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PHONOLOGICAL PRIMING IN WORD PRODUCTION

By

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ABSTRACT

PHONOLOGICAL PRIMING IN WORD PRODUCTION

By

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During the course of word production, the forms of words must be assembled. This research examined the mechanisms at the level of phonological encoding in four phonologically primed picture naming experiments. Reliable inhibition was found in Experiment 1, which required the pronunciation of visually presented primes before the naming of target pictures. The remaining three experiments included the absolute frequency of the picture names as a factor. The primes were presented auditorily in Experiment 2 and visually in Experiment 3, but were not pronounced in either experiments. In Experiment 4, the primes were auditorily presented and pronounced. No effects of phonological relatedness were found in the last three experiments. It is argued that the variable findings suggest phonological priming is not a robust phenomenon in word production when frequency and prime presentation are carefully controlled and that the unreliable effects may be a consequence of the word production architecture.

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CHAPTER I
INTRODUCTION

An average adult speaker makes a correct choice of a word from amongst 30,000 known words about two to five times per second (Levelt, 1989). Despite this rapidity, production processes are surprisingly accurate. An examination of the estimated error rates from two recorded corpora of spontaneous speech (Deese, 1984; Garnham, Shillcock, Brown, Mill, and Cutler, 1982) shows the average occurrence of word errors to be 3.8 per 10,000 words. Clearly word production is a result of highly efficient selection mechanisms. The research reported below was designed to explore some of the features of these mechanisms.

Much of what we know about word production comes from its occasional disruptions. The problems are sometimes manifested as tip-of-the-tongue (TOT) experiences and outright errors. In a TOT state one has the feeling of knowing the intended word, but the form of it is only partially available. In a study by Brown and McNeill (1966) subjects sometimes experienced TOT states when given definitions of fairly obscure words. For example, the definition for the target word 'sextant' was

> a navigational instrument used in measuring angular distances, especially the altitude of sun, moon, and stars at sea.

It was found that subjects who experienced TOT states would often correctly recall the initial segment of the target word as well as the number of syllables and the stress pattern. Furthermore, sound related words (e.g., secant) as well as meaning related words (e.g., compass) came to mind.

The characteristics of the erroneous retrievals in the TOT states are also pervasive in certain overt word errors. Word errors include blends (e.g., taxi/cab--> tab), exchanges (e.g., the sun is in the sky--> the sky is in the sun) and substitutions (e.g., close the door--> open the door). In particular, substitution errors can result in a word that is either related in meaning, sound or both to an intended word (Dell and Reich , 1981). Sound related word substitutions are often referred to as malapropisms. Reminiscent of the TOT partial retrieval, a malapropism tends to have the same number syllables, initial segment, and stress pattern as the intended word. Fay and Cutler (1977) were the first to analyze this type of error and their examples include "week" for "work" and "constructed" for "corrected".

Analyses of TOT states and overt errors have been used to inform accounts of word retrieval in production. These analyses (Garrett, 1980; Dell, 1986; Bock, 1987b; Levelt, 1989) suggest that there are at least two types of representation for lexical items. One is the meaning representation and another is the form representation. In Levelt's (1989) blueprint for the course of production, a first level encodes the meanings and grammatical relations (i.e., subject, verb, object) of lexical items. The abstract representations of lexical items at this level have been referred to as lemmas (Kempen and Hujibers, 1983). A second level encodes the phonological representations of the word forms, or lexemes. From these phonetic programs may be created to guide articulation.

The experiments reported below focus on the level of phonological encoding. In the domain of speech production, there are two contrasting models of phonological encoding. The following section reviews these models.

Models of Phonological Encoding

The model proposed by Shattuck-Hufnagel (1979, 1987) is intended to account for the major types of sound errors. The model, in common with all accounts of phonological encoding, claims that a word form is not retrieved as a whole; rather, the individual phoneme segments must be retrieved and ordered. Support for individual phonemes as processing units comes in part from the observation that speech errors involving the movement of individual phonemes are extremely common in error corpora. In Nooteboom's (1969) analysis of sound errors, 89% involved single phonemes compared to 7% involving consonant clusters and 4% involving other types. The fact that errors often result in misordered segments suggests that there is a mechanism that is responsible for the ordering of segments.

The slots-and-fillers model, proposed by Shattuck-Hufnagel, incorporates a serial ordering mechanism that operates on individual phoneme segments. The encoding process in this model begins with the retrieval of the word forms or lexemes from the lexicon for one planning cycle (e.g., a phrase). These lexemes make available token representations of their constituent phoneme segments which are held in a short term buffer. A set of lexical frames also becomes available. The frames contain ordered slots in which segments are inserted by a serial-ordering mechanism. Shattuck-Hufnagel also proposes a monitoring mechanism that is responsible for eliminating segments from the candidate set once they have been selected for a slot in a frame. According to Shattuck-Hufnagel the major types of sound errors are a result of the malfunctioning of the serial-ordering mechanism, the monitoring mechanism or both.

A malfunction of the serial-ordering mechanism results in a misselection between candidate segments for a specific position. This claim is based on a categorical constraint exhibited by sound errors such that initial consonants interact with other initial consonants, vowels interact with other vowels and final consonants interact with other final consonants. It is also assumed that the intrinsic similarity (i.e., the sharing of phonetic features) of two interacting sounds enhances the likelihood of their misselection. This assumption simply describes the tendency of sound errors to share phonetic features more often than chance would predict (Shattuck-Hufnagel, 1987).

Both anticipatory and perseveratory error types are a result of a misselection by the ordering mechanism as well as a failure of the monitoring mechanism. For example, in the anticipatory error "reading list-->leading list" the ordering mechanism misselected the initial /l/ of "list" for the initial slot of the first word frame. The monitoring mechanism then failed to eliminate the selected /l/

segment from the candidate set. Thus, it was available to be correctly reselected for the initial position of the second word frame. In the perserveratory error, "beef noodle-->beef needle", the monitoring mechanism failed to eliminate the vowel /i/ from the candidate set after it had been correctly selected for the first word frame. Thus, it remained available in the candidate set for the ordering mechanism to misselect it for the second word frame.

Contrasting with the accounts of anticipatory and perseveratory errors, is the explanation for an exchange error, e.g., "york library-->lork yibrary" . Such errors result from only the malfunctioning of the ordering mechanism. In this example, the ordering mechanism misselectected the initial consonant /l/ for the initial slot of the first word frame; then, the monitoring mechanism eliminated it from the candidate set. Thus the /l/ was unavailable for selection for its correct slot position. However, the initial consonant /y/ was still among the candidate set and it was selected by default for the initial slot of the second word frame.

Based on these error accounts, the slots-and -fillers model makes predictions for the relative incidence of the types of errors that seem to be inconsistent with the actual proportions in error corpora. Specifically, since both anticipatory and perseveratory errors are a result of the malfunction of the same two mechanisms both types should be equal in proportion in error corpora. Additionally, since exchange errors result from the malfunction of only one mechanism, they should be greater in proportion than anticipatory errors. However, the examination of various error corpora shows a predominance of anticipatory sound errors over perseveratory sound errors and both of these types predominate over sound exchange errors. This pattern of predominance is found in error corpora including the MIT corpus (Shattuck-Hufnagel, 1987), the tabulation of Dutch errors by Nooteboom (1973), and the tabulation of the Meringer corpus by Nooteboom (1980).

Furthermore, the slots-and-fillers model fails to provide an explicit account for some of its fundamental assumptions. In particular, there is no account for the basis of lexical selection throughout the stages of the model from the retrieval of lexemes to the selection of segments by the ordering mechanism. Additionally, there is no account of how the lexemes make available a candidate set of token segments. Finally, though the assumption that misselection occurs between two similar segments is consistent with sound error observations, there is no explanation within the model for this assumption.

A model, proposed by Dell (1986), extends Shattuck-Hufnagel's model but provides a sufficiently detailed account of phonological encoding to allow for predictions concerning effects at this level on lexical selection. The model is intended to offer an explicit account for the constraints and tendencies exhibited by sound errors, so the relative incidence of error-types predicted is consistent with the actual proportions found in error corpora.

Dell's model incorporates the mechanism of spreading activation. It contains a lexical network of interconnected levels of word representation and a hierarchical arrangement of structural frames that correspond to each of the levels of word representation. The highest level of word representation contains word nodes (e.g., lemmas) which connect to constituent morpheme nodes at the next level. The morpheme nodes in turn connect to their constituent phoneme nodes and the phoneme nodes connect to their feature nodes.

All connections in the lexical network are between levels and allow for a bidirectional flow of excitatory activation. Unlike the token representations in the slots-and-fillers model, the representations of word forms in Dell's model are of a single type. That is, two morphemes such as "some" and "sink" that have the same initial segment will both activate the same one node representing an initial /s/. The feedback of activation between the levels of shared nodes results in a neighborhood or candidate set of primed nodes at each level. The neighborhood of nodes compete via their activation levels for insertion into the slots in the frames at the corresponding levels. Figure 1 depicts the flow of activation for the production of the utterance, "Some swimmers sink".

The flow of activation is initiated by signalling activation, which tags a node as current. This is depicted by the flag marked "c" in Figure 1. Signalling activation increases the node's level of activation above resting level. The resting level of a word node is assumed to reflect its frequency of occurrence such that a high frequency word has a higher resting level than a low frequency word. In Figure 1, the word node categories are quantifier, noun, verb, and plural marker.

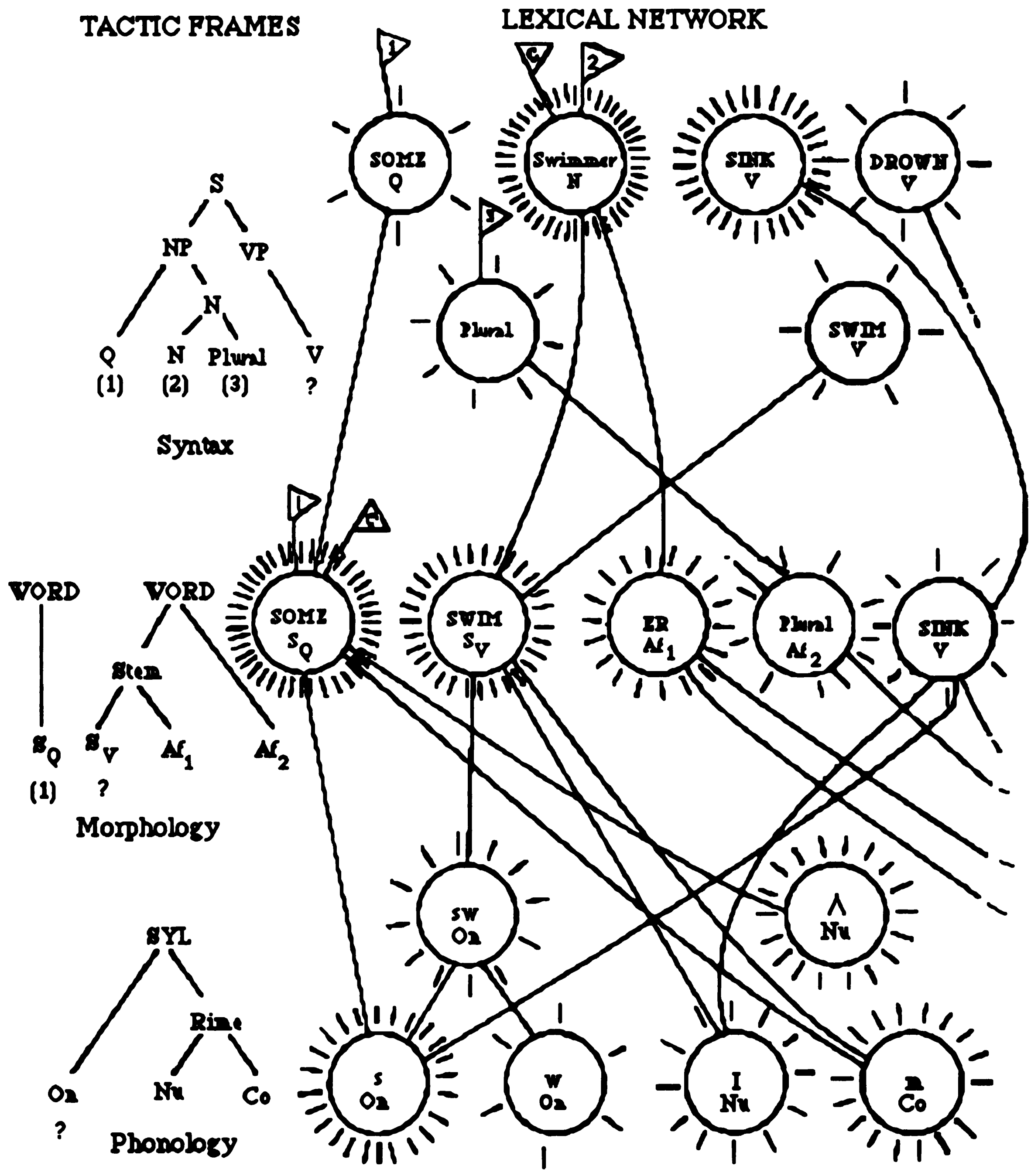

Figure 1. Dell's (1986) production model.

Phonological encoding begins at the morpheme level where word frames are generated containing slots that are marked for the categories of stems and affixes. At the phoneme level a syllable frame is generated that contains slots marked for sound categories such as onset, nucleus and coda. In addition to the slots in the frames at each level being marked categorically, it is assumed that the nodes at each level are marked with respect to their categorical membership. An insertion rule accounts for the categorical constraint exhibited by errors. It does this by selecting only the highest activated node of the candidate set that corresponds to the category of the slot in a frame that is being filled. The numbered flags in Figure 1 indicate the position the node has in the frame it will be inserted at a particular level.

