Journal of Experimental Psychology:
Learning, Memory, and Cognition
1999, Vol. 25, No. 2, 318–344

Copyright 1999 by the American Psychological Association, Inc.
0278-7393/99/$3.00

Semantic and Phonological Information Flow in the Production Lexicon

J. Cooper Cutting and Victor S. Ferreira
University of Illinois at Urbana-Champaign

When speakers produce words, lexical access proceeds through semantic and phonological levels of processing. If phonological processing begins based on partial semantic information, processing is *cascaded;* otherwise, it is *discrete.* In standard models of lexical access, semantically processed words exert phonological effects only if processing is cascaded. In 3 experiments, speakers named pictures of objects with homophone names (*ball*), while auditory distractor words were heard beginning 150 ms prior to picture onset. Distractors speeded picture naming (compared with controls) only when related to the nondepicted meaning of the picture (e.g., *dance*), exhibiting an early phonological effect, thereby supporting the cascaded prediction. Distractors slowed picture naming when categorically (e.g., *frisbee*) related to the depicted picture meaning, but not when associatively (e.g., *game*) related to it. An interactive activation model is presented.

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

It is easy to take our speaking ability for granted. We produce approximately 150 words per minute, while only making an estimated one error for every 1,000 words (Levelt, 1989). Given a thought to convey, a speaker must translate the conceptual structure corresponding to that thought into a linguistic expression. As a speaker utters a sentence, each word of that sentence must be retrieved from a lexicon consisting of an estimated 30,000 lexical items. For each word that is said, the speaker must retrieve the grammatical information that is used to order the word in a sentence and the phonological information that is needed to articulate that word. In this article, we focus on this process of word retrieval or *lexical access.*[1] Specifically, we present four experiments and a computational model that help reveal the representations and processes that underlie lexical access.

J. Cooper Cutting and Victor S. Ferreira, Department of Psychology, University of Illinois at Urbana-Champaign.

Portions of this work were presented at the 9th Annual CUNY Conference on Human Sentence Processing, New York, March 1996 and at the 68th annual meeting of the Midwestern Psychological Association, Chicago, May 1996. This research was supported by National Science Foundation Grants SBR 93-19368 and SBR 94-11627, and by National Institutes of Health Grant R01-HD-21011. Victor S. Ferreira was supported by a Natural Sciences and Engineering Research Council (Canada) Postgraduate Scholarship. We thank Gary Dell, Zenzi Griffin, Karin Humphreys, Wido La Heij, Steve Lupker, and Linda Wheeldon, and two anonymous reviewers for helpful discussions and comments on this article and Danielle Holthaus for assistance in collecting data. Kathryn Bock served as a graduate advisor for this research.

Correspondence concerning this article should be addressed to J. Cooper Cutting, who is now at the Department of Psychology, Illinois State University, Normal, Illinois 61790-4620, or to Victor S. Ferreira, who is now at the Department of Psychology, 0109, 9500 Gilman Drive, University of California at San Diego, La Jolla, California 92093-0109. Electronic mail may be sent to J. Cooper Cutting at cutting@main.psy.ilstu.edu or to Victor S. Ferreira at ferreira@psy.ucsd.edu.

Lexical Access and Lexical Representations

In language production, lexical access takes as input a conceptual representation of the word to be uttered, and provides as output a phonological representation of that word. Over the past 25 years, observational, computational, and experimental investigations have further suggested that en route to computing a phonological output representation, lexical access also proceeds through an intermediate level of representation. Among production researchers, a strong consensus has developed that this intermediate level of representation has two important properties: First, this level encodes grammatical information, such as whether a retrieved word is a noun or verb (Bock, 1982; Levelt, 1989), and for languages that encode grammatical gender, what the gender of a retrieved word is (Badecker, Miozzo, & Zanuttini, 1995; Vigliocco, Antonini, & Garrett, 1997). Second, and of particular relevance to the present work, this level of representation is temporally intermediate, in that the bulk of processing related to the intermediate level of representation occurs prior to the processing that is related to the final, phonological level of representation. Thus, lexical access can be characterized as occurring through two stages, the first mapping a semantic representation onto an intermediate, grammatical representation, and the second mapping this intermediate representation onto a final phonological representation. We refer to the intermediate representations of individual words as *lemmas* (Kempen & Huijbers, 1983; Levelt, 1989) and the component of lexical access that retrieves lemmas as the *semantic processing* component.[2] We refer to the final, phonological representations of words as *phonological word forms,* and the component of lexical

[1] Of course, lexical access occurs as (at least partially overlapping) comprehension and production processes, which could be labeled *lexical access in comprehension* and *lexical access in production.* Because of the focus of this research, we use the generic term *lexical access* to refer to the production process, unless we specifically refer to *lexical access in comprehension.*

[2] Note that this is different from other definitions of *semantic processing,* which involve the activation of semantic information.

access that retrieves these word forms as the *phonological processing* component.

Although evidence from investigations of the *tip-of-the-tongue* state (Brown & McNeill, 1966; Meyer & Bock, 1992; Vigliocco et al., 1997), speech errors (Garrett, 1975; Martin, Dell, Saffran, & Schwartz, 1994), and electrophysiological studies (van Turennout, Hagoort, & Brown, 1997) has suggested that lexical access proceeds generally from a dominantly semantic stage to a dominantly phonological stage of processing, investigations using experimental techniques specifically designed to reveal the time course of lexical access have precipitated a lively debate concerning the precise interactions that occur between the semantic and phonological processing components of lexical access (Dell & O'Seaghdha, 1991; Levelt et al., 1991; Peterson & Savoy, 1998; Schriefers, Meyer, & Levelt, 1990). The present investigation builds on this prior work and provides additional evidence relevant to this debate, so we describe in some detail the points of contention that have arisen.

Discrete Versus Cascaded Processing

As mentioned, all approaches to lexical access in production agree that the bulk of semantic processing occurs prior to phonological processing. However, one point of contention concerns whether this temporal precedence is strict, in that semantic processing must be completed before phonological processing can begin. Such a model claims that the stages of lexical access are *discrete*. Alternatively, phonological processing might begin on the basis of partial information, before semantic processing ends, suggesting that the stages of lexical access proceed in *cascade* (McClelland, 1979). Garrett (1988) and Levelt (1989) have argued for discrete models of lexical access in which semantic processes must select a single lemma before processing can begin at the phonological level. Alternatively, Dell (1986), MacKay (1987), and Stemberger (1985) have proposed interactive–activation based models in which processing proceeds in cascade, so that phonological processing begins on the basis of early partial information provided by semantic processes (see also Dell & Reich, 1981; Harley, 1984; and Humphreys, Riddoch, & Quinlan, 1988).

Cascaded processing systems have the benefit that processing begins at each level as soon as possible, speeding the entire retrieval process. However, this benefit comes with a cost: In a cascaded system, late-stage lower level representations may become active as the result of active early-stage higher level representations that subsequently get ruled out, increasing the possibility of error (e.g., Dell, 1986). On the other hand, the claim of discrete models of lexical access that phonological processing cannot begin until semantic processing ends implies that only a single lexical candidate—the candidate that is selected upon completion of semantic processing—receives subsequent phonological processing.

Another way to consider the issue is to focus on the notion of *selection*. In production, lexical access operates by activating a number of lexical candidates (lemmas) that can encode a concept, moving toward the singling out and eventual articulation of the one lemma that best encodes that concept. Once determined, that candidate is selected; in activation-based approaches, a selected candidate receives additional activation that allows it to undergo (in discrete models) or dominate (in cascaded models) subsequent phonological processing. In either approach, only (and for the most part, all) selected lemmas are ultimately pronounced. The approaches make different predictions, however, concerning the phonological effects of lemmas that are not selected. According to discrete models, only selected lemmas affect phonological processing. In contrast, according to cascaded models, selected lemmas as well as merely activated but unselected lemmas can affect phonological processing. Thus, the relatively extended processing of ultimately unselected material is characteristic of cascaded models but not of discrete models. As described later, the prediction of cascaded models—that semantically processed but unselected material should also undergo phonological processing—has been the focus of much empirical scrutiny.

Competitive and Associative Relations

An important issue that emerges as a result of the experiments reported here concerns the representation of competitive and associative relations among words in the production lexicon. Words like *turtle* and *frog* are competitively related, in that they have similar semantic preconditions—they are accessed by similar sets of features. Competitively related words like these have been shown to exert an interfering effect on one another in certain picture naming tasks (La Heij, Dirkx, & Kramer, 1990; Levelt et al., 1991; Lupker, 1979; Schriefers et al., 1990; Wheeldon & Monsell, 1994). On the other hand, words like *frog* and *pond* are associatively related, in that they are not semantically similar (they are not accessed by similar sets of features), but rather, they are words that correspond to concepts that occur in similar situations, and the words are relatively likely to be used together in an utterance. The evidence is less clear concerning the mutual effect of associatively related words during picture naming; most investigations find that associatively related words facilitate one another but only under specific circumstances (La Heij et al., 1990; Wheeldon & Monsell, 1994; but see Lupker, 1979). Experiment 3 helps to clarify the independent contributions of associative and competitive relations in the production lexicon, and the results are used to detail a model of lexical access, which is presented in the General Discussion.

Prior Research on the Discrete Versus Cascaded Nature of Lexical Access

Whether the semantic and phonological components of lexical access process information discretely or in cascade has been the subject of much recent empirical work. Schriefers et al. (1990; see also Corina & Lostutter, 1996) had speakers provide the names of line-drawn objects while ignoring auditorily presented distractor words. They manipulated the type of relationship between the pictures and distractor words, as well as the time lag (referred to as the *stimulus onset asynchrony,* or SOA) between the onset of the

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

distractor word and the presentation of the picture. The results of these experiments showed that when the distractors were presented early (150 ms prior to the onset of the picture), semantically related words (e.g., the distractor *goat* for a picture of a sheep) interfered with picture naming, relative to an unrelated control distractor condition. When the words were presented later (simultaneous with or 150 ms after the onset of the picture), no interference was observed with semantic distractors. However, phonologically related words (e.g., the distractor word *sheet* for a picture of a sheep) facilitated picture naming only at these later SOAs (0 and 150 ms), and not early, when presented 150 ms before the picture. Thus, effects of semantic distractors are seen early during the process of naming a picture, whereas effects of phonological distractors are seen late, supporting the general notion that semantic processing precedes phonological processing. Furthermore, at no SOA were both semantic and phonological effects seen, suggesting that lexical access completes semantic processing before beginning phonological processing, which supports a discrete lexical access model.

Using a related procedure, Levelt et al. (1991) provided additional evidence that lexical access proceeds discretely. In their experiments, speakers simply named pictures on most trials. However, after presentation of, but prior to the naming of certain critical pictures, speakers heard an auditory probe word or nonword to which they made a lexical decision. These probe words either came very early after the onset of the picture (an average of 73 ms), or after longer delays (373 and 673 ms). In addition to the SOA manipulation, the researchers manipulated the relationship between the critical pictures and the probes. As in Schriefers et al.'s (1990) experiment, the probe could be phonologically related or semantically related to the picture to be named (e.g., *sheet* or *goat* for a picture of a sheep). In addition, the probe word was sometimes phonologically similar to a semantically related item—a semantically mediated phonological probe (e.g., *goal*). They predicted that if semantic and phonological processing cascade, then when naming a picture of a sheep, the semantic similarity between *sheep* and *goat* should cause the *goat* lemma to receive partial activation, which in turn, should cause the *goal* phonological word form to become active, much like *sheet* becomes active for *sheep.* Thus, if processing cascades, mediated priming should occur. On the other hand, if processing is discrete, then the partial activation of the *goat* lemma should not activate the *goat* or *goal* phonological word forms, and mediated priming should not occur. For the nonmediated probes, they found that lexical decision times for semantically related words (*goat* for *sheep*) were affected at early SOAs, but not at later SOAs, and that lexical decisions for phonologically related words (*sheet*) were affected at all SOAs, generally supporting the claim that semantic processing precedes phonological processing. Of importance here, there was no reliable effect of the mediated prime words—lexical decisions to the probe word *goal* presented with a picture of a sheep were no different from those for an unrelated word paired with the picture. These results suggest that partially activated lemmas do not pass on activation to a set of word forms that are phonologically similar to one another, supporting a discrete model of lexical access.

