linear Model with the variables relatedness (related, unrelated) and overlap (onset, offset). Relatedness approached significance by items $F2(1,41)=3.9$, $p=.053$, but not by subjects, $F1\ (1,23)=2.1$, $p=.159$[3]. Overlap was not significant by either subjects or items, F1 & F,2 $= <1$. There was no significant interaction between relatedness and overlap in either case.

[3] The lack of effect for subjects as opposed to items suggests further analysis. For example, subjects could be divided into a faster and a slower group, and results compared. Results could give support to the concept of strategy use being related to inhibitory effects, or of slower subjects being associated with inhibition more than faster subjects.

Planned comparisons were performed of the latencies of related and unrelated items in each condition. In the onset overlap condition, the inhibitory effect of relatedness was significant by items only, $F2\ (1,21)=4.6$, $p=.043$, $F1\ (1,23)=1.8$, $p=.195$. In the offset overlap condition, the inhibitory effect was not significant, F1 & F2 $= <1$.

A similar analysis was performed with the dependent variable error rate. There were no effects for relatedness or for the interaction of relatedness and overlap for either the items or subjects analysis, F1 & F2 < 1. There was an effect approaching significance for overlap by items, $F2\ (1,41)=3.9$, $p=.052$, and a significant effect for overlap in the subjects analysis, $F1(1.23)=5.2$, $p=.032$. Planned comparisons of the related and unrelated items in each condition were performed, but there were no significant results, F1 & F2 <1. Thus there was no support for the concept of inhibitory mechanisms from the error data.

During post experimental questioning, all but a few participants stated that they had noticed the occurrence of similar sounding word pairs. More had noticed similarity in rhyme than in onset. Overall, they felt such similarities had speeded performance. However, all said that they could not predict when a similar sounding word would appear, and that they had not employed any strategy to speed response to a target.

To check for effects of any building awareness of similarities, that might result in strategic effects, and to check for effects of fatigue, an analysis was performed to examine priming effects over the twelve experimental blocks. The analysis was the same as that reported above with the addition of the variable Block (1-12). Mean naming latencies did not differ significantly over the twelve blocks, and the main effect of block was not significant, F1 & F2 <1. Inhibition was observed across the experimental blocks and the interaction of block and relatedness was not significant.

DISCUSSION

The experiment gives some general support to the claim that picture naming is slowed by the prior production of a form-related word that is produced in response to a definition. The effect appears overall for words that share onset and offset sounds with a preceding word. Owing to the nature of the task, one that is closer than most other paradigms to normal word production, the notion that this effect could be occurring in normal speech also has some support. However, the results of the statistical analysis do not allow any firm claim to be made. These results lend support to Wheeldon (submitted), Experiments 1 & 2.

There is no effective support for the claim that there are opposite effects for shared onsets compared with offsets. Effects for both conditions were inhibitory. In particular, there is no evidence of facilitation from shared offsets. However, there is some support for the claim that shared onsets are more strongly associated with inhibition than offsets from the results of the planned comparisons. The inhibitory effect from shared onset was marginally significant but not that for offsets. These results do not, however, confirm Wheeldon's (submitted) key finding in Experiment 3 of a differential effect of form priming for onsets and offsets. Thus there is no clear support for Sevald & Dell's (1994) model of serial phonological encoding combined with phonological competition.

Such effects as did emerge are unlikely to be strategic in the sense that subjects could have been preparing for upcoming items. This is supported by the claims of subjects themselves and the fact that there was no effect for block as a variable. In addition, the prediction for this kind of strategy, at least from the Roelofs' model, is facilitation in the case of shared onsets (Roelofs, 1997; Roelofs & Meyer, 1998).

There is no support from the error data of inhibitory effects. There is also no evidence of a strategy involving a speed for accuracy trade-off. Error rates were relatively high and response times slow. In fact latencies to all items were considerably slower than the latencies of the normed data on which they were based. This might indicate that subjects were carefully monitoring their output albeit unsuccessfully. Another possible conclusion might be that this group of subjects found the task more difficult overall than those involved in the norming. Alternatively it may have reflected a strategy use different from that mentioned in the previous paragraph. This possibility is discussed below.

The results found here could be explained by Stemberger's (1985) model. The inhibitory effect would be a result of competition at the lexical level. The target's lemma would have been suppressed by lateral inhibition from the prime's lemma, and therefore take longer to become reactivated and become an effective competitor. However, this explanation could not account for the fact that shared offsets did not produce as much inhibition as onsets in this experiment. The degree of overlap for onsets and offsets was equal. Much less could it account for Wheeldon's (submitted) finding of facilitation for shared offsets. Further, Wheeldon (ibid.) found no significant interaction between inhibition and word frequency in her experiment, which tested specifically for word frequency effects. Her finding appears to indicate lack of lexical involvement in the inhibitory process.