Once a node has been selected, its activation level is reduced to zero. This "check off" mechanism is similar to the slots-and-fillers model's monitoring mechanism and is assumed to prevent unwanted reselection. However, the activation levels of the checked-off nodes will rebound due to the reverberating activation between the levels. Since the selected nodes are assumed to be always checked-off and then rebound in activation, Dell's account for the major types of sound errors differs from that in the slots-and-fillers model.

The reverberating activation and simultaneous processing at each level of representation will create variability in activation levels. This variability will occasionally result in an unintended node having an activation level that is higher than an intended node at the time of selection. An anticipatory error (e.g., reading list--> leading list) results when an upcoming segment is more activated than an intended segment. A perseveratory error (e.g., beef noodle--

>beef needle) results when a segment that has already been correctly selected and checked-off rebounds to an activation level higher than an intended segment. An exchange error (e.g., york library-->lork yibrary) begins as an anticipatory error where there is a misselection of an upcoming segment. Another misselection then occurs resulting in the filling of a slot by a segment from a previous word that is no longer current. Thus, Dell's model predicts the relative incidence of exchange errors to be less than that of anticipatory errors because the latter involve just one misselection whereas exchange errors involve two misselections. This prediction is more consistent with the actual proportions of error types in various corpora than the slots-and-fillers model.

The explicit account of phonological encoding in Dell's model not only expands upon the slots-and-fillers model but it also allows for more precise predictions concerning the mechanisms of selection at the level of phonological encoding. In particular, the model assumes that the phonological encoding of a stimulus word will create a neighborhood of activated words that share activated phonological segments. For example, the production of the word "cap" will have boosted the activation level of the related word "cat" via the shared segments /c/ and /æ /. If there is a subsequent need to produce the phonologically related word, "cat", it should be facilitated. This raises questions about the occurrence of phonological priming. Is the production of a target word that is phonologically related to a preceding prime word facilitated relative to the production of a target word that is preceded by a phonologically unrelated prime word?

Studies of Phonological Priming

Research that may be relevant to issues of phonological priming has been carried out in studies of visual word recognition. To interpret the results of these studies within the domain of production, one might assume that the activation of orthographically related words results in the activation of phonological representations which are called upon in speaking. Some support for this assumption has been found in a lexical decision task (Meyer, Schvaneveldt and Ruddy, 1974) and in a Stroop task (Tanenhaus, Flannigan and Seidenberg, 1980). Furthermore, as will be discussed below, two recently proposed models of form-related priming (Lukatela and Turvey, 1990; Peterson, O'Seaghda, and Dell, 1990) claim that activated phonological representations play a crucial role in determining the occurrence and types of priming effects. Discovering the types of form-related priming effects has not been a straightforward matter, in part because these effects have been shown to be both facilitatory and inhibitory.

Nonsignificant facilitation for rhyming prime-target word pairs has been found in lexical decision studies (Meyer, Schevaneveldt and Ruddy, 1974; McNamara and Healy, 1988). Hillinger (1980), also employing a lexical decision task, found significant facilitation relative to unrelated controls for auditorily and visually presented primes that were either orthographically and phonologically related with visually presented targets (e.g., LATE - MATE), or only phonologically related (e.g., EIGHT-MATE) with the targets. However, Martin and Jensen (1988) failed to replicate Hillinger's findings for the visually presented prime-target pairs. Jakimik, Cole and Rudnicky (1985) found facilitation in a spoken lexical decision task only when the prime and target words were related both phonologically and orthographically. However, Jakimik et al. could not rule out the possibility that the effects were due to strategies.

A study by Colombo (1986) demonstrated both form-related facilitation and inhibition. She employed a lexical decision task with visually presented prime-target pairs that were either both orthographically and phonologically related (i.e., rhyme pairs) or completely unrelated. Relative to unrelated controls, recognition times were faster for related targets that were low in absolute frequency, but slower for related targets that were high in absolute frequency.

A lexical decision study by Segui and Grainger (1990, Experiment 1) indicates that form-related inhibition is due to the relative frequency of the prime and target word pairs rather than the absolute frequency of the target alone. The prime-target pairs consisted of orthographically related and unrelated primes that were either higher or lower in frequency than their following targets. The results showed a significant inhibitory effect of 32 milliseconds for related targets relative to unrelated targets when they were preceded by primes that were lower in frequency. There was an insignificant facilitatory trend of 15 milliseconds for related targets relative to unrelated targets when they were preceded by higher frequency primes. The results of this experiment were replicated with stimuli that included targets restricted to the medium absolute frequency range, thereby offering additional support for the claim that it is the relative frequency of the related prime-target pair that determines the occurrence of inhibition and not the absolute frequency of the target.

Tasks involving the pronunciation of target words, which may be more directly relevant to the mechanisms of production, have also demonstrated mixed results of form-related priming. A study by Bowles and Poon (1985) required subjects to read aloud a prime word; then a definition for a target word was displayed. Subjects responded with the target word as quickly as possible. The results showed that subjects responded with the target name reliably faster as well as more accurately after an orthographically and phonologically related prime word than after an unrelated prime word. In a similar task employed by Brown (1979) correct target retrieval was found to be more likely following an orthographically and phonologically related prime relative to an unrelated prime. However, Brown's effect was not significant.

Facilitation in the form of reduced interference in Stroop-like picture naming tasks has been found for form-related word-picture pairs (Lupker, 1982; Schriefers, Meyer and Levelt, 1989). Schriefers, Meyer and Levelt (1989) required subjects to listen to words while they named pictures. On critical trials, a word was presented either simultaneously with the onset of the picture presentation (i.e., 0 millisecond stimulus onset asynchrony) or shortly after the picture onset (i.e, 150 millisecond stimulus onset asynchrony). The results showed that words interfered with the naming of the pictures at both SOA's. However, when the words were phonologically related to the picture name there was less interference than when they were unrelated to the picture name. Schriefers et al. argued that relative to the unrelated interfering word condition, the shared phonological segments of the related interfering word allowed for faster retrieval of the target picture's phonological representation during the naming process.

Phonological facilitation was also found by Meyer (1990) utilizing an implicit priming paradigm. Subjects learned word pairs that consisted of a prompt and target that were associatively related (e.g., flame-candle). Upon presentation of the prompt word, subjects produced the corresponding target word. In one condition, five successively produced target words shared the same initial syllable (e.g., production of the target "candle" in response to the prompt "flame" followed by production of the target "canter" in response to the prompt "trot", etc.), In a second condition, the target responses were not phonologically related (e.g., the prompt-target pair "flame"-"candle" followed by the pair "bank"-"money" etc.). The results demonstrated faster response times for successive targets that shared the same initial syllable (i.e., phonologically related) than for successive phonologically unrelated targets. However, despite the facilitation in the response times, there was a greater occurrence of errors in the phonologically related condition than in the unrelated condition.

Evidence for phonological inhibition in a pronunciation task was found in a study by Peterson, O'Seaghda and Dell (1989) in which they replicated Colombo's inhibitory and facilitatory findings.

Prime words were presented for 500 milliseconds, after which subjects named form-related or unrelated target words. The related primes were multisyllabic and shared two or more phonological segments with the targets. Both the inhibition for high frequency related targets and facilitation for low frequency related targets were significant. Thus, the effects demonstrated by Colombo's study are not particular to the lexical decision task.

Additional evidence demonstrating that the phonological representation of a prime word can inhibit the subsequent retrieval of a related target word for production comes from a study by Bock (1987a, Experiment 2). In this study, subjects heard and repeated aloud a prime word that was phonologically related to one of two target words that were elicited by objects in a subsequently displayed picture. Upon presentation of the picture, subjects were to name aloud any two objects that were depicted. For example, a subject repeated a prime word such as MAT which was followed by a picture of a man being stung by a bee. The subject would then respond by saying, "man, bee" or "bee, man". The results showed a significant tendency for subjects to respond with the phonologically primed target after the unprimed target. Thus, in the above example, subjects were more likely to respond with "bee, man" than "man, bee" after repeating the prime word "MAT". Furthermore, in responses containing only one of the target words, more included the unprimed target word than the primed target word. These results have been replicated by Meyer and Bock (1988) with different pictures and primes, in a different language (Dutch). Meyer and Bock also found that the onset of the production of primed words was delayed relative to that of unprimed words.

Thus, the results of form-related priming studies involving lexical decision and pronunciation tasks have not been uniformily facilitatory, but often suggest a mechanism of inhibition. Furthermore, the results of Bock's study suggest that an inhibitory mechanism may operate during free production as well.

Such a mechanism might operate within a level of competing lexical representations that are phonologically related. This mechanism could aid the selection of a word-unit from competing neighbors during the recognition process, accounting for the inhibitory effects of form-related priming (e.g., McClelland and Rumelhart, 1981; Rumelhart and McClelland, 1982). Dell's production model does not contain an intralevel inhibitory mechanism because the activation levels of nodes within a neighborhood do not increase from the continued bottom-up input of a stimulus but rather from the top-down signalling activation that results in a particular node becoming 'current' during the encoding of an utterance. When a particular node is tagged as current its activation level becomes significantly higher than competing nodes of the same category. Therefore, the process of nodes becoming 'current' allows for the correct selection from a competing neighborhood without the need for an intralevel inhibitory mechanism. However, suppose that phonological priming in a production task were to yield inhibitory findings similar to the form-priming results found in recognition and pronunciation tasks. If so, then perhaps an intra-word-level inhibitory mechanism that is proposed to operate during word recognition and pronunciation operates during production as well.

Inhibitory Mechanisms in Models of Form-priming Effects

Colombo's findings of inhibition for high frequency form-related targets led her to explain the results in terms of McClelland and Rumelhart's (1981; Rumelhart and McClelland, 1982) interactive-activation model of word recognition. Similar to the networking in Dell's model, the McClelland and Rumelhart model contains bidirectional excitatory connections between sublexical and lexical levels of representations. However, unlike Dell's model, the selection of a word from its activated neighborhood is accomplished by mutual inhibition within the neighborhood of competing forms (i.e., orthographically related forms). Additionally, there are inhibitory connections from the sublexical nodes to the higher word nodes that do not contain them. These inhibitory connections also aid in keeping the overall activation levels of the neighborhood nodes from exceeding the activation level of the correct stimulus word node.

Although McClelland and Rumelhart's mechanism of mutual inhibition at the word level offers a means to explain form-related inhibition for high frequency targets, Colombo's findings of low frequency target facilitation led her to refine the mechanism so that it did not operate on all neighboring nodes during the selection process. Instead Colombo made the ad hoc proposal that there was a threshold level of activation which high frequency words were likely to reach resulting in their being inhibited. Segui and Grainger made additional refinements on the inhibitory mechanism at the word level based on their findings of a relative prime-target frequency and form-related interaction. They suggest the intra-word-level inhibitory mechanism operates only on the neighboring nodes which are most competitive with the correct stimulus node; specifically those neighboring nodes that are higher in frequency than the correct stimulus node.

Both Colombo and Segui and Grainger attributed the form-related effects of facilitation and inhibition to the orthographic relationships between the prime and targets. Recently two alternative models have been proposed which attribute the form-related findings from lexical decision and word pronunciation studies to activated phonological representations. The first model, proposed by Peterson, O'Seaghda and Dell (1989) does not include an inhibitory mechansim; rather inhibitory effects are claimed to be a result of competition at a sublexical phonemic level. The second model, proposed by Lukatela and Turvey (1990), maintains an intra-word-level inhibitory mechanism. However, the mechanism operates within a neighborhood of phonologically related word representations rather than related orthographic representations.

The Phonological Competition Model

Peterson, Dell, and O'Seaghda's (1989) phonological competition model relies heavily upon the assumptions incorporated in Dell's (1986) production model as well as aspects of the McClelland and Rumelhart model (1981).

As shown in Figure 2 below, the phonological competition model contains three distinct levels: phoneme, letter and word. There are bidirectional excitatory connections between the letter and word levels as well as between the phonological and word levels. The only inhibitory connections in this model are from the letter nodes to the word nodes that do not contain them (represented as lines terminating in a dot in Figure 2); there are no inhibitory connections within the levels of representations. A visually presented stimulus word will initiate the spread of activation from the letter to the word level. This will result in an activated orthographic neighborhood at the word level. The inhibitory connections from the letters to the word nodes that do not contain them keep the activated orthographic neighbors from achieving the same level of activation as the correct stimulus word node.

Each word node is connected to a word frame. The word frame represents the pattern of phoneme categories for the word, e.g., initial consonant (ci), vowel (v) and final consonant (cf) for a three letter word such as 'cat'. When a word node reaches maximum activation its word frame selects the most highly activated phoneme nodes consistent with the categories of the slots thereby establishing the phonological representation.

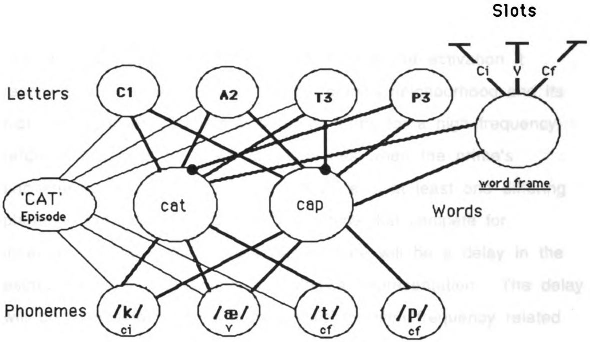

Figure 2. Peterson, Dell and O'Seaghda's (1989) model.

The processing of a stimulus word also results in the establishment of an episodic representaion at the word level (shown as the ellipsed 'cat' episode in Figure 2). The episodic representation receives activation from the letter level and in turn enhances the activation levels of the corresponding phonemes.