In response to Levelt et al. (1991), Dell and O'Seaghdha (1991) presented a simulation of a model of lexical access in which semantic and phonological processes cascade. They made two main points: First, because interaction between processing levels is relatively constrained, most semantic processing occurs early, whereas most phonological processing occurs late, even when activation cascades between levels. Thus, any effects of a phonologically related word will be small and difficult to detect early in the course of lexical access (as in the early SOA condition of Schriefers et al., 1990). Second, the phonological word forms of the mediated primes (e.g., *goal* for *sheep*) will receive only minuscule amounts of activation, essentially because of diminishing returns: The *goat* lemma receives only a fraction of the activation that the *sheep* lemma receives when naming a picture of a sheep, and the *goal* lemma receives only a fraction of that fraction. Thus, an effect of a mediated prime will be difficult to detect at any point during lexical access. Overall, the evidence cited thus far in support of discrete processing in lexical access might instead be due to the difficulty in detecting these small amounts of activation. This analysis raises the possibility that evidence for cascaded semantic and phonological processing might be revealed if the relationship between the target items and the distractor or probe words is especially strong.

Peterson and Savoy (1998) presented several experiments that used a modified version of the task of Levelt et al. (1991). Again, speakers simply named pictures on most trials, but on critical trials, speakers named a visual word presented in the center of the picture. The critical pictures were of objects with names that have near synonyms (e.g., *couch* and *sofa*). The authors hypothesized that the semantic relationship between these near synonyms is sufficiently strong to result in semantically mediated phonological priming. That is, unlike *sheep* and *goat,* which are highly related but distinct, *couch* and *sofa* are nearly interchangeable, and thus the lemmas of the two words are likely to have maximally overlapping semantic preconditions (note that despite their semantic similarity, *couch* and *sofa* have distinct lemma representations, because they could in principle be grammatically distinct, and because each must enable access to different phonological information). Thus, both lemmas should be highly active during lexical access, and provided that processing is cascaded, phonological word forms that are phonologically similar to the two alternatives (e.g., *count* and *soda*) should receive detectable partial activation. Results showed that at early SOAs, semantically mediated phonological primes (e.g., *soda* when speakers named a picture of a couch with *couch*) were named more rapidly than unrelated control words. Jescheniak and Schriefers (1998) tested the same kind of materials (in Dutch), and found a similar pattern of results, using the picture–word interference task used in Schriefers et al. (1990). In accordance with the prediction of a cascading model, the results of both studies suggest that phonological properties of a

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

semantically processed but unselected lexical item can influence lexical access performance.

Like the experiments of Peterson and Savoy (1998), the experiments reported here tested a stronger relationship between picture targets and distractor words than was used in previous experiments. However, rather than examine a strong semantic relationship, the present experiments investigated the consequences of presenting distractors that are semantically related to words that bear a strong phonological relationship to target pictures.

The experimental task was identical to the picture–auditory word task of Schriefers et al. (1990) and Jescheniak and Schriefers (1998), in which speakers named a line-drawn picture as an auditory distractor was presented. The logic behind this task was described by Bock (1996). After visual analysis, the picture stimulus activates the depicted entity's conceptual structure (along with related concepts), eventually leading to the selection of its lemma (marking the end of semantic processing). Selection of this target lemma causes that lemma to undergo phonological processing and become pronounced (marking the end of phonological processing). As this process unfolds, the auditory distractor attempts a "surgical strike"—the auditory stimulus injects activation into production system representations as the normal lexical access process unfolds, revealing relationships among the distractor-relevant and target-relevant production system representations. (Note that by most accounts, the auditory distractor's lemma is not selected, as selecting a lemma usually leads to pronunciation of the selected word.) Furthermore, features of the time course of the lexical access process can be elucidated by determining when, during the lexical access process, distractors with particular relationships to the target are effective. In the present experiments, we investigated whether distractors that bear a strong phonological relationship to target pictures affect naming at a point in lexical access during which semantic relationships are known to be effective. If the phonologically related distractor affects picture naming at the same time as a semantically related distractor, then evidence for an overlapping time course of semantic and phonological processing is revealed and cascading is implicated. If phonological effects are not seen at the same time as semantic effects, then evidence that semantic and phonological processing occur with distinct time courses is revealed, and a discrete processing system is supported.

To investigate whether strong phonological relationships might reveal overlapping semantic and phonological processing, we had speakers name pictures of objects that have names that express more than one meaning. That is, the pictures' names were homophones, like *ball* (which can express the notion of a round toy or a formal dance). Figure 1 presents a simplified model of the lexicon, within which different homophone meanings have different lemmas (because they are distinct grammatical words) but share phonological word forms (because they sound the same; see Griffin, 1995, and Jescheniak & Levelt, 1994, for evidence that homophone pairs share phonological representations). The figure illustrates the difference between homophones, which are only phonologically identical to one another, and words like *frog* and *frost* that Schriefers et al. (1990) used, which are phonologically similar. As is the case with near synonyms for semantic relationships, homophone representations maximize the degree of overlap between the phonological representations of distinct lexical items, and thus afford the opportunity to test the claim that activation cascades to a phonological level of processing during lexical access.

In all of our experiments, speakers named pictures of

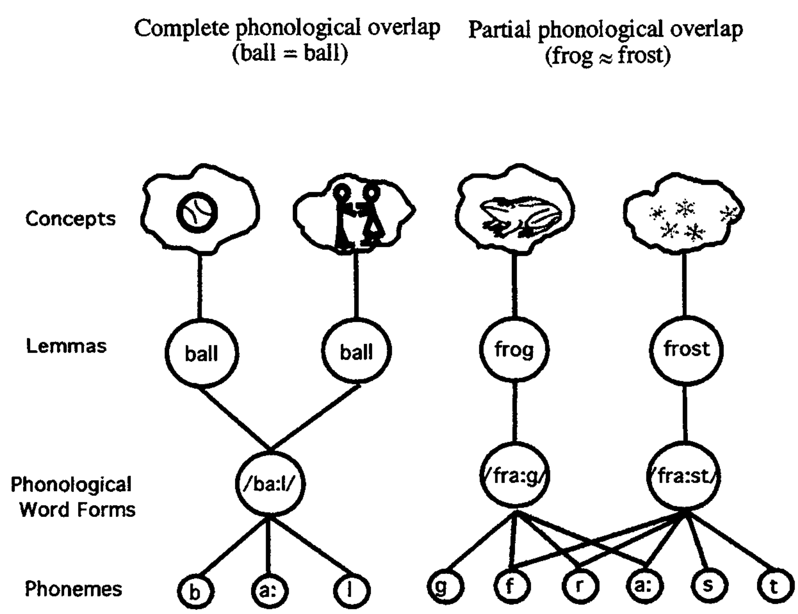

Figure 1. A simplified model of the lexical access system representing *ball, frog,* and *frost.*

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

objects with homophone names while auditory distractor words were presented at the early SOA. In Experiments 1 and 2, the auditory distractor word either was semantically related to the depicted meaning of the object (an *appropriate-meaning* distractor, as in *game* for a picture of a toy ball), mimicking the semantic condition of Schriefers et al. (1990); was semantically related to the nondepicted meaning of the pictured object's name (an *inappropriate-meaning* distractor, as in *dance* for a picture of a toy ball); or, as a control, was unrelated to the picture. Because the word *dance* is semantically related to a word that is phonologically identical to the pictured *ball,* evidence that *dance* affects the time a speaker takes to name a picture of a toy ball implies that phonological processing is involved.

Of course, as shown by Schriefers et al. (1990), simple evidence showing that distractors are phonologically processed and affect production performance is compatible with both discrete and cascaded accounts. Indeed, in Schriefers et al., the fact that semantic distractors only affected naming time at an early SOA but phonological distractors only affected naming time at later SOAs was taken to support a discrete characterization of lexical access; if semantic and phonological effects had both been seen at the early SOA, lexical access would have been better characterized as cascaded. This suggests how the present experiments can distinguish between discrete and cascaded characterizations of lexical access. Because we tested the early (-150 ms) SOA, at which semantically related distractors are normally effective, we expected the appropriate meaning distractors (e.g., *game* for a picture of a toy ball) to have the same interfering effect in our experiments that they did in Schriefers et al. If the inappropriate-meaning distractors (like *dance*), which bear a phonological relationship to the target picture (through the alternative meaning of the picture name) are ineffective at this early SOA but semantic distractors produce interference, then the results of these experiments would converge with those of Schriefers et al., in that the experiments would provide no evidence that phonological processing occurred simultaneously with semantic processing. However, if both inappropriate-meaning and appropriate-meaning distractors affect picture naming times at this early SOA, then the cascaded model's claim that lexical retrieval operates with overlapping semantic and phonological processing is supported.

Experiment 1

The first experiment tested the cascaded versus discrete nature of lexical access by examining whether semantic and phonological processing show evidence of temporal overlap during the production of homophones. We presented speakers with pictures of objects with homophone and nonhomophone names and measured latencies to produce the names of the pictures. An auditory distractor word was presented 150 ms before the onset of the picture. For pictures with nonhomophone names (e.g., *frog*), distractor words were either semantically related (*turtle*), phonologically related (partial phonological overlap, like *frost*), or unrelated (e.g., *hammer*), replicating the distractor conditions that were used by Schriefers et al. (1990). As in the Schriefers et al. early SOA condition, both the discrete and cascading models predict interference with semantic distractors and little or no effect of phonological distractors (relative to the unrelated distractors).

For the pictures of objects with homophone names (say, of a toy ball), distractor words were semantically related to the depicted (appropriate-meaning) meaning of the homophone (*game*), semantically related to the nondepicted (inappropriate-meaning) meaning of the homophone (*dance*), or unrelated. Both models predict that inappropriate-meaning distractors, like all distractors, are semantically processed. However, according to discrete approaches, any semantic effects of the distractor should be restricted to a semantic level of processing. Because the inappropriate-meaning distractors are related to the homophone target pictures through the phonological relationship afforded by the target's name, discrete approaches predict that such distractors should be ineffective. Cascaded approaches allow simultaneous semantic and phonological processing, so a phonologically mediated effect of a semantically processed inappropriate-meaning distractor was predicted.

Method

Participants. Thirty-nine members of the University of Illinois community participated for either class credit or payment. All were native speakers of English.

Materials and design. Twenty-seven black-and-white line drawings of objects with homophone names were selected from the norming study of Ferreira and Cutting (1997). Each picture was paired with an appropriate-meaning and an inappropriate-meaning distractor word. Appropriate-meaning distractors were semantically related to the depicted meaning of the homophone picture, whereas inappropriate-meaning distractors were related to the nondepicted meaning of the name of the homophone picture. Distractors were chosen from the association norms of Twilley, Dixon, Taylor, and Clark (1994) or were coordinate terms of the picture names as specified in WordNet 1.5 (1996). Figure 2 shows an example picture with its distractors.