It would be difficult for the effects to be explained by the phonological competition model proposed by O'Seaghdha et al. (1992). They originally claim that inhibitory effects depend on the combination of four factors, subject awareness, an episodic node, remaining activation and word frequency (cf. O' Seaghdha & Marin, 1997). The assumption is that the speed of processing of the target, which depends on word frequency, is related to the triggering or otherwise of the episodic node. This assumption could work for paradigms in which a distractor is produced very close to or simultaneously with the target. However, it would be unlikely to account for effects at the longer stimulus onset asychronies used in the current experiment. If the assumption of the speed of processing and its relation with triggering of the episodic node are put aside, then this model could account for the effects seen here. This would allow such effects for words of any frequency that had been recently spoken and remained in memory in the episodic node. It would, however, require the model to find another account for differences in effects for high and low frequency words. The triggering of the episodic node could be accounted for by awareness. This does seem possible particularly under experimental conditions and given the comments of subjects. This process has been described as 'backward priming' (Peterson & Savoy, 1998). The suggestion is that some kind of comparative strategy is put into effect. The process of comparison between the item being currently processed and the target may cause reactivation of the prime via the episodic node, as suggested above (cf. O' Seaghdha et al. 1992). However, it may also be that the process of comparison alone slows down reaction irrespective of the concept of an episodic node. Zwitserloed (1996) has suggested that checking for congruency may be a cause of inhibition. Support for some kind of comparative process comes from masking experiments in which facilitation is observed for a masked condition where inhibition is observed in the unmasked condition (e.g. Peterson at al., 1996 (in O'Seaghdha & Marin). It also comes from results with mediated priming experiments, where the effect of mediation is considered equivalent to masking (cf. O'Seaghdha & Marin, 1997; Peterson & Savoy, 1998). The assumption is that where there is no awareness of the prime, there can be no comparative process. There is clear evidence that internal checking of the process of encoding exists (e.g. Wheeldon & Levelt, 1995; Baars et al. 1975; Motley et al., 1982). Thus, although the lack of effect for block appears to indicate lack of a strategy such as that suggested by Roelofs (1997) to account for the results of Bock's (1986, 1987) implicit priming experiments, it is possible that similarity triggers some kind of strategy such as those suggested above. The triggering of such strategies may be dependent on the context in which the word is produced, and thus results vary according to the experimental paradigm.

As mentioned, the results of this experiment do not support the sequential cuing model, itself an adaptation of the model proposed by O'Seaghdha et al. (1992).
However, if the concept of serial activation of segments is abandoned, their model could account for the results from the current experiment. For example, the system of parallel activation and selection of segments for each syllable proposed by Dell (1986, 1988) could be incorporated with a competitive selection mechanism, an idea already suggested by Dell (1988) and Meyer (1990), but without the use of timing to decide the moment of selection. The model would then become sensitive in terms of response time to priming. This would still presumably require the storing of segments that are position specific. With the 'bounce-back' effects of interactive activation, the model would predict slowing down of performance when any competition between segments was hard to solve. This would be the case if differential in activation levels were the criterion for selection of one segment over another.

It would be hard to adapt Roelofs' (1997) model to account for inhibitory effects of onset related primes. He has already indicated that shared onsets would lead to facilitation as evidenced in Bock (1986, 1987) provided the number of syllables and stress were the same for prime and target as was the case in this experiment. There is competition at the level of selection of the motor syllabary programs, but, as previously dis cussed, the currently employed system, Luce's choice rule, does not predict inhibition for form-related priming. Roelofs has suggested that the lack of typical speech errors in experimental data, where one might expect a high incidence, argues against models such as Dell's (1986, 1988). However, this leaves mistaken selection of whole motor syllable programs as the only mechanism to explain speech error data. The reduction of the role of activation in accounting for phonological encoding in the WEAVER model allows it to predict facilitory results well. However, it is strongly challenged by inhibitory results of form priming such as those found here and in Wheeldon (submitted).

As discussed earlier, there are suggestions that inhibitory effects may be effects of strategy rather than effects of the basic system. While masking, speeded recitation and replanning are ways of trying to rule out such effects, they also mean the use of paradigms that are further removed from normal use of the production system, and thus those results also become suspect as possible paradigmatic artifacts. The current paradigm has the advantage of being closer to normal production. However, there is room for strategy use. One possible way to improve the chances of getting results that closely reflect the basic, automated system of phonological encoding could be to reduce the stimulus onset asynchrony, which was rather long in this experiment. As mentioned before, phonological encoding is assumed to be completed within 300 milliseconds of stimulus onset in the case of picture naming (e.g. O'Seaghdha &. Marin, 1997). The decay rate of any remaining activation from the prime is not clear, but we may assume that the shorter the inter-stimulus interval, the stronger any effect would likely be, and the less chance of interference from other factors. It would, given the significance of a reliable inhibitory effect for the two major models of speech production, be worth repeating the experiment with this modification.

In conclusion, currently, it is not possible to account for the differential effects of facilitation and inhibition evidenced in form-priming experiments. This experiment gave support to the idea that inhibitory processes are involved in phonological encoding in normal spoken word production. However, it failed to produce strong and clear results to support Sevald & Dell (1994), and failed to replicate all the results of Wheeldon (submitted). It only suggested that phonologically similar onsets are closely associated with inhibition. Nevertheless, the results challenge the two most highly developed models of speech production. Neither of them can account for this effect in their current forms.

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