Rather than attributing inhibitory effects to an intra-word-level inhibition mechanism, this model places the locus of inhibitory effects at the phonological level. The presentation of a target word after a phonologically related prime will reactivate the prime's word node as well as the prime's episodic representation via the shared letters. The reactivated word node and episodic representation will increase the activation levels of the prime's phonemes once again. A high frequency target word's node reaches maximum activation very quickly due to both the activation it received from having been part of the prime's neighborhood and its high resting level. Therefore the word frame for a high frequency target will attempt to select its phonemes when the prime's phonemes are highly competitive. If there is at least one differing phoneme between the target and the prime that compete for insertion into the target's word frame, there will be a delay in the establishment of the target's phonological representation. The delay will be manifested in slower responses for high frequency related target words.

Although a low frequency target's word node will have a boosted activation level as a result of having been part of a related prime's neighborhood, its low resting level will require more time than a high frequency word node for it to reach maximum activation. This additional amount of time will be sufficient for the prime's phonemes to decay to an uncompetitive level when the low frequency word frame selects its phonemes. A low frequency target word should actually benefit from a previous related prime. The boost in activation of a low frequency related word's node will allow it to establish its phonological representation faster than if it was preceded by an unrelated prime. This benefit will be manifested in faster responses for low frequency related target words relative to unrelated target words.

Support for the phonological competition model comes from Peterson et al.'s replication of Colombo's findings as well as from findings of facilitation for homophone prime-target word pairs (e.g., MUSSEL-MUSCLE) in a naming task (Peterson, O'Seaghda and Dell, 1989). According to Peterson et al. a homophone prime-target pair does not create competition at the phonemic level because there are no differing phonological segments. Although the presentation of a homophone target will reactivate the prime's episodic node via the shared letters, since the phoneme segments of the prime are identical to the target's, the establishment of the target's phonological representation will be facilitated. If the inhibitory effects arise from the competition for selection within an orthographically activated neighborhood at the word level, then the inhibition should have resulted with the homophone prime-target pairs. Furthermore, inhibition was found for form-related non-homophone pairs (e.g., MUSKET-MUSCLE). Since both the homophonic and non-homophonic conditions were orthographically related, assuming the operation of an intra-word-level inhibition mechanism would predict inhibitory effects for both. However, the findings of homophone facilitation and non-homophone inhibition are consistent with the assumptions of the phonological competition model.

Segui and Grainger's findings of an interaction between relative prime-target frequency and relatedness is inconsistent with the phonological competition model's predictions. The inhibitory effects in the phonological competition model arise during the processing of the target rather than during the processing of the prime. Although the inhibitory effects arise from the reactivation of the prime's episodic node during target processing, this episodic representation is claimed to be characteristic of the representations that are considered to be part of a propositional or episodic memory. As such, the episodic representation of the prime should not be influenced by the absolute frequency of the prime as suggested by the frequency attenuation findings from repetition priming (e.g., Scarborough, Cortese, and Scarborough, 1979; Forster and Davis, 1983). Thus, the only frequency factor that this model allows to influence the occurrence of inhibition is absolute target frequency.

The Lukatela and Turvey Model

Lukatela and Turvey's model (1990) is based on Serbo-Croatian lexical decision and word pronunciation studies. Serbo-Croatian unlike English has a strict letter-to-sound correspondence. Thus, word recognition, based upon the activation of phonological representations via the explicit letter-to-phoneme correspondence, is uncomplicated by the presence of irregular or exception words as in English (e.g., the exception word "have"). Dual-route theories of word recognition (e.g., Coltheart, 1978) have proposed that exception words can only be pronounced via direct access to the lexical level by their orthography. However, Lukatela and Turvey (in press) propose that all lexical access in English is accomplished by phonological recoding. This proposal is based on findings of semantic priming effects for pseudohomophone prime target pairs (e.g., TAYBLE-CHAIR) that were equal in magnitude to those found for non-pseudohomophone pairs (e.g., TABLE-CHAIR). These findings suggest lexical access is accomplished via the phonological representation rather than the orthographic representation.

Lukatela and Turvey's model contains a lexical level with bidirectional excitatory connections to a lower sublexical phonemic level, which is in turn connected to a letter level. There is an inhibitory mechanism that operates within the lexical level, and no inhibitory connections between the lexical and lower sublexical levels.

According to this model when a phonological prime is visually presented there is activation among letter units which in turn activate the phoneme segments comprising the prime. As a result, word units at the lexical level that share the same phonemes in the same position as the prime will become partially activated thus creating a phonological neighborhood of competing word units.

A competing neighbor's activation level will depend on three factors: its resting level (which corresponds to frequency of occurrence), the number of phoneme units it shares with the prime and the positions of the shared phonemes. Thus, a high frequency neighbor will quickly reach a high level of activation due to its high resting level. The more phonemes a neighbor shares with a prime the greater the input of excitatory activation it will receive. Furthermore, neighbors that share the initial phonemes with the prime will become the most activated whereas neighbors that share the final phonemes will be activated to a lesser extent. This last proposal is based on the assumption that activation of the initial phoneme relative to the other phonemes resolves most of the uncertainty of the identity of the presented word (Lukatela and Turvey, 1990, p.136). This is the same assumption that is maintained in cohort models of spoken word recognition (Marslen-Wilson and Welsh, 1978; Marslen-Wilson, 1987).

As in McClelland and Rumelhart's model (1981), it is assumed that the net input to a unit will either increase or decrease the activation level of the unit depending on whether the input is positive or negative. The degree of positive or negative effects of the input on a unit will be modulated by the current activity level of the unit. The purpose of this modulation is to keep the input to a unit from increasing or decreasing the unit's activity level beyond maximum and minimum values (the basic scale factors of the implemented model, see McClelland and Rumelhart, 1981, pp. 280-281). Thus, as a unit's activation level approaches either maximum or minimum the modulation reduces the degree of the input's excitatory or inhibitory effects, respectively. Lukatela and Turvey (1990, p.139) refer to this modulation as "Grossberg's principle of self-modulation" (Grossberg, 1978).

According to Lukatela and Turvey, their incorporation of this principle means that the degree of inhibition of a word unit is dependent on its activation level. Thus, a high frequency neighbor, in particular one that shares many of the initial phoneme segments with the prime, will become the most inhibited during the prime word's processing. Consequently, if the high frequency related unit is presented as a target, the response to it will be delayed.

A response to a low frequency related target however, will actually be facilitated despite its word-unit becoming inhibited during prime processing. The facilitation arises from the activation levels of the shared phonemes at the sublexical level. That is, it is possible for the excitation generated at the phonemic level to exceed the inhibition at the word-unit level in the case of low frequency related targets but not in the case of high frequency related targets. This is because low frequency related word units are less activated and so less inhibited during prime processing than high frequency word units. Furthermore, there are no inhibitory connections between the word unit level and the phonemic level. Thus, the feedback between the two levels can only strengthen the activation of the phonemes.

As previously mentioned, contrary to Segui and Grainger's claims and findings, this model does not assume that only related targets that are higher in frequency than a prime are inhibited. The model assumes that all neighboring word-units of a prime are inhibited and the frequency factor that affects the amount of inhibition each neighboring unit receives is the unit's absolute frequency. That is, a high frequency target word unit will become inhibited to the same extent regardless of whether the related prime is higher or lower in frequency than the target word. Therefore, the relative frequency of a prime and target should not interact with the factor of phonological relatedness.

Additionally, based on the claim that inhibitory effects arise at the word-unit level and facilitatory effects arise at the phonemic level, Lukatela and Turvey predict that when a response is dependent upon the output from the word-unit level, as during a lexical decision task, inhibition will be observed. However, if a response can be made directly from the output of the phonemic level, as may be the case in a pronunciation task, then only facilitation will be observed. The prediction of facilitation in a pronunciation task is based on the assumption that if an input phoneme segment, e.g., /b/, is activated above threshold the output unit /b/ will be activated to the same extent. That is, "phoneme units that receive and are activated by stimulation are connected to phoneme units that guide articulation and the connections between the two kinds of phoneme units are realized automatically" (1990, p.146).

Thus, the Peterson, O'Seaghda and Dell findings of facilitation in a pronunciation task involving homophone prime-target pairs are consistent with the Lukatela and Turvey's prediction for the results of pronunciation tasks. However, the inhibition found in Peterson et al's replication of Colombo's findings in a pronunciation task is not consistent with Lukatela and Turvey's claim. Yet, recently Lupker and Colombo (1990) found only facilitation for both high and low frequency phonologically related targets in a pronunciation task. Nevertheless, Lupker and Colombo noted that the related prime-target pairs utilized in the Peterson et al. study shared initial phonological segments whereas the prime target pairs utilized in their study were rhymes that differed in their initial segment.

Results from Colombo's (1986) study, also suggest inhibition is more likely for prime-target pairs that share initial segments. The first two lexical decision experiments utilized rhyming prime-target pairs and the interaction between target frequency and relatedness was found. However, the third lexical decision experiment utilized related prime-target pairs that shared initial segments. The results of this experiment showed not only inhibition for the high frequency related targets but an insignificant trend of inhibition for the low frequency related targets as well. It is not obvious within the phonological competition model why the sharing of initial segments between the prime and target should result in greater inhibition. However, the Lukatela and Turvey model does make the claim that phonologically related neighbors that share an initial segment with the prime will become more inhibited than those that do not.

To summarize, phonological priming in word recognition studies utilizing either the lexical decision task or the pronunciation task has yielded highly variable results. Nevertheless, they suggest that the activation of phonological representations plays an important role. Peterson, O'Seaghda, and Dell's phonological competition model and Lukatela and Turvey's model offer contrasting accounts for this role. Peterson et al's model claims that facilitation arises from the lexical level whereas inhibitory effects arise at the phonological level where the reactivation of an episodic representation of a related prime causes competition among the phonological segments. In contrast, Lukatela and Turvey claim inhibition is a result of processing at the lexical level wherein competing phonological neighbors become inhibited. Facilitation is a result of processing at the phoneme level because without inhibitory feedback between the levels, the shared phonemes become activated to the extent that their activation may exceed the inhibition at the lexical level. Both models maintain that the only word frequency factor that will influence the occurrence of inhibition is absolute target frequency. This is inconsistent with Segui and Grainger's findings of a relative prime-target frequency and relatedness interaction in a lexical decision task.

Although both models were formulated in the domain of word recognition since they assume phonological representations that are utilized during production become automatically activated, predictions derived from the models may be applicable to the domain of word production. In the Peterson et al. model these representations are established when phonological segments are inserted into a word frame. The word frame is the same type of frame representation constructed during the encoding process in Dell's (1986) production model. Lukatela and Turvey claim that the activation of phonological segments from input (e.g., an orthographic representation) results in the activation of corresponding phoneme segments that are used in ouput, i.e., articulation.

However, there is evidence against the assumption that operations affecting the phonological representations derived from stimulus input will affect phonological representations derived for output or production to the same extent and in the same manner (Shallice, Lewis, and McLeod, 1985; Caramazza and Hillis, 1990). Caramazza and Hillis (1991) discuss two patients who show a double dissociation in their impairment of oral and written performance on word and picture naming tasks. However, both of these patients demonstrate no impairment in their comprehension and reading performance.

Nevertheless, the significant findings of priming by auditorily presented primes for visually presented targets in studies such as Tanenhaus, Flanigan, and Seidenberg (1980) and Schriefers, Meyer, and Levelt (1990) do indicate that phonological representations derived from acoustic input will affect those derived for production. Thus, the models proposed by Lukatela and Turvey and Peterson, O'Seaghda and Dell, may be useful in guiding research into the nature of the mechanisms that operate during lexical selection in production. Therefore, with the above findings and models in mind, the experiments reported below were designed to further explore some of the factors that influence the occurrence and nature of phonological priming effects in production. The production task that was employed for all four of the reported experiments involved the naming of pictures. Based on a review of the picture-naming literature, Bock (1987b) claimed that the stages involved in the picture naming process seem to correspond in a general way to the stages of encoding in production. That is, picture naming is believed to involve a stage of categorization (similar to activation of a lemma in production) and then a stage in which the phonological form must be assembled or retrieved (for example, see Carr, McCauley, Sperber, and Parmalee, 1982). Thus, picture naming may provide a way of tapping the word retrieval process in production and examining the selection mechanisms involved.

CHAPTER II

EXPERIMENT 1

The purpose of the first experiment was to determine whether phonological inhibition occurs in a picture naming task. It was designed in an effort to replicate the findings of Bock (1987a) with this task and duplicates many of the features of that experiment. The task involved the visual presentation and naming of words and pictures, and the dependent measure was the naming latency for the pictures. On critical trials subjects named a target picture with a word that was either phonologically related or unrelated to an immediately preceding prime word.

In addition to their phonological relatedness to the targets, primes were selected so that they were either higher or lower in frequency than the name used for the following target picture. Research has demonstrated reliable effects of word frequency on picture naming (Oldfield and Wingfield, 1965; Wingfield, 1968) as well as word naming (Balota and Chumbley, 1985). Furthermore, frequency seems to have greater impact on phonological retrieval than on semantic retrieval of object names (Huttenlocher and Kubicek, 1983). The relative frequency manipulation was included in an effort to determine whether Segui and Grainger's lexical decision findings would transfer to a production task. If an interaction between phonological relatedness and relative prime-target frequency were to be found in this production task it would suggest a mechanism of inhibition that operates among competing word forms during production. Specifically, it would suggest that only the neighboring word forms that are competitive with the prime become inhibited. Such a finding would be inconsistent with the type of inhibitory mechanisms offered in Lukatela and Turvey's model and the Peterson et al. model.