In addition to the homophone pictures, 27 nonhomophone pictures were selected from Snodgrass and Vanderwart's (1980) set. These pictures were also paired with two types of distractor words: phonologically related distractors and semantically related distractors. The phonological distractors and targets shared number of syllables, stress pattern, and their two initial segments and stressed vowel (there were two exceptions that only satisfied some of these constraints: *apple–anchor, horse–house*). Semantic distrac-

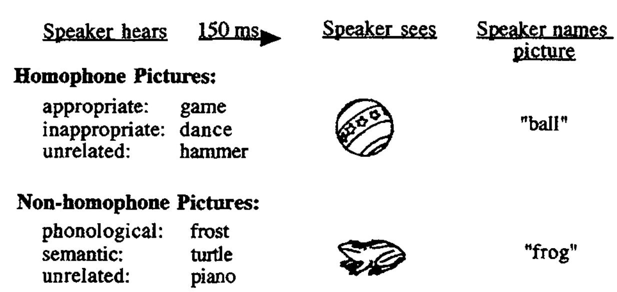

Figure 2. Examples of stimuli and experimental procedure.

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

tors were chosen with WordNet 1.5 (1996) as above. The materials for all experiments are shown in Appendix A.

All of the distractor words were digitally recorded at a rate of 20 kHz on a Macintosh CI computer, using MacSpeech Lab sound editing software.

To create an unrelated condition for both types of pictures, we re-paired the 54 distractor words paired with the homophone pictures (27 appropriate-meaning and 27 inappropriate-meaning) with all 54 pictures (27 homophone names and 27 nonhomophone names) to create an unrelated condition for both types of pictures.

The 54 pictures were arranged in a fixed, randomly generated order, with each picture appearing only once. Three counterbalanced lists were created using this ordering such that for each picture type (homophone vs. nonhomophone name), each list contained nine items in each distractor condition. Across the three lists, each homophone picture was paired with each homophone distractor condition (appropriate-meaning, inappropriate-meaning, and unrelated) once, and each nonhomophone picture was paired with each nonhomophone distractor condition (phonological, semantic, and unrelated) once.

Procedure. Speakers were presented with the pictures using the PsyScope experiment software (Cohen, MacWhinney, Flatt, & Provost, 1993) on a Macintosh Quadra 650 computer with a 17-in. color monitor and an external speaker. Naming responses were collected with a Shure unidirectional head-worn microphone (Shure Brothers, Evanston, IL) and a PsyScope button box millisecond timer. Speakers were told that they would see pictures and hear words presented by the computer, and were instructed to name the pictures with a one-word name as quickly as possible, ignoring the auditory words. Each trial began with the presentation of a fixation point (an asterisk) at the center of the screen for 500 ms. Then, following a 500-ms blank screen, the auditory distractor word was presented through the external speaker. The picture was presented 150 ms after the onset of the distractor word and remained on the screen until the voice key was triggered by the speaker's naming response. A blank screen followed the picture naming response for 500 ms before the onset of the next trial. The experimenter sat next to the participant, coding the accuracy of each response and of the voice-key detection.

Results

For all experiments reported here, any observation with a latency more than 2.5 *SD*s above or below that picture's or that speaker's mean was excluded. In Experiment 1, this cutoff removed 6.1% of correct observations. Speakers used an incorrect picture name on 5.4% of all trials, and no speed–accuracy trade-offs relevant to the important theoretical comparisons were apparent (Tables 1 and 2 present the percentage of errors by condition for all experiments). The voice key mistriggered on 4.9% of all trials. All misnamed and mistriggered trials were excluded from analysis. The resulting means were submitted to two separate analyses of variance (ANOVAs), with speakers (F_1) and pictures (F_2) as random variables, and 95% confidence interval halfwidths (CIs) are reported separately for the speaker and picture means. To explore specific effects, we compared experimental conditions with unrelated control conditions using planned comparisons. For example, the nonhomophone semantic condition was compared with its unrelated control condition to measure semantic interference; similar comparisons were made for the phonological, appropriate-meaning, and inappropriate-meaning experimental conditions. All significant main effects and planned comparisons were reliable at the .05 level, unless reported otherwise.

Table 1 reports the results of Experiment 1. First, for pictures with homophone names, the prediction of cascaded models of lexical access were confirmed: Pictures were named faster when paired with inappropriate-meaning distractors (881 ms) than when paired with unrelated distractors (914 ms). Pictures paired with appropriate-meaning distractors were named slightly more slowly (925 ms) than those in the unrelated condition, providing only weak evidence for the predicted semantic interference in this condition. The overall effect of distractor word type was significant by speakers, $F_1(2, 76) = 4.62$, CI = ±32.5 ms, and marginally significant by items, $F_2(2, 52) = 2.78, p < .08$, CI = ±39.7 ms. Using the unrelated distractors as a baseline, we found that the 33 ms of facilitation in the inappropriate-meaning condition was significant by speakers and marginally significant by items, $F_1(1, 76) = 4.23$; $F_2(1, 52) = 3.09, p < .09$. The 11 ms of interference in the appropriate-meaning condition was not significant (Fs < 1).

For the nonhomophone pictures, the pattern in Schriefers et al.'s (1990) early SOA condition was replicated: Pictures paired with semantic distractors were named more slowly (902 ms) than pictures paired with unrelated distractors (838 ms), whereas phonological distractors were ineffective (834 ms). Overall, the effect of distractor word type was significant, $F_1(2, 76) = 12.18$, CI = ±26.3 ms; $F_2(2, 52) = 9.69$, CI = ±39.2 ms. The 64 ms of semantic interference was significant, $F_1(1, 76) = 14.92$; $F_2(1, 52) = 13.82$, but the 4 ms of phonological facilitation was not (Fs < 1).

Comparison of the two unrelated conditions shows that the pictures with homophone names were named more slowly (914 ms) than pictures with nonhomophone names (838 ms). This was most likely due to differences between the pictures that comprised the homophone and nonhomophone conditions because the pictures were entirely distinct in the two conditions.[3] This difference between the picture type conditions, however, should not have impacted the effects of distractor type, because the theoretically crucial comparisons were completely within their respective picture conditions.

Discussion

For the homophone pictures, inappropriate-meaning distractor words facilitated naming, relative to an unrelated control condition. According to cascaded models of lexical access, semantically processed but unselected material undergoes phonological processing, so that a semantically pro-

[3] Reaction time data collected in an independent norming study (Ferreira & Cutting, 1997) measured naming times when pictures were presented without distractors, and revealed a 75 ms difference between the mean naming time of the 27 homophone pictures (892 ms) and the mean naming time of 25 of the nonhomophone pictures (817 ms), which is close to the difference (76 ms) observed in Experiment 1. The two pictures not included in the norming study ("chair" and "sandwich") were named with faster-than-average naming times in Experiment 1.

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

Table 1
Summary of Results of Experiments 1 and 2

Experiment and target	RT (ms)	Facilitation (+)/ inhibition (−)	CI	% correct	% error	% trimmed	% machine error	No. of speakers	No. of items
Experiment 1: Picture names not studied									
Homophone targets (round *ball*)									
Appropriate (*game*)	925	−11	32.5	80.1	6.8	5.7	7.4	24†	15
Inappropriate (*dance*)	881	+33*/†	39.7	82.6	8.0	6.3	3.1	28*	17
Unrelated (*hammer*)	914	—		76.1	11.7	6.3	6.0	—	—
Nonhomophone targets (*frog*)									
Phonological (*frost*)	834	+4	26.3	91.2	0.9	4.0	4.0	20	11
Semantic (*turtle*)	902	−64*/*	39.2	86.6	4.0	5.4	4.0	30*	22*
Unrelated (*piano*)	838	—		88.3	1.4	5.4	4.8	—	—
Experiment 2: Picture names studied									
Homophone targets (round *ball*)									
Appropriate (*game*)	795	−7	20.6	88.4	2.1	4.6	4.9	23	17
Inappropriate (*dance*)	764	+24*/*	20.1	90.3	1.2	5.6	3.0	30†	19*
Unrelated (*hammer*)	788	—		87.0	1.2	3.7	8.1	—	—
Nonhomophone targets (*frog*)									
Phonological (*frost*)	750	+8	18.8	91.4	0.5	3.9	4.2	26	14
Semantic (*turtle*)	791	−33*/*	27.5	83.6	1.6	8.6	6.3	32*	18†
Unrelated (*piano*)	758	—		90.5	0.5	3.9	5.1	—	—

Note. Number of observations is 351 for Experiment 1 and 432 for Experiment 2. The CI column reports confidence intervals for analysis of variance by speakers and by items, respectively. No. of speakers and No. of items columns report number of speakers and items that showed effects in the direction indicated by the Facilitation/inhibition column. Experiment 1 included 39 speakers, and Experiment 2 included 48. All experiments had 27 items. Asterisks and daggers represent reliable and marginally reliable results (respectively) in planned comparison (Facilitation/inhibition, reported for speakers and for items), and for sign tests (No. of speakers and No. of items); cells without symbols report nonreliable differences. RT = reaction time.
†$.05 < p < .10$. *$p < .05$.

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

Table 2
Summary of Results of Experiments 3 and 4

Experiment and target	RT (ms)	Facilitation (+)/ inhibition (−)	CI	% correct	% error	% trimmed	% machine error	No. of speakers	No. of items
Experiment 3A: Appropriate meaning distractors									
Homophone targets (baseball *bat*)									
Competitor (*glove*)	844	−29*/†	26.1	85.8	3.7	6.2	4.3	25*	14
Associate (*racquet*)	821	−6	35.5	92.0	0.9	3.7	3.4	19	15
Unrelated (*envelope*)	815	—		90.7	1.2	5.6	2.5	—	—
Nonhomophone targets (*frog*)									
Competitor (*turtle*)	816	−33*/*	21.4	90.7	0.3	6.8	2.2	26*	16
Associate (*pond*)	802	−19†/0	26.8	93.5	0.6	4.0	1.9	23†	15
Unrelated (*mailbox*)	783	—		92.0	0.3	4.3	3.4	—	—
Experiment 3B: Inappropriate meaning distractors									
Homophone targets (baseball *bat*)									
Competitor (*bird*)	768	+15†/0	16.1	86.1	1.9	5.3	6.7	27	18†
Associate (*cave*)	765	+18*/0	26.4	89.1	1.9	5.1	3.9	27	15
Unrelated (*pig*)	783	—		88.2	1.6	5.1	5.1	—	—
Experiment 4: Comprehension task									
Homophone targets (baseball *bat*)									
Competitor (*bird*)	885	−10	39.7	97.2	0.5	—	2.3	10	14
Associate (*cave*)	873	+2	29.9	94.9	1.4	—	3.7	9	17
Unrelated (*alphabet*)	875	—		94.4	0.9	—	4.6	—	—
Nonhomophone targets (*frog*)									
Competitor (*turtle*)	857	+34†/*	39.3	93.1	0.5	—	6.5	16†	18†
Associate (*pond*)	849	+42*/*	25.8	94.9	0.5	—	4.6	13	21*
Unrelated (*mailbox*)	891	—		95.4	0.9	—	3.7	—	—

Note. Number of observations is 324 for Experiment 3A, 432 for Experiment 3B, and 216 for Experiment 4. The CI column reports confidence intervals for analysis of variance by speakers and by items, respectively. No. of speakers and No. of items columns report number of speakers and items that showed effects in the direction indicated by the Facilitation/inhibition column. Experiment 3A included 36 speakers, Experiment 3B included 48, and Experiment 4 included 24. All experiments had 27 items, except the homophone condition in Experiment 3A, which had 25. Reported RTs for Experiment 3A and 3B are means, for Experiment 4 are medians. Asterisks, daggers, and zeroes represent reliable, marginally reliable, and nonreliable results (respectively) in planned comparisons (Facilitation/inhibition, reported for speakers and for items), and for sign tests (No. of speakers and No. of items); cells without symbols report nonreliable differences. RT = reaction time.
†.05 < p < .10. *p < .05.

cessed inappropriate-meaning distractor like *dance* can affect the production of a homophone like *ball,* even though the relationship between that distractor and target is phonologically based. Discrete models do not allow the semantic effects of a distractor to have phonological consequences, and so an effect of the inappropriate-meaning distractors is unexpected.

For the pictures with nonhomophone names, semantically related distractors interfered with picture naming, whereas phonological distractors had no effect, replicating the pattern demonstrated by Schriefers et al. (1990). Contrasting the homophone picture inappropriate-meaning condition (which resulted in significant facilitation) with the nonhomophone picture phonological distractor condition (which did not) demonstrates the consequences of the full phonological overlap between the alternative lemma representations of a homophone (like *ball* and *ball*), compared with the partial phonological overlap between phonologically similar words (like *frog* and *frost*). Early in processing, hearing *frost* only partially activates the *frog* phonological word form, resulting in an undetectable amount of activation. Alternatively, hearing *dance* activates the fully shared *ball* phonological word form, resulting in detectable priming. Thus, the failure to find evidence of cascaded processing with phonologically similar primes is likely to be due to the fact that the weaker phonological relationships that occur with phonological primes influenced target production less than the stronger phonological relationships that occur with inappropriate-meaning primes.

A curious result concerns the difference between the appropriate-meaning distractor condition (*game* with a picture of a toy ball) with homophone pictures and the semantic distractor condition (*turtle* with a picture of a frog) with the nonhomophone pictures. In essence, both conditions have speakers name pictures while hearing simple semantic distractors, so performance in the two conditions should have been similar. Instead, the interference in the appropriate-meaning distractor condition was a nonsignificant 11 ms, whereas the interference in the semantic distractor condition was a significant 64 ms. One explanation of this difference may be related to the pictures chosen in each condition. All of the nonhomophone pictures were selected from Snodgrass and Vanderwart's (1980) set, a widely used set of normed pictures, whereas the homophone pictures were selected from a wider range of sources, including some that were drawn specifically so that they would depict objects with homophone names (see Ferreira & Cutting, 1997). For this reason, it is possible that the homophone pictures were simply more difficult to recognize, and the appropriate-meaning semantic distractors helped speakers recognize the pictures more rapidly. In other words, picture identification priming (facilitation) might have traded off against semantic interference in production, resulting in the small 11-ms effect. This possibility was explored in Experiment 2. Before the naming portion of the experiment, speakers were asked to study all of the pictures with their names, presumably reducing any identification differences between the homophone and nonhomophone pictures.

Furthermore, although the pattern of results of Experiment 1 is relatively clear, the facilitation with inappropriate-meaning distractors while naming homophone pictures was only marginally significant by items. We hoped that because speakers in Experiment 2 studied the pictures and names prior to the experiment proper, naming latencies would be more stable, allowing significant item effects to emerge.

Experiment 2

Examination of the inappropriate-meaning distractor condition shows that phonological facilitation can occur at an SOA that normally exhibits semantic effects. However, the predicted semantic interference was smaller in the appropriate-meaning distractor condition with homophone pictures than that in the semantic distractor condition with nonhomophone pictures. The second experiment examined the possibility that the reduced interference may have resulted from a greater difficulty in recognizing the homophone pictures. We replicated the first experiment, except that speakers were preexposed to all of the pictures with their names. Because this preexposure should make all pictures easier to recognize, this experiment assessed whether the absence of semantic interference with homophone pictures is due to priming the identification of those pictures with the appropriate-meaning distractors. Furthermore, the experiment served as a replication of the first experiment with a new set of speakers.

Method

Participants. Forty-eight speakers drawn from the same population as in Experiment 1 participated.

Materials and design. The materials and design were identical to those of Experiment 1.

Procedure. The procedure was identical to the procedure used in Experiment 1, except that prior to testing, the speakers were given a booklet containing all 54 pictures (homophone and nonhomophone), each on its own page. The name of the picture was printed below each picture, in lowercase letters. The speakers were asked to study the picture names long enough so that they could remember and use the same picture names during the naming portion of the experiment.

Results

Using the procedure described in Experiment 1, we eliminated 5.3% of correct observations as outliers; errors occurred on only 1.2% of all trials (preexposure reduced picture naming errors compared with Experiment 1), and the voice key mistriggered on 5.2% of all trials. Errors and mistriggerings were excluded. The results of Experiment 2 are shown in Table 1. As in Experiment 1, the prediction of cascaded models was confirmed: Pictures with homophone names were named more rapidly when paired with inappropriate-meaning distractors (764 ms) than when paired with unrelated distractors (788 ms). Again, however, pictures paired with appropriate-meaning distractors were named only slightly more slowly (795 ms) than those in the unrelated condition. The overall effect of distractor type was significant by both speakers and items, $F_1(2, 94) = 4.55$,

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

CI = ±20.6 ms; $F_2(2, 52) = 6.03$, CI = ±20.1 ms. The 24 ms of facilitation (compared to the unrelated baseline) in the inappropriate-meaning distractor condition was significant, $F_1(1, 94) = 5.02$; $F_2(1, 52) = 6.80$, whereas the 7 ms of interference in the appropriate-meaning distractor condition was not ($Fs < 1$).

For the nonhomophone pictures, the same pattern of results emerged in Experiment 2 as in Experiment 1. Semantic distractors slowed the naming of pictures (791 ms) compared with the unrelated control condition (758 ms), and phonological distractors were ineffective (750 ms). The overall effect of distractor type was significant, $F_1(2, 94) = 13.94$, CI = ±18.8 ms; $F_2(2, 52) = 5.68$, CI = ±27.5 ms. The 33 ms of semantic interference was significant, $F_1(1, 94) = 16.31$; $F_2(1, 52) = 6.90$, whereas the 8 ms of phonological facilitation was not ($Fs < 1$).

Again, with unrelated distractors, pictures with homophone names were named more slowly (788 ms) than pictures with nonhomophone names (758 ms), although this difference is 46 ms smaller than in Experiment 1. In fact, the only difference in the pattern of results between Experiments 1 and 2 is that Experiment 2 speakers named pictures more rapidly in all conditions, reflecting the effect of studying the pictures before the naming portion of the experiment.

Discussion

The pattern of results replicated that found in Experiment 1, again supporting the predictions of the cascaded model of lexical access. For the homophone pictures, inappropriate-meaning distractors facilitated picture naming, whereas appropriate-meaning distractors showed a nonsignificant trend toward interference. For the nonhomophone pictures, we again replicated the Schriefers et al. (1990) results: Semantically related distractors interfered with picture naming, but the effect of phonological distractors was not different from the effect of unrelated control items. Furthermore, all effects in Experiment 2 were significant across items, suggesting that the observed pattern generalizes well across different pictures.

A possible problem with the first two experiments concerns the assignment of distractors to the unrelated control conditions. Because two different "related" conditions were tested within each set of pictures, it was impossible to straightforwardly reassign the distractors from both related conditions to the single control condition. Because the homophone conditions were of greatest theoretical importance, the appropriate and inappropriate homophone picture distractors were reassigned to all 54 (homophone and nonhomophone) pictures, so that unusually disruptive distractors could be identified (none of any importance were revealed). However, this scheme raises a difficulty in that potential inherent distractor effects are no longer completely controlled. Although we have examined and failed to find support for a number of possible artifactual interpretations, it remains possible that at least some of the differences seen among the distractor conditions are due to such inherent distractor effects, rather than the effect of the relationship between distractor and target.

Again in Experiment 2, the interference caused by appropriate-meaning distractors (e.g., *game* for a picture of a toy ball) was small and nonsignificant. Given that semantic interference was observed with the nonhomophone pictures (e.g., *turtle* for a picture of a frog) but not with the homophone pictures, the claim that lexical retrieval occurs in cascade can be questioned, because there was no direct evidence that for these particular homophone pictures, semantic processing occurred at the point during which the distractors affected target naming. Experiment 3 investigated another property of the materials in Experiments 1 and 2 that might have led the appropriate-meaning distractors with homophone pictures to affect homophone target naming in a manner different from the semantic distractors with nonhomophone pictures.

Experiment 3

Research on picture naming and single word production has shown that different types of semantic relations between processed words affect lexical access differently. On the one hand, words like *turtle* and *frog* are semantically similar in that the words come from the same psychological category (say, water animals). We call taxonomically related words like these *competitors.* On the other hand, words like *frog* and *pond* are similar in the sense that the concepts that these words represent are related thematically, and are likely to be used together in an utterance. We call thematically associated words like these *associates.*

Investigations of the effect of competitors in the picture–word interference literature has provided convincing evidence that under the timing conditions investigated here, competitors interfere with target picture naming. Glaser and Düngelhoff (1984), Lupker (1979), La Heij et al. (1990) all presented target pictures to be named with a superimposed visual distractor word that was categorically related to the picture. Results showed that when the picture and word were presented simultaneously or nearly simultaneously, these competitors interfered with target naming. Two sets of experiments in the language production literature also suggest that competitors interfere with target naming. Schriefers et al. (1990), already described, showed that an auditory distractor word that commenced early (150 ms prior to picture onset) slowed picture naming times when that distractor bore a competitive relationship to the target (e.g., *turtle–frog*). Wheeldon and Monsell (1994) had speakers produce a word in response to definition on a prime trial, and on a subsequent target trial speakers named a picture. Results showed that producing a competitor on a prime trial slowed target picture naming times, and that this interference was greater when two neutral trials intervened between prime and target than when the prime trial immediately preceded the target trial.

The effect of associates on word production is less consistent. Lupker (1979) found that simultaneously presented visual distractors with associative relations affected picture naming in a manner no different from distractors without such a relation. On the other hand, La Heij et al. (1990) found that associatively related competitors facili-

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

tated picture naming, especially when the visual distractor was presented 400 ms prior to the onset of the picture. Recall that Wheeldon and Monsell (1994) found greater interference when competitors were presented two trials before targets, compared to when competitors were presented immediately before targets. Subsequent experiments showed that the diminished competitive effect when the prime immediately preceded the target was due to a hypothesized associative effect that occurred with those immediate primes; if an associate (a category superordinate) was always read prior to target production, primes produced both on the immediately preceding trial and two trials earlier caused equivalent semantic interference during target picture production, at a level comparable to that observed in the immediate prime condition when an associate was not read. Overall, competitors interfere with word production, whereas associates sometimes facilitate production.