Since selection must take place at a lexical level during the picture naming process findings of inhibition would be consistent with operations within the Lukatela and Turvey model. However, since a target picture should not reactivate an orthographic episodic representation of the prime and facilitation is assumed to be a result of processing at a lexical level, findings of facilitation may be consistent with the operations within the Peterson et al. model.

Method

Subjects

The subjects were 40 Michigan State University undergraduates. Each received course credit for their participation. All were native English speakers and had normal or corrected to normal vision.

Materials

The primary materials for the experiment consisted of 24 target pictures with two phonologically related and two phonologically unrelated primes for each. The target pictures came from Snodgrass and Vanderwart's (1980) standardized set of pictures. Each of the 24 target pictures had 100% name agreement in the norms. There were 18 target pictures with one syllable names and six target pictures with two syllable names. The frequency range of the target picture names was from 2 to 303 occurrences per million (Francis and Kucera, 1982).

Two phonologically related primes were selected for each picture. None of the primes were semantically related in an obvious way to the following target pictures. The related primes were selected with the constraint that they had the same number of syllables and same stress pattern as the corresponding target picture name, shared at least the first two phonological segments with the corresponding target picture name, and did not differ by more than three segments overall. They were also selected with the constraint that one related prime was higher in frequency and one was lower in frequency than the corresponding target picture name's frequency while meeting the relatedness constraints.

The mean total number of segments for the targets was 3.83. The mean total number of segments for the higher frequency related primes was 4.13. The mean number of identical segments between the higher frequency related primes and their corresponding target picture names was 2.38 and the mean number of differing segments was 1.71. The mean total number of segments for the lower frequency related primes was 4.04. The mean number of identical segments between the low frequency related primes and the corresponding target picture names was 2.67 and the mean number of differing segments was 1.5.

Two phonologically unrelated primes were also selected for each target picture. The unrelated control primes were chosen with the constraint that they did not share any phonological segments in the same position as the corresponding target picture name. The mean number of total segments for the higher frequency unrelated primes was 4.21. The number of differing segments between the primes and targets was calculated by counting each segment that differed <u>in each position</u>. When either word of the prime-target pair had more segments than the other, the additional segments were also counted as differing segments. For example, this method yields a total of four different segments and zero similar segments between the prime word /send/ and the target word /bus/ (note that the /s/ appears in different positions. The mean number of differing phonological segments between the unrelated higher frequency prime-target pairs was 3.71. The mean number of total segments for the lower frequency unrelated primes was 3.83. The mean number of differing phonological segments between the unrelated lower frequency prime-target pairs was 3.71. Each unrelated control prime had the same number of syllables and same stress pattern as its corresponding target picture name.

For each target picture one unrelated prime matched the frequency of its higher frequency related prime and the other prime matched the frequency of its lower frequency related prime. The mean frequency of both the higher phonologically related primes and the higher unrelated control primes was 247. The average frequency of the lower frequency phonologically related primes was seven and the average frequency of the lower frequency unrelated control primes was eight.

In addition to the target pictures and priming words the materials included 60 filler words and 60 filler pictures. The filler pictures were also selected from Snodgrass and Vanderwart's set. The pictures and words were selected so there was an approximately equal distribution of initial phonetic segments across the English phonetic alphabet and an equal number of one and two syllable words in the materials.

Four lists were constructed from these materials. Each list contained all 24 target pictures. Half the target pictures were immediately preceded by related primes (six higher in frequency and six lower in frequency than the following target picture) and the other half were preceded by unrelated primes (six higher in frequency and six lower in frequency than the following target picture). The four primes for each picture were assigned to different lists so that across all four lists each picture was preceded once by each of its primes.

In addition to the 24 target pictures and 24 prime words each list contained all of the filler words and pictures with each of the filler words and pictures occurring twice. Thus, the total number of items in each list was 288. The filler pictures and words were randomly repeated with no consistent pattern of alternation between the pictures and words. The prime-target pairs were randomly distributed with the constraint that at least eight filler items occurred between each pair.

Apparatus

The experiment was run on a MacIntosh 512K computer equipped with a Metaresearch board. An external voice key (Gerbrands Corporation model # G1431T) interfaced with a millisecond clock on the board was used to measure oral naming latencies.

Procedure

Subjects were run individually. Each was seated in front of the CRT screen of the computer. The experimenter informed the subjects that the experiment was a picture and word recognition task in which a list of pictures and words would be presented one at a time. They were instructed to name aloud as quickly as possible each of the pictures and words. The subjects were told that some of the pictures and words would occur twice and others only once. They were informed that a recognition test would be given at the end of the experiment and the test would examine their ability to recognize whether certain pictures and words had occurred once or twice. This offered the subjects a rationale for the performance of the task so unusual attention would not be given to the normal process of word production.

The words were presented in upper case letters in 12 point Chicago font. They appeared in the center of the screen. The pictures were also individually displayed in the center of the screen. On each trial an item (either a word or a picture) was displayed and 500 milliseconds from the triggering of the voice key by the naming of the item, the next trial's item was presented. Thus, on critical trials, subjects named a prime word and 500 milliseconds from the initiation of the prime word's pronunciation a target picture appeared which was also named aloud. The voice onset time for the pictures was measured to the nearest millisecond from the onset of the picture to the triggering of the voice-key by the subject's picture-naming response.

The total time from the prime presentation to the picture presentation was 500 milliseconds plus the amount of time needed to begin to pronounce the prime. Based on the mean naming latencies for the primes that were collected for 12 pilot subjects, the time needed to begin to pronounce the primes was approximately 560 milliseconds (range from 460 to 642 milliseconds). This estimate is consistent with the mean naming latencies for monosyllabic words presented without primes by Andrews (1989, Experiment 3) in a study investigating the effects of word frequency and neighborhood. She found a mean naming latency of 594 milliseconds for low frequency words and 580 milliseconds for high frequency words (both means for words with large neighborhoods). Thus, the average interstimulus interval in the present experiment was approximately 1060 milliseconds.

Each 288 item list was presented in four blocks of 72, allowing for short breaks between the blocks. Each subject was also run through a practice block consisting of 72 filler items. A block was initiated by a key press in response to a visually displayed prompt on the CRT screen.

The experimenter remained in the room throughout the experiment. All dysfluencies, erroneous voice-key triggerings, and inappropriate naming responses were noted as they occurred. In addition, all responses produced by the subject were tape-recorded.

Upon completion of the naming task, a recognition test was administered. A random selection of the pictures and words were presented and the subjects pressed a designated key on a computer keyboard indicating whether they recognized the item as having occurred once or twice. Feedback in the form of the words "right" or "wrong" was displayed after each recognition response. No data were collected from this test.

At the end of the experiment subjects were asked if they noticed a sound relationship between the pictures and the words and if the relationship caused them to anticipate words and pictures sounding alike.

Results

Trials in which an error occurred were not included in the reaction time analysis. The means for subjects and items were calculated only on the basis of the good responses. The number of good responses for each subject in each condition ranged from three to six with an average of five. The reaction time data were submitted to an analysis of variance with relative prime-target frequency (primes higher or lower in frequency than targets) and phonological relatedness (primes related or unrelated to targets) as factors. In all analyses to be reported the effects were considered significant when their probabilities were less than or equal to .05.

The mean latencies for target pictures are given in Figure 3 and Table 1.

There was a significant main effect of phonological relatedness in the subject analysis ($F(1,39)=8.36$) and in the item analysis, ($F(1,23)=12.22$). This reflected targets being named slower following related primes than following unrelated primes. There was no significant effect of relative prime-target frequency in either the subject or item analysis ($F(1,39)=1.39$ and $F(1,23)=1.12$, respectively).

Table 1. Experiment1 picture naming latencies.

	Prime conditions	
	Higher Frequency Prime	Lower Frequency Prime
Unrelated	775 (7)	786 (7)
Related	808 (13)	849 (8)

Note. Error percentages for each condition are in parentheses.

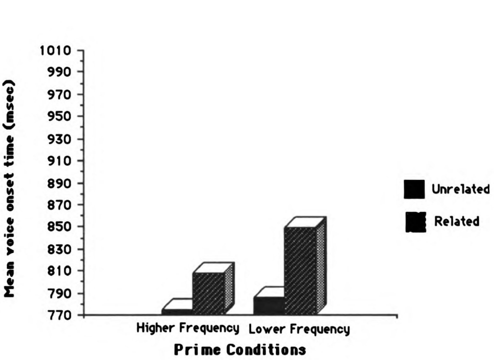

Figure 3. Graph of Experiment 1 picture naming latencies.

Although the inhibitory effect for targets preceded by lower frequency related primes was larger than the inhibitory effect for targets preceded by higher frequency related primes in the item means (i.e., -64 versus -49 milliseconds) and nearly twice as large in the subject means (i.e., -63 versus -32 milliseconds), there was no significant interaction between phonological relatedness and relative prime-target frequency in either the subject or item analysis, ($F(1,39)=.48$ and $F(1,23)=.32$, respectively).

For each subject in each condition the reaction times that were either two standard deviations above or below the subject's condition mean were excluded (five observations were eliminated). Means were then calculated on the basis of the remaining times (i.e., 871 observations) and subjected to the same analysis as the untrimmed data. The subject analysis and the item analysis both yielded a significant main effect of phonological relatedness ($F(1,39) = 7.81$ and $F(1,23) = 12.10$, respectively). The main effect of relative prime-target frequency was not significant in either the subject or item analysis ($F(1,39) = 1.19$ and $F(1,23) = 1.05$, respectively). Additionally, the interaction between phonological relatedness and relative prime-target frequency was not significant in either the subject or item analysis ($F(1,39) = .30$ and $F(1,23) = .18$, respectively).

For each item in each condition the reaction times that were either two standard deviations above or below the item's condition mean were excluded (31 observations were eliminated). Means were then calculated on the basis of the remaining times (i.e., 845) and subjected to the same analysis as the untrimmed data. The subject and item analysis again both yielded a significant main effect of phonological relatedness ($F(1,39) = 6.38$ and $F(1,23) = 9.12$, respectively). The main effect of relative prime-target frequency was not significant in either the subject or item analysis ($F(1,39) = 1.56$ and $F(1,23) = .90$, respectively). The interaction between phonological relatedness and relative prime-target frequency also did not reach significance in either the subject or item analysis ($F(1,39) = .71$ and $F(1,23) = .23$, respectively).

Thus, the analyses of the trimmed data according to either the subject or item means did not produce any different results than the analysis of the untrimmed data.

Only eight of the 40 subjects said they did not notice a sound relationship between some of the pictures and words during the naming experiment. Of the 32 subjects who did notice the relationship, only six subjects said they anticipated pictures sounding similiar to words they read aloud. The awareness or expectations of the sound relationship may have influenced the latencies for the target pictures (Neely, 1977). The results of Lupker and William's study (1989) suggest expectations may facilitate the naming of target pictures following form-related primes. Thus, an analysis of the 32 subjects who noticed the sound relationship was carried out to determine whether their awareness would produce differing results from that of the primary analyses. The results of this analysis however, did not differ from the primary analyses. Only a main effect of phonological relatedness was significant in the subject analysis ($F(1,31) = 11.41$) and the item analyses ($F(1,23) = 9.15$). This result was consistent with the primary analysis in reflecting inhibition for target pictures following phonologically related primes relative to unrelated primes. The main effect of relative prime-target frequency was not significant in the subject analysis ($F(1,31) = 1.55$) and only marginally significant in the item analysis ($F(1,23) = 3.24$; $p = .09$). This effect in the item analysis reflected faster mean latencies following higher frequency primes (800 milliseconds) than following lower frequency primes (823 milliseconds). The interaction between relative prime-target frequency and phonological relatedness was not significant in either the subject or item analyses.

Error Results

A trial was scored as an error if (a) the subject misnamed the target (b) the subject misnamed the prime (c) the subject's response was too soft to trigger the voice key or the voice key was triggered by lip smacks or other erroneous noises. There was a total of 84 errors (8.8% of all responses). There were 47 misnamed targets (5% of all responses). The numbers of errors in each category are given in Table 2.

Table 2. Experiment 1 error results.

Condition	Voice key error	Misnamed target	Misnamed prime	TOTAL
<u>Higher Primes</u>				
Unrelated (224)	1	11	4	16
Related (208)	11	19	2	32
<u>Lower Primes</u>				
Unrelated (224)	3	7	6	16
Related (220)	4	10	6	20
TOTAL (876)	19	47	18	84

Note. The total number of correct responses out of 240 for each condition is in parentheses.

A 2 (phonological relatedness) X 2 (relative prime-target frequency) analysis of variance for the total number of errors (i.e., 84) was carried out. There was a significant main effect of phonological relatedness in the subject analysis ($F(1,39) = 4.64$). This reflected the total number of errors following related targets (52) to be greater than the total number following unrelated targets (32). However, the main effect of phonological relatedness was not significant in the item analysis ($F(1,23) = 1.90$). The main effect of relative prime-target frequency was marginally significant in the subject analysis ($F(1,39) = 3.66$; $p = .06$) reflecting more errors for the higher frequency prime conditions (48) than the lower frequency prime conditions (36). The main effect of relative prime-target frequency was not significant in the item analysis ($F(1,23) = .86$). The interaction between the factors of phonological relatedness and relative prime-target frequency was not significant in either the subject or item analyses ($F(1,39) = 1.99$ and $F(1,23) = 2.03$, respectively).

Discussion

The results of the first experiment demonstrated reliable inhibition in the production latencies of picture names that followed phonologically related prime words. In addition the total number of errors following related primes was greater than that following unrelated primes. This was particularly evident for the target misname and voice key errors. The erroneous target names often resulted in alternative names e.g., "bunny" for the picture of the rabbit, or associates e.g., "king" for the picture of a crown, despite the target pictures having 100% name agreement in the norms. Additionally, seven of the eleven voice-key errors that occurred in the higher frequency prime condition were due to stuttering of the initial consonant of the target name , e.g., "p-p-pear", or a hesitation noise, e.g., "uhh-fork". Thus, these errors may also reflect the inaccessibility of the picture names due to inhibition from the processing of a related prime.