Examination of the pictures and words from Experiments 1 and 2 reveals that the appropriate-meaning condition for the homophone pictures consisted mostly of associates, whereas the semantic condition for the nonhomophone pictures consisted mostly of competitors. In the appropriate-meaning condition, which caused only negligible interference, 21 of the 27 distractors were associates (e.g., *game* for a picture of a toy ball), whereas the remaining 6 distractors were competitors (e.g., *money* for a picture of a bank check). With the nonhomophone semantic distractors, which caused robust interference, 26 of the distractor words were competitors (e.g., *frog* for a picture of a turtle), whereas the remaining word was an associate (e.g., *queen* for a picture of a crown). Because competitors consistently cause interference, whereas associates do not (La Heij et al., 1990; Wheeldon & Monsell, 1994), it is possible that the reduced interference seen in the appropriate-meaning homophone conditions of Experiments 1 and 2 was the result of those appropriate-meaning distractor conditions consisting largely of associates of the target pictures.[4]

Interestingly, the inappropriate-meaning distractors in Experiments 1 and 2 also consisted of the same mixture of competitors and associates (to the nondepicted meanings of the homophone pictures). Of the 27 inappropriate-meaning distractors, 21 were associates of the nondepicted meaning of the homophone pictures (e.g., *dance* for *ball*), whereas the remaining 6 were competitors of the nondepicted meaning (e.g., *bottom* for *top*). Despite the preponderance of associates in the inappropriate-meaning condition, however, a reliable facilitatory effect was found (compared to the appropriate-meaning condition, where the same proportion of associates failed to produce any reliable effect). These results provide a hint that associative relations can facilitate picture naming, but especially when the distractors are associated to a meaning that a speaker is not trying to express.

In Experiment 3, we tested whether competitors and associates exert different effects during lexical access with the homophone and nonhomophone pictures used in Experiments 1 and 2. In Experiment 3A, we manipulated whether distractor words were competitors or associates of the depicted meaning of the homophone and nonhomophone pictures. If the competitor versus associate distinction is crucial in observing interference, the competitor conditions should result in more interference than the associate conditions. In Experiment 3B, we manipulated whether distractor words were competitors or associates of the nondepicted (rather than the depicted) meaning of the homophone pictures. On the basis of the analysis of Experiments 1 and 2, the facilitatory effects of associates should be greater when the associates are related to the nondepicted meaning of a homophone picture. Because there were only small numbers of competitors in the inappropriate-meaning conditions of Experiments 1 and 2, it was unclear to what extent those competitors contributed to the significant effects reported. Thus, a prediction cannot be made concerning the effect of competitors of the nondepicted meaning of the homophone pictures.

Experiment 3A

In Experiment 3A, we used the same homophone and nonhomophone pictures that we used in Experiments 1 and 2. Each picture was paired with two semantic distractors: a competitor (a member of the same semantic category), like *frisbee* for a picture of a toy ball, and an associate (a related item that is not from the same semantic category), like *game*. Note that for the homophone pictures, the distractors were related only to the depicted meaning of the picture; competitors and associates of the nondepicted meaning were tested in Experiment 3B. On the basis of prior research (La Heij et al., 1990; Lupker, 1979; Schriefers et al., 1990; Wheeldon & Monsell, 1994), both homophone and nonhomophone pictures paired with competitor distractor words should show reliable interference, whereas pictures paired with associate distractor words should not. If this prediction is borne out, then the lack of robust interference with the appropriate-meaning distractors in Experiments 1 and 2 can be attributed to the dominant proportion of associatively related distractors in that condition.

Method

Participants. Thirty-six speakers drawn from the same population as Experiments 1 and 2 participated in this experiment.

Materials and design. Except as noted below, this experiment used the same 54 pictures that were used in the previous experiments, with new distractor words. Each of the homophone and nonhomophone pictures were paired with two types of distractors that were semantically related to the depicted meaning of the pictures: competitors and associates. Competitor distractor words were taken from the same semantic category as the picture names. Associate distractor words were related to picture names but were not taken from the same semantic category. The distractor words from Experiments 1 and 2 were reclassified into these semantic categories, and WordNet 1.5 (1996) was used to generate additional distractors. In addition, the 54 competitor and associate distractor words originally paired with the homophone pictures were each re-paired with all 54 homophone and nonhomophone pictures to create an unrelated condition.

[4] We thank Linda Wheeldon for pointing this out.

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

Three counterbalanced lists were constructed using the same fixed, randomly generated order of picture presentation that was used in the earlier experiments. Within a list, each picture appeared only once. For each picture type (homophone or nonhomophone), each list had nine items from each distractor condition (competitor, associate, or unrelated). Across the three lists, each picture appeared paired with a word of each distractor type exactly once. However, because of experimenter error, the unrelated distractors for *pool* and *ball* were misassigned, as shown in Appendix A. These items were eliminated, leaving 25 pictures in the homophone condition (results were affected only in that item effects were slightly more robust with the pictures included).

Procedure. The procedure was the same as that used in Experiment 2.

Results

Outliers occurred on 5.3% of correct observations, errors occurred on 1.1% of all trials, and the voice key mistriggered on 3.0% of all trials. Table 2 shows the results of Experiment 3A. Semantic distractors with competitive relations to picture names produced interference, whereas associates were ineffective. A similar pattern of results emerged for homophone and nonhomophone pictures: When a competitor distractor word was heard, pictures were named more slowly compared to the unrelated control condition (homophone pictures: 844 ms vs. 815 ms; nonhomophone pictures: 816 ms vs. 783 ms). When an associate distractor word was heard, pictures were named with smaller differences, compared to control (homophone pictures: 821 ms vs. 815 ms; nonhomophone pictures: 802 ms vs. 783 ms).

As in the previous experiments, separate ANOVAs were conducted for the two picture conditions. For homophone pictures, the overall effect of distractor type was significant only by speakers, $F_1(2, 70) = 3.56$, CI = ± 26.1 ms; $F_2(2, 48) = 2.13$, CI = ± 35.5 ms. The 29 ms of interference in the competitor condition was significant by speakers and marginally significant by items, $F_1(1, 70) = 6.86$; $F_2(1, 48) = 3.47$, $p < .07$, whereas the 6 ms of interference in the associate condition was not ($F\text{s} < 1$). For nonhomophone pictures, the overall effect of distractor type was significant by speakers and marginally significant by items, $F_1(2, 70) = 6.30$, CI = ± 21.4 ms; $F_2(2, 52) = 2.44$, $p < .10$, CI = ± 26.8 ms. The 33 ms of interference in the competitor condition was significant, $F_1(1, 70) = 12.6$; $F_2(1, 52) = 4.87$, whereas the 19 ms of interference in the associate condition was only marginally significant by speakers, $F_1(1, 70) = 3.13, p < .09$; $F_2(1, 52) = 1.42$.

Discussion

In accordance with prior research, pictures in the competitor distractor condition were named more slowly than those in the control condition, whereas pictures named in the associate distractor condition were affected in a manner not different from pictures named in the control condition. This was true for pictures with both homophone and nonhomophone names. These results suggest that the lack of interference with appropriate-meaning distractors in Experiments 1 and 2 was due to the preponderance of associatively related distractors in that condition of those experiments. When semantic distractors are competitively related, as in the competitor distractor conditions of Experiment 3A, picture naming is slowed.

Across these experiments, the pattern of results supports the cascaded characterization of lexical access. Inappropriate-meaning distractors facilitated picture naming in Experiments 1 and 2, suggesting that the shared phonological word form of a homophone can be primed through activation of the unintended meaning of that homophone. That is, at the early SOA that we tested, evidence of phonological processing was discovered. The same homophone pictures that showed a phonological effect in Experiments 1 and 2 also showed semantic interference with competitively related distractor words in Experiment 3A. That is, at this same early SOA, evidence of semantic processing was discovered. Furthermore, across all three experiments, semantically related distractors (which were nearly always competitors) presented with nonhomophone pictures resulted in semantic interference. Taken together, the results suggest that semantic and phonological processing occur with overlapping time courses, implicating a cascaded model of lexical access.

Experiment 3A replicated prior findings in the picture naming literature, in that categorically related distractors interfered with picture naming, whereas associatively related distractors inconsistently affected picture naming. However, as noted, the inappropriate-meaning distractors in Experiments 1 and 2 were mostly associatively related to the nondepicted meaning of the homophone pictures, yet they still resulted in consistent facilitation. Experiment 3B investigated whether the inappropriate-meaning distractors affect picture naming when categorically or associatively related to the nondepicted meaning of the homophone picture. Evidence that associatively related distractors can affect picture naming in this situation would help specify in greater detail the mechanism by which the inappropriate-meaning distractors affect picture naming, and generally, will help to illuminate the nature of the information processing pathways that are engaged during lexical access.

Experiment 3B

In Experiment 3B, we manipulated whether distractors were associatively or competitively related to the nondepicted meaning of the homophone pictures. In Experiment 3A, associates of the depicted meaning of target pictures inconsistently and nonsignificantly affected picture naming. On the basis of the analysis of Experiments 1 and 2, Experiment 3B should show that associates of the nondepicted meaning of the homophone pictures have a more consistent facilitatory effect on picture naming times than when associates are related to the depicted meaning.

Method

Participants. Forty-eight speakers were drawn from the same population as the previous experiments.

Materials and design. This experiment used the same 54 pictures that were used in the previous experiments, paired with a new set of distractors. As in Experiment 3A, each picture was paired with an associatively and competitively related distractor word, except that the distractors were related to the nondepicted meaning of the homophone picture's name. Distractor words were chosen with the assistance of WordNet 1.5 (1996) as in Experiment 3A. In addition to the 27 homophone pictures, the 27 nonhomophone pictures were included as fillers. An unrelated condition was created by re-pairing competitor and associate distractor words from the homophone pictures with the entire set of 54 pictures. Three counterbalanced lists were generated as in Experiment 3A.

Procedure. This experiment used the same procedure that was used in Experiments 2 and 3A.

Results

Across all conditions, outliers occurred on 5.6% of correct observations, errors occurred on 1.8% of all trials, and voice key mistriggerings occurred on 5.2% of all trials. The mean naming times for the included homophone pictures in the three distractor conditions are reported in Table 2. Distractors that were competitively (768 ms) or associatively (765 ms) related to the nondepicted homophone meaning caused faster picture naming times, compared to when the distractors were unrelated to the homophone picture (783 ms). Thus, distractors that are semantically related to the nondepicted meaning of a homophone seem to facilitate picture naming, regardless of whether that semantic relation is a competitive or an associative one.

The overall effect of distractor type was marginally significant by speakers and not significant by items, $F_1(2, 94) = 3.00$, $p < .06$, CI = ± 16.1 ms; $F_2(2, 52) < 1$, CI = ± 26.4 ms. Distractors that were competitively related to the nondepicted homophone meanings facilitated picture naming times by 15 ms, an effect that was marginally significant by speakers, $F_1(1, 94) = 3.03$, $p < .09$; $F_2(1, 52) = 1.4$. Distractors that were associatively related to the nondepicted homophone meaning facilitated picture naming times by 18 ms, which was significant only by speakers, $F_1(1, 94) = 5.59$; $F_2(1, 52) = 1.50$. Overall, effects were weaker in Experiment 3B than in Experiment 2, possibly because in Experiment 2, disregarding competitor–associate status permitted distractors to be more closely related to the nondepicted meanings of the pictures.

Discussion

The results of Experiment 3B identify a role for associative relations in lexical access. Although the differences were smaller and somewhat less robust in Experiment 3B than in Experiment 2, when semantic distractors were associatively related to the nondepicted meaning of a homophone picture, they were as effective at facilitating homophone picture naming as when those distractors were competitively related to the picture. However, Experiment 3A showed that distractors that were associatively related to the depicted meaning of a homophone did not consistently affect picture naming times (for homophone or nonhomophone pictures). Thus, in Experiments 3A and 3B, an interesting dissociation emerged: Associates related to the meaning that a speaker wishes to express are ineffective, whereas associates related to a meaning that a speaker does not wish to express can speed picture naming times, provided that the unintended meaning shares a phonological representation with the intended meaning, as occurs with homophones. A possible explanation for this pattern of results is provided in the General Discussion, along with an implemented interactive activation model of lexical access.