Although the inhibitory effects for targets preceded by lower frequency related primes were nearly twice as large as those for targets preceded by higher frequency related primes, the interaction between relative prime-target frequency and phonological relatedness failed to reach significance, However, the results suggest that an inhibitory mechanism operates during production.

An account such as the one proposed by Lukatela and Turvey's model may handle these results. The recognition and pronunciation of a prime word may have caused phonologically related representations at a lexical level to become inhibited. The presentation of a following phonologically related target picture that required the selection of one of the inhibited representations for production would have resulted in a delayed response relative to the naming of an unrelated target picture. Lukatela and Turvey maintain that inhibition will be observed only when a response is based on the output of the lexical level. Since subjects named target pictures rather than words, this production task should require selection from the lexical level for a response. Thus, the observation of inhibition is consistent with Lukatela and Turvey's account. Furthermore, their model predicts that related prime-target pairs that share initial segments become the most inhibited. Thus, it is possible that the observed inhibition may be largely attributable to the overlapping onsets of the phonologically related stimuli.

Nevertheless, the account offered by Lukatela and Turvey's model does not offer a means for explaining the insignificant trend in greater inhibition for related targets that followed lower frequency primes than for those that followed higher frequency primes. Only the factor of absolute target frequency should influence phonological relatedness which was not a factor that was examined in the first experiment.

The inhibitory findings are not consistent with Dell's (1986) production model, which predicts only facilitation. The Peterson, O'Seaghda and Dell model may account for the findings since their model allows for competition at the phonological level to delay responses for related prime-target pairs relative to unrelated prime-target pairs. However, their model also maintains that absolute target frequency influences the occurrence of inhibition. Since both the Lukatela and Turvey and the Peterson et al. models incorporate this frequency factor into their accounts of phonological priming the remaining experiments will include target frequency as a factor.

Since Experiment 1 required the overt pronunciation of visually displayed prime words in addition to the naming of following target pictures the observed inhibition may have been a result of articulatory interference during motor programming at a more peripheral level of production. Inhibition in articulatory motor programming has been suggested in studies by Yaniv, Meyer, Gordon, Huff, and Sevald (1990) and Meyer and Gordon (1985). In the study conducted by Meyer and Gordon (1985), subjects were visually presented with two syllables which consisted of final segments that either shared phonetic features (e.g., the syllable pair "up" and "ub" share a place of articulation feature) or did not (e.g., "ud" and "up"). Subjects prepared to say the first syllable and after a preparation interval they were cued to overtly respond with either the prepared syllable or the second unprepared syllable. The results showed an increase in response latencies for the unprepared syllable when it shared phonetic features with the prepared syllable relative to when it did not. Meyer and Gordon suggested that the shared features slowed the programming operations needed to switch from the prepared response to the unprepared response. Although the subjects in Experiment 1 produced the primes rather than only preparing to say them, the effects of the programming for the prime response may still have contributed to the inhibitory effects of the target responses.

In addition to the inability to conclude from Experiment 1 whether the locus of inhibitory effects is at a lexical versus motor programming level, the use of visually presented primes precludes drawing a conclusion that an inhibitory mechanism was operating within a neighborhood of phonological representations rather than orthographic representations. Experiments 2 and 3 were conducted in an attempt to separate these issues.

The remaining experiments included overall target frequency as a factor in addition to the factors of phonological relatedness and relative prime-target frequency. Furthermore, Experiments 2 and 3 eliminated the pronunciation of the primes; only the pictures were named. The elimination of the pronunciation of the prime allowed for control over the interstimulus interval. Since the interval from the initiation of the prime's repetition to the target presentation was 500 milliseconds in Experiment 1, the interval from the offset of the prime presentation to the onset of the target presentation was set at 500 milliseconds for Experiment 2. Prime words were presented auditorily in Experiment 2 and visually in Experiment 3.

Previous work (Bock, 1987, Experiment 3) used auditorily or visually presented primes that were either phonologically related or unrelated to target words depicted in following pictures. There was inhibition regardless of whether subjects were required to repeat the primes aloud, mouth them silently, or simply listen to them, and the magnitude of the inhibition was about the same across all these conditions. Based on these findings it was expected that the inhibition would still be found in both experiments.

CHAPTER III

EXPERIMENT 2

Method

Subjects

Eighty subjects participated in Experiment 2. The subjects earned extra credit from an introductory Psychology course for their participation. None had participated in the previous experiment. All were native English speakers. None professed to having any hearing impairments and all had normal or corrected to normal vision.

Materials

The materials from the first experiment were employed in this experiment. However, a median split of the target pictures was made dividing them into an absolute low frequency group with a frequency range for their names of two to 33 (mean equal to 18) occurrences per million and an absolute high frequency group with a frequency range for their names of 38 to 203 (mean equal to 96) occurrences per million (Francis and Kucera, 1982).

The additional factor of absolute target frequency was counterbalanced across the four lists such that in each absolute frequency category half the target pictures were immediately preceded by related primes (three higher in frequency and three lower in frequency than the target) and the other half were preceded by unrelated primes (three higher in frequency and three lower in frequency than the following target). The four primes for each picture were assigned to different lists so that across all four lists each picture was preceded once by each of its primes.

The filler and priming words were recorded by a female speaker (the author) and digitized at a sampling rate of 10 kHz using MacSpeech Lab II software (GW Instruments). The samples were edited using the same software to remove all extraneous noise from the beginning and end of the recordings. The mean duration of the recordings of the primes was 480 milliseconds (range from 323 milliseconds to 714 milliseconds).

The edited samples were analog-converted and presented to ten subjects in order to determine their perceptibility. These ten subjects did not participate in any of the reported experiments. Each of the 96 prime words (four for each of the 24 targets) were auditorily presented one at a time over headphones (Sennhieser model HD414) in the same manner as they were presented in Experiment 2. Each subject was asked to repeat aloud the words and the experimenter transcribed the responses as they were made. Ninety of the ninety-six prime words were correctly repeated by at least eight of the ten subjects. Four of the remaining six prime words were correctly repeated by seven of the ten subjects and the other two were correctly repeated by five of the ten subjects. Of the latter two, one was a phonologically related prime (i.e., shirk, a prime for the target shirt) and the other was a phonologically unrelated prime (i.e., faith, a prime for the target pear).

The target and filler pictures were the same as Experiment 1. They were displayed in the center of a monochrome CRT screen.

Four lists containing 296 items were constructed as in Experiment 1. Each list contained all 24 target pictures and primes in addition to 64 filler pictures and 64 filler words with each of the filler items occurring twice. The filler items were randomly repeated with no consistent alternation between the pictures and words. The prime-target pairs were randomly distributed with the constraint that at least eight filler items occurred between each pair.

Apparatus

The presentation of the lists and the timing of the responses were controlled by a MacIntosh IIci computer with a monochrome CRT screen. A voice key (Gerbrands Corporation model # G1341T) monitored voice onsets.

Procedure

Subjects were run individually. Each was seated in front of the CRT screen of the computer. The subjects were instructed that the experiment was a word and picture naming task. They were told they would either see a picture on the screen or hear a word played over the headphones. They were instructed to listen carefully to the words and to name aloud the pictures as quickly as possible. The subjects were informed that some of the pictures and words would occur twice and others only once and that a recognition test would be given at the end of the naming part of the experiment to examine their ability to recognize which items occurred twice and which occurred once.

The auditory presentation of the words coincided with a blank CRT screen. The interstimulus interval between the offset of a prime word and the onset of a target picture was 500 milliseconds. The interstimulus interval between the filler items differd because of variations in the times required to buffer the sound files. Thus, the length of the interval before each of the word trials depended on the time for the word to be read by the program. The mean of these times was1878 milliseconds (range from 1216 to 2738 milliseconds). In order to create interstimulus intervals preceding the filler picture trials that were consistent with those preceding the filler words, each interstimulus time preceding a word also randomly occurred before a filler picture.

The pictures remained on the CRT screen until the triggering of the voice key, at which point the screen was blanked. Voice onset times for target pictures were measured to the nearest millisecond from the onset of the picture to the triggering of the voice key.

The 296 item lists were presented in three blocks allowing for short breaks between the blocks. The first block contained 24 filler trials before the first critical prime-target pair. Both of the two remaining blocks began with eight fillers before a critical prime-target pair occurred. Each block was initiated by a key press in response to a visually displayed prompt on the CRT screen.

As in Experiment 1, the experimenter remained in the room throughout the experiment. All dysfluencies, erroneous voice key triggerings and inappropriate naming responses were noted as they occurred. All the responses produced by the subject were tape-recorded.

Upon completion of the naming experiment, a recognition test was administered. None of the pictures were presented in the recognition test. All 24 of the prime words that occurred in the list that the subject was assigned to in the naming experiment were presented again in the recognition test. The prime words were randomly distributed amongst 24 filler words that had been presented in the naming experiment. The 48 recognition test items were auditorily presented over the headphones as in the naming experiment. The subjects were instructed to listen to each word, repeat it aloud and then decide whether they thought they heard the word once or twice in the naming experiment. The experimenter transcribed each repetition of the prime and filler words as the subject responded. The subjects made the recognition decision by pressing appropriate keys on the computer key board and the response was stored by the computer in a data file. No feedback was given for the recognition decisions.

Finally, subjects were asked if they noticed any relationships between the pictures and the words in the experiment, and if any detected relationship influenced their responses.

Results

As in the first experiment, trials in which an error occurred were not included in the reaction time analysis. In addition, since it was impossible to guarantee 100% perceptibility of the auditorily presented primes during the naming experiment, trials in which the prime was subsequently incorrectly repeated in the recognition test were also excluded from the analyses. Thus, the means for subjects and items were calculated only on the basis of good naming responses in the naming experiment and correct prime repetitions in the following recognition test. The total number of correct naming responses was 1,743 (90% of all the responses). The number of good responses for each subject in each condition ranged from 1 to 3. The reaction time data were submitted to an analysis of variance with relative prime-target frequency (primes higher or lower in frequency than the targets), absolute target frequency (high frequency or low frequency targets) and phonological relatedness (primes related or unrelated to targets) as factors. Results of Experiment 2 are presented in Table 3 and Figure 4.

Table 3. Experiment 2 picture naming latencies.

	Higher Frequency Prime	Lower Frequency Prime
High Frequency Targets		
Unrelated	823 (6)	826 (10)
Related	822 (4)	810 (6)
Low Frequency Targets		
	Higher Frequency Prime	Lower frequency Prime
Unrelated	974 (8)	956 (11)
Related	963 (9)	956 (20)

Note. Error percentages per condition are in parentheses.

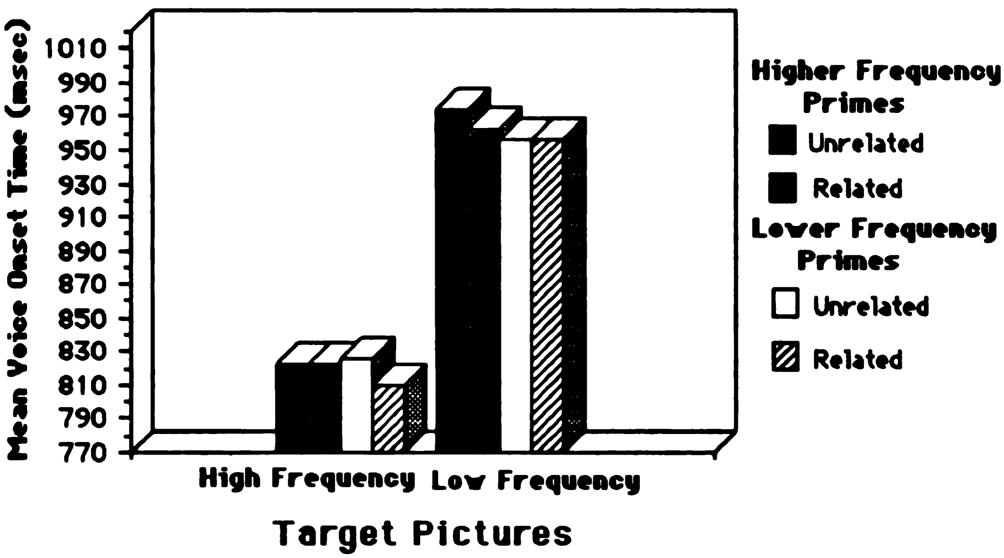

Figure 4. Graph of Experiment 2 picture naming latencies.

The only effect to reach significance in both the subject and item analyses was absolute target frequency, F(1,79) = 124.08 and F(1,22)= 9.56 respectively. This reflected faster naming responses for high frequency targets than low frequency targets.

The main effect of phonological relatedness was not significant in the subject analysis (F(1,79)= .35) or item analysis (F(1,22)= 0). The main effect of relative prime-target frequency was also not significant in the subject analysis (F(1,79)= .49) or item analysis (F(1,22) = .16). Furthermore, the interaction between phonological relatedness and relative prime-target frequency was not significant in the subject analysis (F(1,79) = .01) or item analysis (F(1,22) = .05). Phonological relatedness did not significantly interact with target frequency in the subject analysis

(F(1,79) = .01) or in the item analysis (F(1,22) = .94); nor was the interaction between relative prime-target frequency and absolute target frequency significant in the subject analysis (F(1,79)= .12) or item analysis (F(1,22) =.01). Finally, the interaction involving all three factors was not significant in either the subject analysis (F(1,79)= .26) or in the item analysis (F(1,22) = 1.49).

As mentioned above, the primary analyses did not include the picture naming times that were preceded by a prime that was subsequently incorrectly repeated during the recognition test. This restriction eliminated 78 observations. Inclusion of these times did not change the results found in the primary analysis. Once again only a significant main effect of absolute target frequency was significant in the subject analysis (F(1,79) = 138.64) and in the item analysis (F(1,22) = 9.18). No other main effects or interactions were significant.

Error Results

Table 4 contains the number of errors that occurred in each condition. There were 50 voice key triggering errors (3% of all responses) and 49 misnamed target picture responses (3% of all responses). Consistent with the latency results, there were more misnaming responses for low frequency target pictures (47) than for high frequency target pictures (2). There were 78 incorrect prime word repetitions during the recognition test.

Table 4. Experiment 2 error results.

Condition	Voice key error	Misnamed target	Misnamed prime	TOTAL
		High Frequency Targets		
Prime Type				
Higher Unrelated (226)	9	0	5	14
Higher Related (230)	5	1	4	10
Lower Unrelated (216)	5	1	18	24
Lower Related (226)	6	0	8	14
		Low Frequency targets		
Prime Type				
Higher Unrelated (222)	4	12	2	18
Higher Related (219)	5	16	0	21
Lower Unrelated (213)	6	12	9	27
Lower Related (191)	10	7	32	49
TOTAL (1,743)	50	49	78	177

Note. The total number of correct responses out of 240 for each condition are in parentheses.

An analysis of variance with the factors of phonological relatedness, relative prime-target frequency and absolute target frequency was carried out on the total number of errors (i.e., collapsed across the three error categories). There were several significant main effects and interactions in the subject analysis, including the interaction involving all three factors. The main effect of target frequency was significant in the subject analysis ($F(1,79) = 17.79$), but only marginally significant in the item analysis ($F(1,22) = 3.16$, $p = .09$). There was a significant main effect of relative prime-target frequency in the subject analysis ($F(1,79) = 13.21$) as well as in the item analysis ($F(1,22) = 7.68$). The main effect of phonological relatedness was not significant in either the subject analysis ($F(1,79) = .82$) or the item analysis ($F(1,22) = .24$).

The interaction between phonological relatedness and absolute target frequency was significant in the subject analysis ($F(1,79) = 11.38$), but not significant in the item analysis ($F(1,22) = 2.95$). The interaction between relative prime-target frequency and absolute target frequency was also significant in the subject analysis but not in the item analysis ($F(1,79) = 4.07$) and ($F(1,22) = 1.56$), respectively. However, the interaction between relative prime-target frequency and phonological relatedness was not significant in either the subject or item analysis ($F(1,79) = 1.15$) and ($F(1,22) = .59$), respectively.

Conclusions based on these main effects and interactions are superceded by the significant interaction involving phonological relatedness, relative prime-target frequency and absolute target frequency in the subject analysis ($F(1,79) = 3.88$). This interaction was not significant in the item analysis (F(1,22) = 2.17). The interaction reflected the large number of errors in the low frequency target condition with lower frequency related primes. Of the 49 errors in this condition 32 were a result of incorrect repetitions of the primes during the recognition test; the 17 remaining errors were due to misnamed targets and voice key errors that occurred during the naming experiment. Thus, the interaction is mainly a result of the greater failure to correctly repeat the lower frequency related primes for the low frequency targets during the recognition test.

An analysis of the total number of errors excluding the prime repetitions (i.e., 99 errors) from the recognition test yielded only a significant main effect of absolute target frequency in both the subject analysis (F(1,79) = 19.29) and item analysis (F(1,22) = 5.04). This was consistent with the latency analysis in that there were more target misnames and voice key errors for low frequency target pictures (72) than for high frequency target pictures (27). No other main effects or interactions were significant.

Discussion

Contrary to the prediction that inhibition would be found for targets preceded by phonologically related primes there were no significant effects of phonological relatedness. The relative frequency of the prime and target likewise had no significant effect on the naming latencies of the pictures. Only absolute target frequency affected picture naming consistent with previous findings

(Oldfield and Wingfield, 1965; Wingfield, 1968). Thus, although the target pictures were not originally selected with respect to the factor of absolute target frequency, the division of the stimuli into the two frequency categories by a median split successfully achieved the goal.

The lack of an effect of phonological relatedness seems to be inconsistent with the findings of Bock (1987a). Despite eliminating the pronunciation of the primes as well as changing to an auditory mode of presentation, it was expected that the phonological representation of the primes would still cause inhibition in the naming of following related target pictures. However, in Bock's study, subjects were required to make a recognition decision for each of the primes on a trial-by-trial manner. This requirement may have insured that the auditorily presented primes were fully recognized as words. That is, the subject's recognition decision to the prime immediately after its presentation may have insured full processing or the selection of the prime's word unit at the lexical level prior to the presentation of a target.

Since the purpose of an intra-word-level inhibitory mechanism, such as that proposed by Lukatela and Turvey, is to select the stimulus word unit from a neighborhood of competing units during the recognition process, if the recognition process is not complete then inhibition may not be observed. Likewise, the Peterson, O'Seaghda and Dell model does not predict the occurrence of inhibition without the recognition of a phonologically related prime. However, in their model the lack of inhibition is a result of a weak episodic representation of the prime's processing. Peterson et al., tested this prediction by masking the primes of their related and unrelated prime-target pairs from their replication of Colombo's experiment. The elimination of inhibitory effects confirmed the predictions. In addition, facilitation was found for both low- and high- frequency related targets.

Experiment 2 did not require any response to the prime that demonstrated recognition during the picture naming experiment. To the extent that the results of the recognition test reflected the processing or recognition of the prime and filler words during the naming experiment, there is slight indication that some processing occurred. The mean correct prime recognition (i.e., correctly identifying a prime word as having occurred once during the naming experiment) for 79 of the 80 subjects (one subject's data were missing due to experimenter error) was 16 (range from ten to 24). The mean correct recognition for the fillers (i.e., correctly identifying a filler word as having occurred twice) was 14 (range from 0 to 23). Although the mean correct recognition for the primes was greater than the fillers, the mean correct judged frequency of the primes was 1.99 and the mean correct judged frequency of the fillers was 2.14. The difference between these means is not significant (t-test, $p= .57$).

Although all the filler trials and half of the experimental trials were phonologically unrelated, 60 of the 80 subjects said they noticed a sound relationship between some of the words and pictures during the naming experiment. Sixteen of the 60 subjects who said they detected a sound relationship between the words and the pictures also claimed they anticipated the names of pictures to sound similar to preceding words.

Subjects who detected the sound relationship, and in particular those who used the relationship to anticipate pictures, may have processed the primes during the naming experiment to a greater extent than those who did not notice a sound relationship. Thus, the awareness of the sound relationship may have influenced the naming latencies for the pictures. An analysis was conducted only on the data for those subjects who noticed a sound relationship (i.e., 60 subjects). The results of this analysis did not differ from those of the primary analyses. That is, only the main effect of absolute target frequency was significant in the subject and item analyses, ($F(1,59) = 92.51$) and $F(1,22) = 11.40$, respectively). This effect was in the same direction as the primary analyses, i.e., faster naming latencies for high frequency targets than for low frequency targets. No other main effects or interactions were significant.

Thus the results Experiment 2 do not shed much light on the locus of the inhibitory effects that were found in Experiment 1. Perhaps the inhibitory effects observed in Experiment 1 were due to the processing of an orthographic representation of the prime and/or to the pronunciation of the prime. Experiments 3 and 4 were conducted to examine these possibilities. Experiment 3 presented the primes visually and did not require their pronunciation before the naming of a following target picture.

CHAPTER IV
EXPERIMENT 3

Method

Subjects

Eighty Michigan State University undergraduate students participated in this experiment in exchange for extra credit in an introductory Psychology course. None had participated in the previous experiments. All were native English speakers and had normal or corrected to normal vision.

Materials

The same four lists employed in Experiment 2 were utilized in this experiment. However, the prime and filler words were visually rather than auditorily presented.

The words were displayed in uppercase letters in the center of the screen. They were displayed in 18 point bold Chicago font. In an effort to simulate as many of the aspects of Experiment 2 as possible, the words in Experiment 3 were displayed for 480 milliseconds which was the mean duration of the recordings of the prime words in Experiment 2. In addition the same variable interstimulus times between the filler trials in Experiment 2 occurred in Experiment 3. Furthermore, as in Experiment 2, the interstimulus interval from the offset of the prime presentation to the onset of the target picture presentation was 500 milliseconds.

Procedure

The procedure utilized in Experiment 3 was identical to that in Experiment 2 with the exception that the subjects were instructed to read silently rather than listen to the words. In addition, the subjects were not instructed to repeat aloud the words presented for the recognition test.

Results

As in the previous two experiments, trials in which an error occurred were excluded from the reaction time analyses. Thus, the means for subjects and items were calculated only on the basis of good naming responses. Unlike Experiment 2, no trials were eliminated from the analyses based on performance on the recognition test since subjects were not required to repeat the words presented in this experiment's recognition tests.

The total number of good naming responses was 1837 (96% of all responses). The number of good responses for each subject in each condition ranged from 1 to 3. As in the previous experiment, the reaction time data were submitted to an analysis of variance with relative prime-target frequency (primes higher or lower in frequency than the targets), absolute target frequency (high frequency or low frequency targets) and phonological relatedness (primes related or unrelated to targets) as factors. The results are presented in Figure 5 and Table 5.

Table 5. Experiment 3 picture naming latencies.

	Higher Frequency Prime	Lower Frequency Prime
High Frequency Targets		
Unrelated	795 (4)	815 (4)
Related	819 (3)	823 (4)
Low Frequency Targets		
Unrelated	959 (6)	969 (4)
Related	935 (4)	980 (5)

Note. Error percentages for each condition are in parentheses.

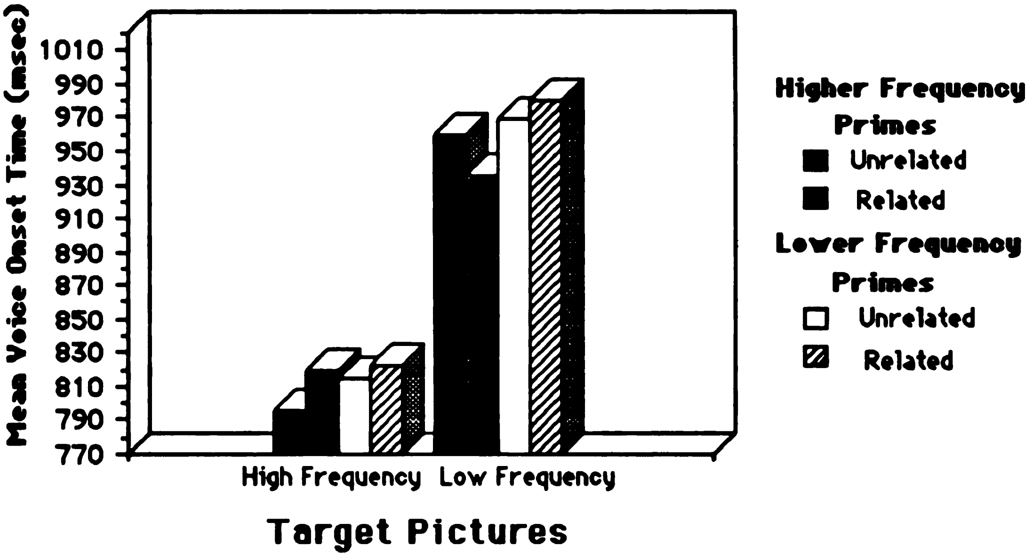

Figure 5. Graph of Experiment 3 picture naming latencies.

Despite some indication of inhibition for related targets, the only effect to reach significance was the main effect of absolute target frequency. This main effect reached significance in both the subject analysis, $F(1,79) = 140.37$, and the item analysis, $F(1,22) = 6.54$. This reflected faster naming latencies for high frequency target pictures than for low frequency target pictures. Neither the main effect of phonological relatedness nor the main effect of relative prime-target frequency achieved significance in the analyses. Additionally, no interactions involving any of the factors were significant.

Errors Results

Table 6 contains the number of errors that occurred in each condition. There were 35 voice key triggering errors (2% of all responses) and 48 misnaming responses for the target pictures (2% of all responses). An analysis of variance was conducted on the total number of errors (83) with the factors of phonological relatedness, relative prime-target frequency and absolute target frequency. There were no significant main effects or interactions in either the subject or item analyses. The main effect of relatedness yielded $F(1,79) = .62$ by subjects and $F(1,22) = .79$ by items. The main effect of absolute target frequency yielded $F(1,79) = 1.29$ by subjects and $F(1,22) = .27$ by items. The main effect of relative prime-target frequency yielded $F(1,79) = .01$ in the subject analysis and $F(1,22) = .01$ in the item analysis. The interaction between relatedness and absolute target frequency produced $F(1,79) = .02$ by subjects and $F(1,22) = .02$ by items. In the subject analysis, the interaction between relatedness and relative prime-target frequency yielded $F(1,79) = 1.08$ and in the items analysis $F(1,22) = 1.29$. The interaction between relative prime-target frequency and absolute target frequency yielded $F(1,79) = .11$ by subjects and $F(1,22) = .12$ by items. The interaction involving all three factors yielded $F(1,79) = .47$ in the subject analysis and $F(1,22) = .78$ in the item analysis.

Table 6. Experiment 3 error results.

Conditions	Voice key error	Misnamed target	TOTAL
	High Frequency Targets		
Prime Type			
Higher Unrelated (230)	4	6	10
Higher Related (232)	6	2	8
Lower Unrelated (230)	8	2	10
Lower Related (231)	6	3	9
	Low Frequency Targets		
Prime Type			
Higher Unrelated (225)	5	10	15
Higher Related (231)	1	8	9
Lower Unrelated (230)	2	8	10
Lower Related (228)	3	9	12
TOTAL (1,837)	35	48	83

Consistent with the latency results, there were more misnaming responses for low frequency target pictures (35) than for high frequency target pictures (13).