A final issue that required investigation concerned the nature of the processing that occurs with the distractor stimuli. Specifically, the claim that an effect of inappropriate-meaning distractors supports a cascaded model of lexical access is based on the assumption that the facilitated processing that occurs with inappropriate-meaning distractors is the direct result of the semantic processing (or, at least, activation from the lemma) of those distractors. Whether this assumption holds was investigated in Experiment 4.

Direct Comprehension-to-Production Effects

According to the interpretation provided in Experiments 1–3, the facilitatory effect of inappropriate-meaning distractors supports a cascaded characterization of lexical access. However, a model like that presented in Figure 3 illustrates an alternative explanation that does not implicate cascading. In this model, phonological representations are distinct between comprehension and production, but lemma and conceptual representations are shared. Such a model has received some empirical and theoretical support (Cutting, 1997; Levelt, Roelofs, & Meyer, in press; but see Caramazza, 1997; Zwitserlood, 1994). Within the model illustrated in Figure 3, distractors must be able to affect lemma and semantic representations (i.e., processing must occur along Path A), because auditory distractors are typically understood, and can have semantic effects (e.g., the competitive effect illustrated here in Experiments 1–3). However, phonological facilitation at late SOAs (e.g., Schriefers et al., 1990) implies the existence of the lateral connections in Figure 3, so that comprehension word form representations can rapidly and directly activate their corresponding production word form representations, facilitating target production. When phonologically similar distractors are presented early, no facilitation occurs, presumably because the facilitatory priming is transitory in nature, and therefore dissipates before target processing can proceed to a dominantly phonological level. It is important to note that these later, direct comprehension-to-production connections could underlie the facilitation seen with inappropriate-meaning distractors in Experiments 1–3 (see Balota & Paul, 1996, for evidence showing that the divergent meanings of a homophone can have convergent effects in lexical tasks), implying that cascading is not involved (because the source of the priming activation would not have been the lemma level).

This counterexplanation is complicated by the fact that the facilitation that occurs with phonological distractors (e.g., Schriefers et al., 1990) appeared only at late SOAs, suggesting that the priming that results from this direct comprehension-to-production path is transitory in nature. In contrast, the facilitation found with inappropriate-meaning

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

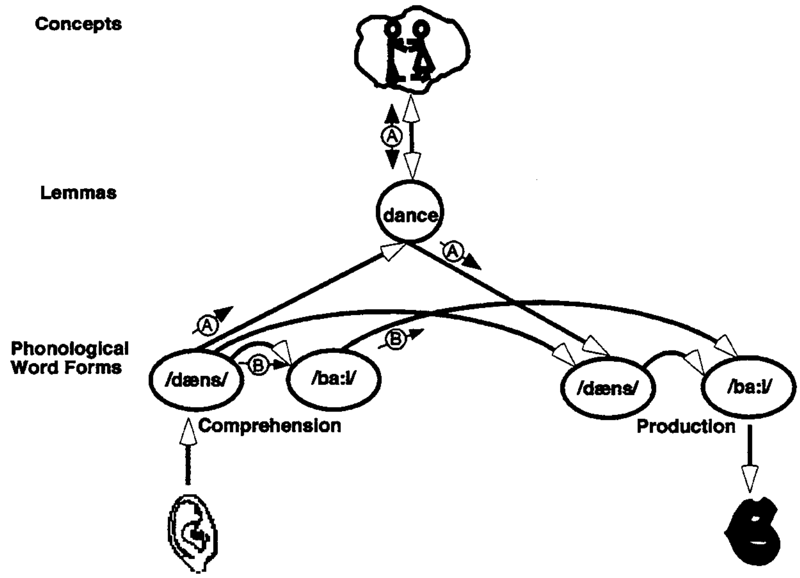

Figure 3. Model of lexical access in comprehension and production, illustrating possible influences of distractor processing on target production.

distractors in Experiments 1–3 occurred when those distractors were presented at an early SOA. However, it may be that the inappropriate-meaning distractors, perhaps because of the mediated relationship they bear to the production targets (e.g., *dance* to the *dance* meaning specific interpretation of *ball,* and then to the shared *ball* phonological word form), are processed with a particularly slow or enduring time course, allowing the comprehension-to-production facilitation, assumed to be rapid and transitory, to be slower or longer lasting.

However, there are a number of difficulties with this interpretation. To begin, just as *dance* can facilitate *ball* in comprehension, so should *game* and *frisbee* facilitate *ball;* yet, in Experiments 1–3, such appropriate-meaning distractors were ineffective or interfering rather than facilitatory. More generally, unlike the tight coupling that is implied by this alternative interpretation, there is a lack of correspondence between patterns of priming in comprehension and production. Semantic priming is robust and facilitatory in comprehension experiments (for review, see Neely, 1991), occurring with both categorically (i.e., competitively) and functionally related prime–target pairs, which need not be associatively related (McRae & Boisvert, 1998; Moss, Ostrin, Tyler, & Marslen-Wilson, 1995). As discussed here, robust semantic priming in production has only been revealed with categorically related prime–target pairs, and when revealed, it is inhibitory (although facilitation has been found in picture naming when prime and target are presented successively, e.g., Carr, McCauley, Sperber, & Parmelee, 1982). On the other hand, phonological priming in comprehension, when revealed, is inhibitory (e.g., Hamburger & Slowiaczek, 1996), whereas such priming in production is facilitatory (Schriefers et al., 1990). Finally, the semantically mediated phonological primes (i.e., the inappropriate meaning distractors) speeded picture naming in these experiments by 15–33 ms, whereas such effects in comprehension are much smaller, at about 5 ms, and require large numbers of observations to detect (O'Seaghdha & Marin, 1997).

These considerations suggest that the direct links from comprehension to production are too weak to allow activation in the comprehension system to unduly influence production, and specifically, to be responsible for the facilitation that was observed with the inappropriate-meaning distractors in Experiments 1–3. Instead, it seems likely that the phonologically based facilitation with inappropriate-meaning distractors is the result of semantic processing (or, minimally, lemma activation) in the production system (Path A). To test whether such lemma activation is important to elicit the inappropriate-meaning facilitation revealed in Experiments 1–3, we conducted a fourth experiment that used materials and procedures as similar as possible to those of Experiments 1–3, but with an important difference: Instead of using the semantically demanding picture naming task that was used in Experiments 1–3, Experiment 4 used a more comprehension-like task that is less likely to engage semantic processing during task performance (see O'Seaghdha & Marin, 1997, for a recent discussion of comprehension–production differences). If the facilitation from inappropriate-meaning distractors seen in Experiments 1–3 was due to direct comprehension-to-production influences (like through Path *B*), then such effects should be manifest in a semantically undemanding task like shadowing, because the shadowing task presumably engages these same direct comprehension-to-production connections.[5] If the facilitation from inappropriate-

[5] Another possible route could exist from the comprehension

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

meaning distractors is diminished or eliminated in the shadowing task, then it suggests that the semantic processing contribution demanded by the picture naming task is important to achieve the inappropriate-meaning facilitation.

Experiment 4

Experiment 4 was a comprehension analogue of Experiment 3. Participants in Experiment 4, like those in Experiments 1–3, heard a distractor word at the beginning of each trial (such distractors are typically called *primes* in comprehension tasks, but we retain the term *distractor* to facilitate comparison to the production experiments). Instead of seeing a picture, Experiment 4 participants then heard the name of the target picture immediately following the distractor. The speakers' task was to repeat the target word as quickly as possible. Such phonological repetition tasks, often termed *shadowing* tasks, require little semantic processing, because speakers can respond accurately by merely parrotting the sounds that they hear. The purpose of the experiment was to examine whether the priming effects seen in the earlier experiments may have been due to direct comprehension-to-production paths at the phonological word form level rather than semantic processing during normal production. We assume that the shadowing task requires little semantic processing; if we see a similar pattern of effects in this experiment as was seen in the earlier experiments, then those earlier effects evidently did not crucially rely on the semantic processing that occurs in a picture naming task. Because the shadowing task has been shown to be sensitive to semantic priming (Slowiaczek, 1994), the question of special interest is whether the stimuli used here are able to show facilitatory effects.

The target words used in Experiment 4 were the names of the same nonhomophone and homophone picture targets that were tested in Experiments 1–3. For the nonhomophone targets, the competitor and associate distractors from Experiment 3A were used. For the homophone targets, the inappropriate competitor and associate distractors from Experiment 3B were used. Note, however, that when the name of a target picture was presented as a word, its meaning was no longer constrained, so that the inappropriate distractors for the homophone targets were, for the most part, no different from the appropriate distractors for the nonhomophone pictures (an important difference is addressed in the *Discussion*). If the facilitation seen with inappropriate-meaning distractors in Experiments 1–3 resulted from the direct comprehension-to-production path among phonological word forms (rather than as a consequence of lemma activation), then inappropriate-meaning distractors should facilitate in the semantically undemanding shadowing task used in Experiment 4 as much as those distractors facilitated in the semantically demanding picture naming task used in Experiments 1–3.

over to the production representation of *dance,* then to the production representation of *ball.* The influence of such a route was also tested by Experiment 4, because no involvement of lemma representations is implicated under such an account.

Method

Participants. Twenty-four speakers drawn from the same population as Experiments 1–3 participated in Experiment 4.

Materials and design. Experiment 4 used the names of the 27 nonhomophone and 27 homophone pictures as target words. Each target word appeared in one of three distractor conditions: Either the distractor was competitively related to the target (e.g., *turtle–frog; bird–bat*), associatively related to the target (e.g., *pond–frog, cave–bat*), or was not related at all (e.g., *mailbox–frog; alphabet–bat*). For the nonhomophone targets, the distractors from Experiment 3A were used, and for the homophone targets, the distractors from Experiment 3B were used. Thus, with respect to the pictures used in Experiments 1–3, the nonhomophone distractors were related to the depicted meaning of the picture, whereas the homophone distractors were related to the nondepicted meaning of the picture (except for the unrelated control condition).

Procedure. Distractor and target words were auditorily presented in rapid succession. To mimic as closely as possible the rapid stimulus presentation conditions of the picture–word task, the target words were presented as soon as possible after the distractor words (targets began 50 ms after distractor offset). (Although it was impossible to precisely anticipate the length of the shadowing latencies, the timing conditions in Experiment 4 proved to have been close to those of the production experiments. In Experiment 4, the average interval between the onset of the distractor and the onset of the speaker's response was 1,647 ms, ranging between 1,328 ms and 2,114 ms. Taking the production task of Experiment 3, this stimulus–response interval averaged 1,612 ms, ranging between 1,327 ms and 2,077 ms.) As in the production experiments, participants were asked to ignore the distractor word (i.e., "the first word"), and repeat the target word ("the second word") as quickly as possible. All other aspects of the procedure were identical to those of Experiments 1–3.

Results

Because the distribution of reaction times was different for the shadowing task of Experiment 4, compared to the picture naming task of Experiments 1–3, median response times were analyzed in Experiment 4, and no outliers were removed (the treated mean latencies showed the same pattern, but with less statistical power). Shadowing errors occurred on only 0.7% of all trials, and voice key mistriggerings occurred on only 5.1% of all trials. The results of Experiment 4 are shown in Table 2. Nonhomophone targets preceded by competitively (849 ms) or associatively (857 ms) related distractors showed facilitation, relative to the unrelated baseline (891 ms), whereas latencies to homophone targets preceded by competitively (873 ms) or associatively (885 ms) related distractors were not substantially different from the unrelated baseline (875 ms). Thus, only the nonhomophone targets showed the facilitation that normally occurs in comprehension tasks with semantically related primes.