Discussion

As in Experiment 2 the only factor found to influence the naming of target pictures was the absolute frequency of the pictures' names. Low frequency target pictures had significantly longer naming latencies than high frequency target pictures. Although more errors were produced for the low frequency targets than for high frequency targets (46 versus 37 respectively) this difference was not significant.

Again, to the extent the results of the recognition test administered at the end of the naming experiment, demonstrate the amount of processing the words received during the naming experiment, there is some evidence that the primes were recognized. The mean number of correctly identified primes (i.e., correctly identifying the prime as having occurred once) was16 (range from seven to 24). The mean number of correctly identified fillers (i.e., correctly identifying the filler as having occurred twice) was 15 (range from 0 to 21). Although the overall mean correct recognition was greater for the primes than the fillers, the mean correct judged frequency of the primes was 2.02 and the mean correct judged frequency of the fillers was 2.09. The difference between these means is not significant (t-test, $p= .71$).

There were 34 subjects who said they detected a sound relationship between some of the words and pictures during the naming experiment. Of these subjects only ten said they anticipated words and pictures sounding similar. An analysis of the data from the 34 subjects was conducted to determine whether their awareness of the sound relationship affected the naming latencies of the target pictures. However, the results did not differ from that of the primary analyses. Only a significant main effect of absolute target frequency was significnat by subjects ($F(1,33) = 49.37$) and by items ($F(1,22) = 10.06$). This effect was in the same direction as the primary analyses. No other main effects or interactions were significant.

Fewer subjects noticed a sound relationship between the primes and pictures in Experiment 3 than in Experiment 2, 34 versus 60, respectively. Perhaps processing the orthographic representation of the prime without the need to pronounce it made the phonological relationship less salient than processing the auditory representation of the prime.

Nevertheless, the null results of both Experiment 2 and Experiment 3 suggest that neither the processing of a prime word's orthographic representation nor the phonological representation affects the naming of a following related target picture. Thus, the inhibitory effects found in Experiment 1 may be attributable to the pronunciation of the related prime before the naming of the target picture. That is, the inhibitory effects may be at the level of articulatory programming as suggested by the results of Meyer and

Gordon (1985). Experiment 4 was conducted to examine this possibility by requiring the pronunciation of auditorily presented primes before the naming of target pictures.

CHAPTER V
EXPERIMENT 4

Method

Subjects

One hundred and twelve Michigan State University undergraduate students participated in this experiment in exchange for extra credit in an introductory Psychology course. None had participated in the previous experiments. All were native English speakers and had normal or corrected to normal vision. None professed to having hearing impairments.

Materials

The same lists employed in Experiment 2 were used in this experiment.

Procedure

The procedure was identical to that in Experiment 2 with the exception that the subjects were instructed to repeat aloud the words in addition to naming aloud the pictures. Since the interstimulus interval between the offset of the primes and the onset of the target pictures in both Experiments 2 and 3 was 500 milliseconds, the prime-target interstimulus intervals in this experiment were determined by adding 500 milliseconds to the duration of the recorded pronunciation for each of the primes. This duration was used as an estimate of the subjects' pronunciation durations for the primes. Thus, the target picture was presented after an interval equal to 500 milliseconds plus the duration of the prime word, with this interval timed from the end of the prime. This resulted in a mean interstimulus interval between the primes and targets of 981 milliseconds (range from 823 milliseconds to 1214 milliseconds).

Results

As in the previous experiments, trials in which an error occurred were eliminated from the analyses of the picture naming latencies. Thus, trials which contained an erroneous voice key triggering, a misrepetition of the prime, or misnaming of the target picture were not included. There was a total of 2,236 good naming times (83% of all responses). The number of correct responses for each subject per condition ranged from 1 to 3. As in the previous three experiments the times were analyzed with the factors of phonological relatedness, relative prime-target frequency and absolute target frequency. The results of the analyses are presented in Table 7 and Figure 6.

Once again there was only a significant main effect of absolute target frequency in both the subject and item analyses ($F(1,111) = 244.67$ and $F(1,22) = 15.97$, respectively). This reflected faster naming latencies for high frequency target pictures than for low frequency target pictures. The main effect of phonological relatedness was not significant in the subject analysis ($F(1,111) = .02$) or in the item analysis ($F(1,22) = 0$). In addition, the main effect of relative prime-target frequency was not significant in the subject or item analyses ($F(1,111) = .70$ and $F(1,22) = .24$, respectively).

Table 7. Experiment 4 picture naming latencies.

	High Frequency Targets	
	Higher Frequency Prime	Lower Frequency Prime
Unrelated	830 (12)	844 (21)
Related	836 (12)	863 (20)
	Low Frequency Targets	
	Higher Frequency Prime	Lower frequency Prime
Unrelated	1004 (15)	1025 (16)
Related	1013 (12)	984 (27)

Note. Error percentages for each condition are in parentheses. The percentages include all error categories, i.e., voice-key errors, target misnames, and prime repetitions.

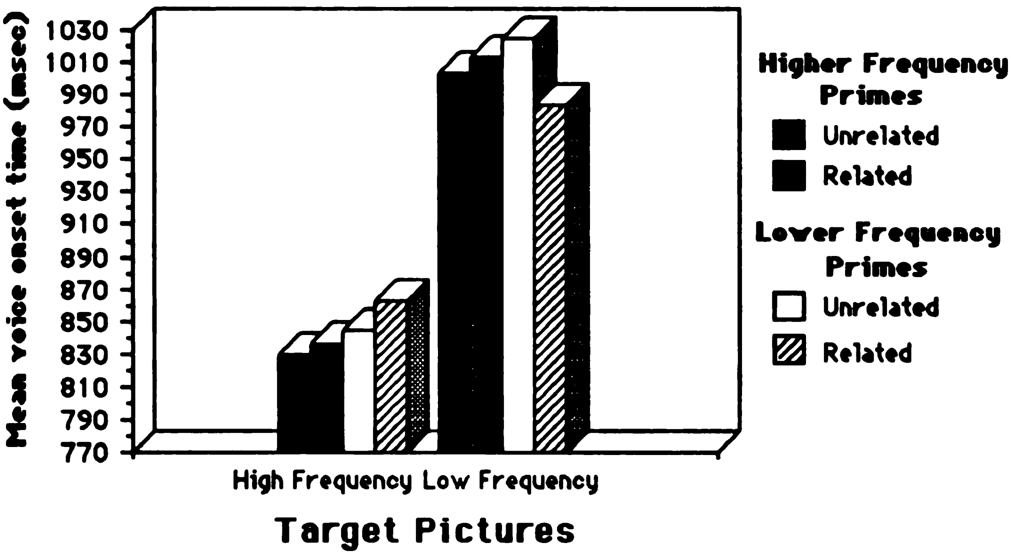

Figure 6. Graph of Experiment 4 picture naming latencies.

The interaction between phonological relatedness and relative prime target frequency was insignificant in the subject analysis (F(1,111) = .53) as well as in the item analysis (F(1,22) = .14). The interaction between phonological relatedness and absolute target frequency was not significant in the subject analysis (F(1,111) = 1.70) or in the item analysis (F(1,22) = 1.73). The interaction between relative prime-target frequency and absolute target frequency was also not significant by subjects (F(1,111) = .92) or by items (F(1,22) = 1.20). Furthermore, the interaction involving all three factors was not significant in the subject or item analyses (F(1,111) = 2.09 and F(1,22) = .54, respectively).

Errors Results

There were 143 voice key triggering errors (5% of all responses), and 81 target picture misnaming responses (3% of all responses). Consistent with the latency results, there were more misnaming responses for the low frequency targets (69) than for the high frequency targets (12). There were also 228 prime repetition errors (8% of all responses). More lower frequency primes (176) were misrepeated than higher frequency primes (52). The errors are presented in Table 8.

An analysis of variance was conducted on the total number of errors (i.e., 452) with the factors of phonological relatedness, relative prime-target frequency, and absolute target frequency. The results demonstrated a main effect of relative prime-target frequency in both the subject and item analyses ($F(1,111) = 33.90$ and $F(1,22) = 9.15$, respectively). This reflected more errors in the lower frequency prime conditions (283) than in the higher frequency prime conditions (169). The main effect of absolute target frequency was not significant in the subject ($F(1,111) = .89$) or item analyses ($F(1,22) = .16$). Furthermore, the main effect of phonological relatedness was not significant by subjects ($F(1,111) = 1.94$) or by items ($F(1,22) = .70$).

Table 8. Experiment 4 error results.

Condition	Voice key error	Misnamed target	Misnamed prime	TOTAL
		High Frequency Targets		
Prime Type				
Higher Unrelated (297)	19	2	18	39
Higher Related (295)	17	4	20	41
Lower Unrelated (266)	22	2	46	70
Lower Related (268)	19	4	45	68
		Low Frequency targets		
Prime Type				
Higher Unrelated (286)	20	20	10	50
Higher Related (297)	11	24	4	39
Lower Unrelated (281)	19	13	23	55
Lower Related (246)	16	12	62	90
TOTAL (2,236)	143	81	228	452

Note. The total number of correct responses out of 336 possible responses for each condition are in parentheses.

The interaction between phonological relatedness and relative prime-target frequency was significant in the subject analysis ($F(1,111) = 5.14$) but not in the item analysis ($F(1,22) = 1.29$). The interaction between phonological relatedness and absolute target frequency was not significant in the subject analysis ($F(1,111) = 1.52$) or in the item analysis ($F(1,22) = .70$). Likewise, the interaction between relative prime-target frequency and absolute target frequency was not significant by subjects ($F(1,111) = .01$) or by items ($F(1,22) = 0$).

The interaction involving phonological relatedness, relative prime-target frequency and absolute target frequency was significant in the subject analysis ($F(1,111) = 10.09$) but not in the item analysis ($F(1,22) = 1.82$). This interaction reflects the number of errors in the conditions involving low frequency targets. There were more errors occurring in the higher frequency unrelated prime condition (50) than in the higher frequency related condition (39) and more errors in the lower frequency related prime condition (90) than in the lower frequency unrelated prime condition (55). As Table 8 shows, the differences in the total number of errors for these conditions are mostly due to misrepetitions of the primes. Of the 90 errors that occurred in the lower frequency related prime condition for low frequency targets, 62 were misrepeated primes. The interaction thus reflects difficulties understanding the primes rather than naming the target pictures.

When the prime repetition errors were excluded from the analysis. there was a significant main effect of absolute target frequency ($F(1,111) = 11.58$) in the subjects analysis but not in the item analysis ($F(1,22) = 2.34$). This result relected more voice-key errors and target misnames for low frequency targets than for high frequency targets. No other main effects or interactions were significant in this analysis for either subjects or items.

Discussion

As in Experiments 2 and 3, primes that were phonologically related to the names of following target pictures did not significantly affect the time to name the pictures relative to phonologically unrelated primes. The only factor that was again found to influence the naming latencies for target pictures was the absolute frequency of the names. This contrasts with the findings of Experiment 1, where the primes were also pronounced before the naming of the target pictures. This suggests that the inhibition that was found in the first experiment was not due to the pronunciation of the primes.

However, the interval between the onset of the visual prime presentation and the onset of the target picture (i.e., the stimulus onset asynchrony or SOA) in the first experiment was estimated to be 1,060 milliseconds. In the present experiment, with auditory primes, this interval is estimated to be 1,845 milliseconds. This estimate is based on the average duration of the auditory primes (480 milliseconds) plus the time needed to begin to repeat the primes (mean pronunciation time = 385 milliseconds, range from 292 to 701 milliseconds, time is based on pilot subjects) plus the time for the subject's pronunciation of the prime (about 480 milliseconds) plus an additional constant time of 500 milliseconds. Thus, the difference in the SOAs of Experiment 1 and Experiment 4 is in part due to the difference in the interval from the subject's initiation of the pronunciation of the prime to the onset of the target presentation. In Experiment 1 this interval was 500 milliseconds, in Experiment 4 this interval was about 980 milliseconds. Although the results of Experiment 4 may suggest the pronunciation of the prime did not contribute to the inhibition observed in Experiment 1, the difference in the SOAs, of these two experiments do not rule out the possibility. This issue is addressed again in the General Discussion.

The overall mean correct recognition for the primes (i.e., identifying the prime as occurring once during the naming experiment), was 18 (range from seven to 24). The mean overall correct recognition for the fillers (i.e., correctly identifying the filler word as occurring twice during the naming experiment) was 14 . However, the greater overall recognition accuracy for the primes than the fillers may reflect a bias to respond with "once" rather than "twice" on the recognition test. The mean correct judged frequency for the primes was 2.42 and the mean correct judged frequency for the fillers was 3.64. The difference between these means is significant (t-test, $p < .01$).

Ninety-four of the 112 subjects claimed they noticed a sound relationship between some of the pictures and words in the naming experiment. Only 14 of the 94 subjects who noticed said they anticipated pictures sounding similar to the words. An analysis of the data from the 94 subjects was carried out to determine whether their awareness of the sound relationship affected the naming latencies for the pictures. However, as in the results of the primary analyses, there was only a significant main effect of absolute target frequency in both the subject and item analyses ($F(1,93) = 215.84$ and $F(1,22) = 17.66$, respectively). This effect, once again, reflected faster naming times for high frequency target pictures than low frequency target pictures. No other main effects or interactions were significant in either the subject or item analyses.