With nonhomophone targets, the overall effect of distractor type was marginally significant by participants and significant by items, $F_1(2, 46) = 3.0$, $p < .06$, CI = ±39.3 ms; $F_2(2, 52) = 3.9$, CI = ±25.8 ms. The 42 ms of facilitation with competitor distractors was significant, $F_1(1, 46) = 5.5$; $F_2(1, 52) = 4.5$, and the 34 ms of facilitation with associate distractors was marginally significant by participants and significant by items, $F_1(1, 46) = 3.2$, $p < .08$; $F_2(1, 52) = 7.0$. On the other hand, for the homophone targets, the overall effect of distractor type was not significant, $F_1(2, 46) = 1.2$, CI = ± 39.7 ms; $F_2(2, 52) < 1$, CI = ± 29.9 ms. Neither the 2 ms of facilitation that occurred with competitor distractors reached significance (both Fs < 1), nor did the 10 ms of interference that occurred with associate distractors, $F_1(1, 46) = 2.0$; $F_2(1, 52) < 1$.

Discussion

Speaker performance in the comprehension task in Experiment 4 was quite different from performance in the production tasks of Experiments 1–3. For the nonhomophone targets, word repetition showed reliable facilitation when word targets were preceded by competitively related distractors (as in Slowiaczek, 1994), but picture naming showed interference when pictures were preceded by the same distractors; word repetition showed reasonably consistent facilitation when words were preceded by associatively related distractors, but picture naming showed no consistent effects when pictures were preceded by the same distractors. For the homophone targets, word repetition showed no consistent effects when word targets were preceded by "inappropriate-meaning" distractors, but picture naming showed reasonable facilitation when pictures were preceded by these same distractors. At a general level, these results suggest that the link between representations that underlie comprehension effects (like garden variety semantic priming) and representations that underlie production effects (like the categorical interference or inappropriate-meaning facilitation observed here) is weak. It cannot be safely concluded that because a distractor (prime) has an effect in a comprehension task, that that distractor will have the same effect in a production task.

More specifically, the results of Experiment 4 suggest that the inappropriate-meaning facilitation observed in the production experiments is unlikely to have been caused by direct comprehension-to-production links. In the production experiments, the inappropriate-meaning distractors caused facilitation, whereas in the comprehension experiment, the inappropriate-meaning distractors were largely ineffective. (Note that it is unlikely that the ineffectiveness of the inappropriate-meaning distractors in the comprehension experiment was due to some insensitivity established by procedural details, because the nonhomophone targets were reliably facilitated by their related distractors in the same experiment.) Thus, Experiment 4 suggests that some component of the semantic processing that occurs with the picture naming task is important to observe facilitation with the inappropriate-meaning distractors used in Experiments 1–3.

Why were the auditorily presented inappropriate-meaning distractors sufficient to cause facilitation in the picture naming task of Experiments 1, 2, and 3B, but not in the shadowing task of Experiment 4? The two tasks have many differences that may cause auditory primes to exert different effects. One possibility is that the auditory distractors are processed differently in the two tasks, perhaps in that they are processed more semantically in the picture naming task (note that the fact that semantically related distractors facilitated shadowing times in Experiment 4 does not implicate semantic processing, in that mutually influential relationships may emerge among nonsemantic representations that are semantically related elsewhere in the system; e.g., Lukatela & Turvey, 1994). Another possibility is that part of the locus of the facilitation in the picture naming task is in facilitated selection times of the target (e.g., *ball*) lemmas, due to feedback. Because lemma selection is presumably not involved in the shadowing task, such facilitation should not occur. A final possibility we offer is that any facilitatory effect at the level of the phonological word form may be larger in a picture naming task than in a shadowing task (e.g., the facilitatory effect in Experiment 4's shadowing task was roughly equal in magnitude to the inhibitory effect in Experiment 3's picture naming task, whereas Schriefers et al., 1990, found in a picture naming task that phonological primes facilitated naming time more than competitor primes inhibited naming time [62 ms vs. −39 ms]). This might occur because the auditory target stimulus in a shadowing task might more quickly "top out" a word form representation's activation (because the stimulus itself contains phonological information), whereas a picture stimulus may cause a word form to acquire activation more slowly, leaving room for a weaker priming effect to appear. Regardless of the precise reason, the picture naming and shadowing tasks clearly show different patterns of priming, most clearly evidenced by the performance difference in the nonhomophone associate condition.

That said, why was there a difference in the comprehension task between the nonhomophone targets (which showed facilitation from related distractors) and the homophone targets (which were unaffected)? This difference is probably due to the fact that the homophone targets are likely to be more weakly related to their distractors than the nonhomophone targets. First, of the 27 homophone pictures used in the production experiments, 19 depicted the dominant meaning of the homophone (e.g., the picture of a ball depicted the dominant *toy ball* meaning). Therefore, for these 19 targets, the inappropriate-meaning distractors (e.g., *dance*) were related to a subordinate meaning of the picture. Thus, in Experiment 4, the inappropriate distractors for the homophone target names were mostly related to a subordinate meaning of that homophone. This is unlike the case with the nonhomophone targets, which only referred to a single meaning; therefore, for the nonhomophone targets, the distractors were related to the single dominant meaning of the target name (e.g., *pond–frog*). Second, when the original materials were designed, the homophone pictures were selected on the basis of their homophonic status, and related words were then found for the chosen homophone pictures. In contrast, because the nonhomophone pictures had no selectional restrictions, they were initially selected because they bore strong relationships to the tested distractors. Because of these two factors, there was likely to be a difference between the homophone and nonhomophone targets in the strength of the relationship to their respective distractors in Experiment 4.

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

General Discussion

The experiments make three empirical points: (a) When speakers named a picture of an object with a homophone name, an auditory distractor word that was semantically related to the nondepicted meaning of that picture speeded picture naming (relative to an unrelated control condition). Furthermore, the lack of an observed facilitation effect in a comprehension task with these same distractors suggests that the facilitation crucially involves production processing. (b) Distractor words that were semantic competitors of the depicted meaning of a picture (same taxonomic category members) slowed picture naming latencies, whereas distractor words that were associatively related to the depicted meaning of a picture had little or no effect on picture naming latencies. (c) Unlike the case in (b) where distractors were related to a picture's depicted meaning, the facilitation observed when distractors were related to the nondepicted meaning of a homophone picture (the effect described in [a]) occurred regardless of whether those distractors were competitively or associatively related to that nondepicted meaning.

Across the experiments, the pattern of results suggests that the processing components of lexical access operate in cascaded fashion. When distractors were semantically related to the nondepicted meaning of a homophone picture, speakers named the picture more quickly. Because the depicted (target) and nondepicted (distractor-related) meaning of a homophone are related only through their shared phonological word form, this facilitation is evidence that nontarget representations are phonologically processed in this task. By itself, this result implies that phonological representations can acquire activation from multiple sources, because both a target and a nontarget representation increased in phonological activation. However, the experiments also provide evidence that semantic processing occurs concurrently with phonological processing. When distractors were competitively related to the depicted meaning of a picture (homophone or nonhomophone), speakers named pictures more slowly, providing evidence that nontarget lexical representations were semantically processed. Together, the phonological and semantic processing of nontargets under the same timing conditions suggest that phonological and semantic processes operate with overlapping time courses, supporting a cascaded model of lexical access.

Our conclusions converge with those of Peterson and Savoy (1998) and Jescheniak and Schriefers (1998), who showed that nearly interchangeable words like *couch* and *sofa* simultaneously affect phonological processing. Although those results support a fully cascaded model of lexical access, they are also consistent with a modified discrete model of lexical access, where under special circumstances, multiple semantically similar lemmas can be selected for subsequent phonological processing (Butterworth, 1992). The results of our experiments, however, show that phonological processing can be affected by semantically processed material even when that material is not semantically similar to the target representation. Here, distractors related to the unintended meaning of a homophone facilitated phonological processing when heard. However, the intended and unintended meanings of a homophone are semantically dissimilar. Thus, unselected semantically processed material can affect phonological processing, even when those lemmas are semantically dissimilar to the selected material.

The claim that multiple lemmas can be selected in a single production event raises the possibility that in the inappropriate-meaning conditions, both the homophone name target and the inappropriate-meaning distractor may have been selected. If so, then the phonological effects of the inappropriate-meaning distractors are expected, even under a discrete model of lexical access, because the inappropriate-meaning distractors would have been selected, and thereby undergone phonological processing. By our reading, such a model amounts to a perspective wherein not all semantically activated alternatives undergo phonological processing (as a fully cascaded model would claim), but only highly active alternatives do. Such a model, although discrete in a sense, could just as well be characterized as a cascaded model with a threshold activation function (so that only highly active semantic alternatives achieve threshold and undergo phonological processing). Such a model may best be considered a hybrid discrete/cascaded model. It is important to note that such a hybrid model is crucially different from standard discrete models (e.g., Levelt, 1989; Levelt et al., in press), in which decisions about which lemmas undergo phonological processing are thought to be informed only by semantic information, not merely by activation broadly defined.

Although the results of these experiments suggest that lexical access operates in cascaded fashion, it is important to emphasize the limits of the cascading. As the results of Schriefers et al. (1990) show, even words that are very phonologically similar (like *frog* and *frost*) are not simultaneously active early during lexical access, and the results of Levelt et al. (1991) show that a word that is phonologically similar to another word that is semantically similar to some target word (e.g., *goal* to *sheep,* through *goat*) is not simultaneously active with that target. As Dell and O'Seaghdha (1991) have pointed out, the degree of cascading in interactive systems must be seriously constrained, because some of the activation that does cascade corresponds to unintended material. However, a small amount of cascading activation is beneficial, because it allows the lower phonological level to begin processing of the intended material (as well as some unintended material) as soon as possible, speeding the process of lexical access. The results of Peterson and Savoy (1998) and those presented here show that cascaded activation is small but detectable under special circumstances: when semantic alternatives are particularly interchangeable, or when a shared phonological representation can receive priming activation.

A Model of Lexical Access

Here, we present a computational model of lexical access that instantiates the claims developed in this research. The model presented here is intended to be a simplification and elaboration of existing models of lexical access, to demon-

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

strate the architectural points described above. The model is consistent with other cascaded models of lexical access (Dell, 1986, 1988; Harley, 1984; Humphreys et al., 1988; Stemberger, 1985), although the different scope of the present model from those of past models leads to some differences. In all of these models, activation spreads from semantic to lemma to phonological representations in cascade.

In contrast, the model presented here is different from models presented by Roelofs (1992, 1997; see Levelt et al., in press). The most important difference between the present model and those presented by Roelofs (1992, 1997) is that the latter explicitly forbid cascaded activation. That is, in the models of Roelofs (1992, 1997), activation spreads freely among semantic and lemma representations until a single lemma is selected (under most circumstances), at which point activation is allowed to spread to representations that encode phonological information.

Other differences exist between Roelofs (1992, 1997) and the present model, although these other differences are not taken to carry theoretical force in this context. Specifically, the models of Roelofs assume a different means for representing semantic similarity and a different competitive mechanism. Roelofs's models capture a wide range of effects that the present model was not intended to handle (e.g., morphemic, metrical, and syllabic effects), whereas only the present model contains a mechanism to account for associative effects. Of particular importance, it is likely that the models in Roelofs (1992, 1997) could handle the effects revealed in our experiments (perhaps with minor modifications), but only if the assumption of discrete activation flow from lemma to phonological representations is relaxed.