CHAPTER VI
GENERAL DISCUSSION

Experiment 1 was conducted to examine whether prime words would inhibit or facilitate the production of phonologically related target picture names relative to unrelated target picture names. Dell's (1986) production model predicts facililtation for phonologically related prime-target pairs since there is no inhibitory mechanism within this model that operates within a neighborhood of competing activated lexical representations. However, a review of word recognition studies involving form-related prime target pairs, in addition to picture-naming studies with phonologically related pairs, suggests phonological representations may become inhibited during production. Furthermore, the findings from the lexical decision studies of Colombo (1986) and Segui and Grainger (1990) suggest that the form-related priming effects resulting from processes during word recognition are complex. Specifically, form-related priming effects may be both facilitatory and inhibitory and seem to interact with word frequency.

Two recently proposed models, one by Lukatela and Turvey (1990) and the other by Peterson, O'Seaghda and Dell (1989), offer an account of Colombo's findings of facilitation for low frequency targets and inhibition for high frequency targets. Both models maintain that form-related effects found in naming and lexical decision studies are a result of the processing of phonological representations.

The models differ in their account of the locus of inhibitory and facilitatory effects. The Lukatela and Turvey model attributes inhibitory effects to an intra-word-level inhibitory mechanism, whereas Peterson et al. place the locus of the inhibitory effects at the phonological segment level. Neither of these models account for Segui and Grainger's findings, which suggest it is the relative frequency of the related prime-target pair rather than the absolute frequency of the target alone that determines the occurrence of inhibition. In particular, their results showed that targets preceded by higher frequency related primes are facilitated whereas targets preceded by lower frequency related primes are inhibited relative to unrelated primes.

Experiment 1 did reveal reliable inhibition for naming target pictures when they were preceded by phonologically related primes. This inhibition was not significantly modified by prime frequency, although it was somewhat greater for target pictures preceded by lower frequency related primes than for target pictures preceded by higher frequency related primes.

These effects may be attributable to an intra-word-level inhibitory mechanism, such as that proposed by Lukatela and Turvey, or to competition among phonological segments for the establishment of a phonological representation, as proposed by Peterson, O'Seaghda and Dell. However, Experiment 1 did not control for the factor of absolute target frequency, which is the only frequency factor that is claimed to influence the occurrence of phonological inhibition in both of these models. Thus, the remaining three experiments included absolute target frequency in addition to the factors of phonological relatedness and relative prime-target frequency.

Experiment 2 examined the effects of auditorily presented phonological primes on the naming of following target pictures. Subjects in this experiment named aloud the target pictures but did not pronounce the prime words. The results demonstrated no effect of phonological relatedness on the naming of the target pictures. Only absolute target frequency reliably affected the naming latencies, with faster naming latencies for the high frequency target pictures than for the low frequency target pictures.

Since the phonological representation from the auditorily presented primes seemed not to affect the naming latencies for related targets on its own, Experiment 3 examined the possibility that the inhibitory effects observed in Experiment 1 were a result of processing an orthographic representation of a related prime. Thus, the primes were again presented visually but were not pronounced before the naming of the target pictures. Once again there was no effect of phonological relatedness on the naming of target pictures.

Experiment 4 examined the possibility that the inhibitory effects observed in the first experiment were due to the pronunciation of the related primes. The primes in Experiment 4 were presented auditorily and subjects repeated them before naming the target pictures. No reliable effects of phonological relatedness were found. Thus, the results of Experiments 2, 3 and 4 suggest that phonological primes neither inhibit nor facilitate the production of names for following target pictures, when different target frequencies and relative frequencies of primes and targets are equally represented in an experimental list, so that no subject contributes disproportionately to these conditions.

The consistent effects of the frequency of occurrence of the name used for the target pictures suggest that selection from a level that is sensitive to word frequency occurred during the picture naming process. The effects of frequency are comparable to previous findings of Oldfield and Wingfield (1965) and Wingfield (1968). However, Clark and Clark (1977) argued that the frequency effects observed for picture naming latencies by Wingfield were not due to the frequency of occurrence of the names for the pictures, but rather to the typicality of the pictured objects.

There is some suggestion that this may be true in the present experiments as well. The Snodgrass and Vanderwart (1980) picture norms provide familiarity ratings for the target pictures. These ratings are based on the raters' opinions of the frequency with which they come in contact with, or think about the concept of the depicted objects (the rating scale ranges from one, or low familiarity, to five, or high familiarity). The mean familiarity ratings for the low and high frequency target picture groups are 3.40 and 4.33, respectively. The difference between these means is significant (unpaired t value = 2.75, p= .01 for a two-tailed test).

To examine whether the familiarity of the target pictures may have influenced their naming latencies, the overall mean latency for each target picture was calculated from the means across all conditions in Experiments 2, 3, and 4, which controlled for absolute target frequency. The mean latencies were then correlated with the pictures' familiarity ratings and the absolute frequency of their names. A higher correlation was found with familiarity (r = -.63) than with frequency (r = -.42). In addition, the partial correlation between between familiarity and the mean latencies with frequency held constant was higher than the partial correlation between frequency and mean latencies with familiarity held constant (r = .57 and r = -.26, respectively). Thus, these correlations suggest familiarity may affect picture-naming latency more than the frequency of the name.

By controlling for the factor of absolute target frequency in Experiments 2 through 4 the inhibitory effects found in Experiment 1 were eliminated. A post hoc examination of the means (both subject and item) for the first experiment, separated according to absolute target frequency, revealed large inhibitory effects for the low frequency targets preceded by related primes. For low frequency targets, the inhibitory effect for lower frequency primes was 92 milliseconds compared to 74 milliseconds for higher frequency primes. In contrast, the inhibitory effects for the high frequency targets were relatively small, 30 milliseconds, for lower frequency and zero for higher frequency primes. Of the 12 low frequency targets, ten showed an overall inhibitory effect (collapsed across the lower and higher frequency prime conditions) and 6 of these showed an overall inhibitory effect that was greater than 100 milliseconds (crown, rabbit, fork, barrel, pear, and sock). However, an examination of these items' means in Experiments 2, 3, and 4 did not reveal a consistent pattern of inhibition.

The inhibition observed in Experiment 1 may have been a consequence of the unequal distribution of the low frequency targets across relative frequency and relatedness conditions. The unequal distribution could have affected the subjects' performance in the naming task. This possibility is currently being examined in an experiment that employs the same procedure and materials as Experiment 1, with the list arrangement of the subsequent experiments.

As noted in the introduction, the results of phonological priming studies employing a variety of tasks have been quite variable. The results of the present experiments are consistent with this variability. Hillinger (1980) found reliable facilitation for form-related targets in a lexical decision task, whereas Martin and Jensen (1988) did not. Colombo (1986) and Peterson et al. reported inhibition in lexical decision and naming tasks, respectively, in which absolute target frequency was controlled. However, Peter, Lukatela and Turvey (1990) failed to find phonological priming (inhibitory or facilitatory) in a naming task in which they also controlled for absolute target frequency. Since, the study by Segui and Grainger (1990) did not include absolute target frequency as a variable, it remains to be seen whether their results can be replicated when target frequency is considered along with relative prime frequency. Although Experiments 2 through 4 failed to replicate the Segui and Grainger findings, picture naming may be and probably is different from visual word naming in important respects.

The inconsistency in the findings of phonological priming may in part be due to variations in the stimulus onset asynchrony (SOA) between the prime-target pairs. Lupker and Colombo (1990), employing a lexical decision task, replicated Colombo's findings at a 315 millisecond SOA. At a shorter 140 millisecond SOA, only inhibition was observed for both high frequency and low frequency related targets. However, in a naming task employing both the 315 and 140 millisecond SOAs, there was no evidence of inhibition at either SOA, but there was small but significant faciltation for both high and low frequency targets at the 315 millisecond SOA.

The intervals between the prime-target pairs in the present study were not consistent across the four experiments. In Experiment 1, the interval from the onset of the prime to the onset of the target was approximately 1060 milliseconds. This estimation is based on the average time needed to begin to pronounce the visual primes (i.e., 560 milliseconds) plus the 500 millisecond delay from the voice-key triggering of the pronunciation to the picture presentation, incorporated in the experiment. In Experiment 2, the interval from the onset of the auditorily presented primes to the onset of the target presentations was approximately 980 milliseconds. Since the target presentation occurred 500 milliseconds from the offset of the primes, the interval varied according to the duration of the different primes (the average equals 480 milliseconds). The interval from the onset of the visual primes to the onset of the target pictures in Experiment 3 was 980 milliseconds and did not vary.

The interval in Experiment 4, as in Experiment 1, required the pronunciation of the primes before the target presentations. The interval from prime repetition to the onset of the target presentation was set in the experiment by adding 500 milliseconds to the duration of the recorded pronunciation for each of the primes. Thus, approximately 980 milliseconds from the triggering of the voice-key by the prime's pronunciation, the target picture appeared. However, the interval measured from the onset of the auditorily presented prime to the onset of the target picture includes not only this 980 milliseconds, but the duration of the prime and the time needed to begin to repeat it. Based on the repetition latencies for ten pilot subjects, the amount of time needed to begin to repeat the primes is 385 milliseconds (range from 292 to 701 milliseconds). This time added to the 980 milliseconds, plus the 480 millisecond average duration of the recording, results in an approximate interval of 1,845 milliseconds or nearly 2 seconds.

Thus, the range from the onset of the primes to the onset of the target pictures in the present experiments is from 980 milliseconds to about 2 seconds. This range is above the SOAs Lupker and Colombo found to be of importance, but their study employed word prime-target pairs rather than word-picture pairs and there was no pronunciation of the primes. Since the processing involved in picture naming involves at least a stage of identification or categorisation followed by the retrieval or assembly of the phonological word appropriate to the identification (Huttenlocher and Kubicek, 1983; McCauley, Parmalee, Sperber and Carr, 1980; Clark and Clark, 1977; Oldfield and Wingfield, 1964, 1965; Wingfield, 1968), the critical stimulus onset asynschronies (if there are such) may be expected to differ from those found to influence phonological priming in word pronunciation. However, as mentioned in the introduction, a study by Schriefers, Meyer, and Levelt (1990) found facilitatory phonological priming effects at very short SOAs (i.e., 0 and 140 milliseconds) during picture-naming. Further examination of the influence of SOAs in production tasks of phonological priming in production tasks may be important research for the future.

Conclusion

As stated in the introduction, the ability to produce rapid and relatively error-free speech suggests that word production is a result of highly accurate selection mechanisms. In theories of production, the expression of an intended message proceeds through two major levels (e.g., Fromkin, 1971; Garrett, 1980; Kempen and Hujibers, 1983; Dell, 1986; Bock, 1987b; Levelt, 1989). The first level involves the selection, from approximately thirty thousand lexical items, words that are appropriate to the intended meaning. The next level involves the retrieval or assembly of the phonological representation for the lexical item that will guide the preparation for its overt expression. Since the rate of spontaneous speech can range from two to five words per second (Levelt, 1989; Levelt, Schriefers, Vorberg, Meyer, Pechmann, and Havinga, 1990) the selection mechanisms operating at these two levels are not only accurate but highly efficient.

The present research focused on the influence that phonological priming may have on mechanisms of selection at the phonological level. Dell's (1986) production model incorporates the mechanism of spreading activation within a network of lexical representations. The spread of activation in this network allows for selection at one level to prime selection at other levels. Thus, to the extent that phonological priming influences the activation of levels involved in phonological encoding, it was expected that the present experiments might reveal these influences. However, the results demonstrated inconsistent effects of phonological priming.

Since an important goal of production is to convey meaning, the top-down operations that effect selection at the first level of production may result in a flow of activation that is little perturbed by fluctuations in activation levels at lower levels of encoding. For example, the process of nodes becoming "current" in Dell's (1986) model, which regulates word selection, is one reflection of this top-down flow of activation. Although variations in activation levels can result in the selection of incorrect lexical representations, this is a relatively rare occurrence, as the error-rate for spontaneous speech domonstrates. Thus, although the bottom-up effects of phonological priming may change the activation levels of phonological representations, this influence may be to weak to reliably manifest itself in the process of picture naming. Although it is essential to examine whether factors, like the interval between prime and the production of a target affect phonological priming in picture naming, it may be that the architecture of normal word production heavily dampens the effects of noise in the word form system.

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APPENDIX

APPENDIX

Experimental items

Lower Frequency Primes		High Frequency Pictures	Higher Frequency primes	
Unrelated	Related		Related	Unrelated
FROWN	DOT	dog	DOOR	MONTH
NUDGE	STARK	star	START	FACE
RANT	KEEN	key	KEEP	FAR
THRILL	HORDE	horse	HOUSE	SCHOOL
RAT	BUMP	bus	BUILD	SEND
FLICK	SUB	sun	SUCH	THINK
BLOOM	CALF	cat	CAMP	PLEASE
SPIT	TRAY	tree	TRUE	STAGE
FLUB	CHAMP	chair	CHANGE	QUITE
GATE	BEND	bed	BEST	CLASS
PAVE	DREAD	dress	DRAW	FULL
LIZARD	PENDANT	pencil	PERSON	MOMENT
		Low Frequency Pictures		
TRICKY	CANKER	carrot	CAREFUL	SURVIVE
CLINK	SHIRK	shirt	SHORT	SPACE
RAY	FORGE	fork	FORCE	GIRL
PANTRY	RABID	rabbit	RATHER	MANNER
BAIT	PANG	pear	PARK	FAITH
MEMO	BERRY	barrel	BASIC	TRIAL
FELON	SANDAL	sandwich	SAMPLE	PERFORM
JEWEL	CANNON	candle	CAPTAIN	SOLDIER
SAP	FRAUGHT	frog	FRONT	LORD
KIT	SOP	sock	SONG	POOL
LOUSE	FIG	fish	FILL	PLANT
BRAID	CRUMB	crown	CROWD	THROAT