The model, shown in Figure 4, possesses distinct semantic, grammatical, and phonological representations of words (represented respectively by the nodes at the top level, middle level, and bottom level in Figure 4). The activation of grammatical representations from semantic representations through interlevel excitatory connections comprises semantic processing, and the activation of phonological representations from grammatical representations through interlevel excitatory connections comprises phonological processing. These processes are cascaded, in that phonological representations are activated by grammatical representations as soon as the latter become active, not only after selection.

As shown in Figure 4, the model makes specific claims about the representations of similarity relations among lexical items. Weak, excitatory connections, shown by dotted lines, connect lemmas to semantically similar representations (e.g., the toy *ball* lemma is connected to the *frisbee* semantic representation), and interconnect associated word form representations (e.g., the *ball* word form is connected to the *game* word form). These connections cause these representations to activate one another. Inhibitory connections, shown by lines terminated with dots, implement a competitive relationship between mutually exclusive lemma representations (e.g., *frisbee* and *ball* compete for selection). Specific motivations for each connection type in Figure 4 are provided in the detailed description of the model in Appendix B.

Of central importance in the model is the representation of a homophone like *ball.* Each meaning of the homophone is represented by distinct semantic and grammatical representations, which then converge on a single shared phonological word form. To simulate the distractor conditions, the model includes both competitive and associated lexical representations for each meaning of the homophone. Thus, *frisbee* and *game* are the competitor and associate (respectively) for toy *ball,* whereas *dance* and *formal* are the competitor and associate for dance *ball.* Also included is an unrelated control item, labeled *tree* in the model.

The experimental situation was simulated by activating the semantic representation of the target (toy *ball*), and allowing activation to spread. Once the toy *ball* lemma achieved threshold activation, it was selected and "fired," causing a large amount of activation to spread to all connected nodes, eventually causing the target phonological word form (*/ba:l/*) to achieve threshold. The number of time steps required for the target phonological word form to reach threshold is the selection time for that target.

The effect of the distractor was simulated by activating the distractor's lemma representation just before target processing (as in Roelofs, 1992), for a small number of time steps. Activation spread from the distractor's lemma through to all connected representations, speeding or slowing selec-

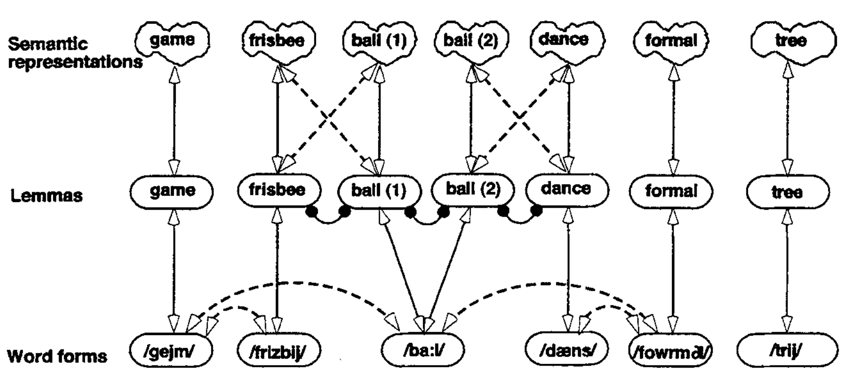

Figure 4. Interactive activation model of lexical access.

tion time depending on the nature of the distractor. Ten separate simulations were run in each condition, with each simulation adding a different amount of random noise to the model's weight parameters. Other simulation details are provided in Appendix B.

The results of running the simulation in the five test conditions are shown in Figure 5. A one-way ANOVA across the five conditions (see Appendix B for details) revealed significant differences among the five conditions, $F(4, 36) = 80.2$, CI $= \pm 1.11$ time steps. The model accounts for the pattern of effects seen in the experiments, although the quantitative fit of the model is compromised largely by an overestimate of associative effects in the appropriate-meaning distractor condition. The model accounts for the large amount of interference observed with appropriate-meaning competitors, as settling times were 4.6 time steps longer in this condition, $F(1, 36) = 70.6$. The model predicts that appropriate-meaning associates should result in faster picture naming times (a 2.7 time step effect), $F(1, 36) = 22.6$. Both inappropriate-meaning distractor conditions facilitated settling times: The inappropriate-meaning competitor condition was 2.6 time steps faster than the unrelated condition, $F(1, 36) = 24.3$, whereas the inappropriate-meaning associate condition was 4.2 time steps faster, $F(1, 36) = 58.9$.

The interference that is observed with appropriate-meaning competitors occurs because of the lateral inhibitory connections between competitor lemmas. When the *frisbee* lemma is clamped, it remains highly activated while a small amount of activation is sent to the toy *ball* lemma (through the *frisbee* semantic representation). Because the *frisbee* lemma has more activation than the toy *ball* lemma, the latter's activation is zeroed by the large inhibitory connection between these two representations. Then, when the target is processed and the toy *ball* semantic representation is clamped, the toy *ball* lemma has to overcome the inhibitory influence of the *frisbee* lemma. As a result, the toy *ball* lemma requires more time steps to achieve threshold, the *ball* phonological word form acquires activation more slowly, and selection time of the *ball* word form is increased. Generally, the model claims that interference is observed with semantically similar distractors because the lemma representation of a semantically similar distractor competes with the lemma representation of the target, slowing target selection. Such an explanation is in agreement with most production models of lexical access (Glaser & Glaser, 1989; Humphreys, Lloyd-Jones, & Fias, 1995; Roelofs, 1992; Starreveld & La Heij, 1995).

According to this account, appropriate-meaning associates do not cause competition because this distractor is not semantically similar to the target (e.g., *game* is not similar to toy *ball*), and so lemma representations of associates do not compete with target lemma representations. On the contrary, associates exhibit mutually excitatory influence at the level of phonological word forms, and so target production is actually speeded. In terms of the model, when the *game* lemma is clamped, activation is sent to the *game* phonological word form, which sends activation to the *ball* phonological word form through the lateral excitatory connection.

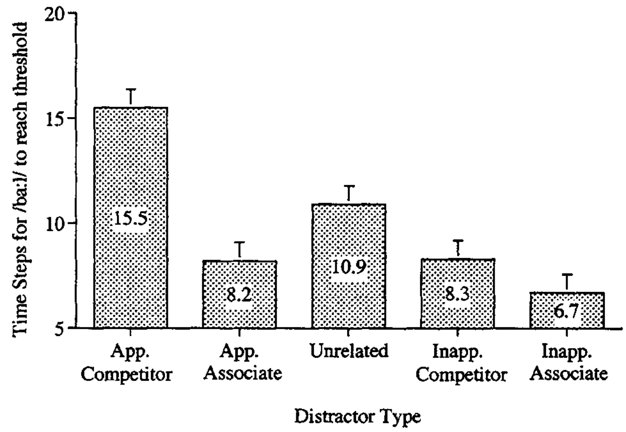

Figure 5. Number of time steps to select target phonological word form in the interactive activation model in each simulated distractor condition. App. = appropriate; Inapp. = inappropriate.

Furthermore, because the *game* and toy *ball* lemmas do not compete, no interference ensues from their simultaneous activation. The result is, in fact, a small amount of facilitation in the selection of the *ball* phonological word form.

Interestingly, the facilitation in the appropriate-meaning associate condition is relatively small (compared to, say, the inappropriate-meaning associate condition). This occurs because in the model, the appropriate-meaning associate (*game*) is associated not only to the target (*ball*), but to competitors of the target (*frisbee*). Thus, appropriate-meaning associates exert an excitatory influence not only on target material, but also on material that competes with the target material, diminishing the facilitatory effect of the associate. Of course, the amount of facilitation observed will depend on the relative magnitude of the facilitatory effect due to association and the interfering effect due to activation of competitors. In fact, Experiment 3 found trends toward interference in the associate conditions (6 and 19 ms for homophone and nonhomophone pictures, respectively), whereas the presented model predicts facilitation. It may be the case that if the lexical space of the model were to be increased, that the inhibitory component of the effect would increase, because the greater number of taxonomically related (i.e., competitive) neighbors would increase. Regardless, as noted earlier, associates do sometimes exert a facilitatory effect on word production (La Heij et al., 1990; Wheeldon & Monsell, 1994), so the model's claim of facilitation with associates is not without empirical corroboration. Overall, this complex nature of the effect of appropriate-meaning distractors may account for the inconsistent nature of associate effects in the lexical access literature (this explanation is similar to that of La Heij et al., 1990, and Wheeldon & Monsell, 1994).

In the model, the associative connections among phonological word forms provide the mechanism by which inappropriate-meaning distractors can exert a facilitatory effect. For inappropriate-meaning associates, the lemma for the word *formal* activates its phonological word form, which

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

then sends priming activation to the *ball* phonological word form through the excitatory lateral connections. This priming activation gives the shared word form a head start when the target is processed, resulting in facilitation. For inappropriate-meaning competitors, the *dance* lemma activates the *dance* phonological word form, which then activates the *ball* phonological word form through the *formal* phonological word form. Again, this priming activation results in a head start for the *ball* phonological word form.

The model illustrates the advantage of investigating the influence of inappropriate-meaning distractors in the experiments. Because inappropriate-meaning distractors like *dance* and *formal* are not in the same semantic field as the target toy *ball,* activation of the inappropriate-meaning lemmas exerts no competitive influence on target processing. This is in contrast to the case with appropriate-meaning associates like *game,* which are in the same semantic field as the target, and thus processing such associated lemmas does exert competitive effects on target processing. As a result of avoiding semantic field competitive effects, the effects of associative relations were more clearly demonstrated, in the inappropriate-meaning associate (*formal*) condition. The role of associative relations during lexical access is thus more clear: Associates exert an excitatory influence on lexical access, but that influence is often obscured by confounded competitive effects.

Note that the model predicts an advantage for inappropriate-meaning associates over inappropriate-meaning competitors—a 1.6 time step difference—whereas Experiment 3B only found a 3-ms difference between these conditions. Indeed, such a difference is predicted by the model, because competitors are one link further removed from targets, compared to associates. Verification of the prediction awaits future research.

Note also that this model, as implemented, does not include a mechanism to account for the late SOA phonological facilitation found in, for example, Schriefers et al. (1990). To account for such effects, the model minimally requires a mechanism for distractors' comprehension phonological representations to directly affect their corresponding as well as phonologically similar production representations (currently, distractors only directly affect lemma representations). As discussed earlier, such direct comprehension-to-production effects must be fast acting and transitory, because phonological similarity effects are generally not seen at early SOAs.

The pattern of excitatory and inhibitory effects in the model occurs only when information is processed in cascade. All facilitatory effects occur because of priming activation that is sent to the target phonological word form. If nontarget representations are not allowed to send activation to subsequent processing levels prior to selection (i.e., if processing is discrete), then the target phonological word form can never be primed, and no facilitatory effects can occur. The appropriate-meaning competitor condition shows that at the same time that facilitatory priming is sent to phonological word forms, semantic processing is still in progress, because lemma selection is slowed through lemma competition.

Overall, the computational model presented here helps to clarify the mechanisms that might underlie the pattern of effects observed in the experiments. Competitive effects occur because semantic representations partially activate more than one lemma representation, requiring a competitive mechanism to perform the selection. It is an amplified form of this competition that is observed in the appropriate-meaning competitor condition, when a distractor enhances competitor activation. Facilitatory effects occur when phonological word forms receive priming activation from nontarget representations. Here, the facilitatory effect of processing a distractor is seen because the semantic dissimilarity of the alternative meanings of homophones avoids the normal semantic competition effect that is observed. This facilitatory effect implicates a representational role for associates in lexical access—a consequence that is normally obscured by an accompanying competitive effect.

Conclusions

Taken together, the results of the three production experiments and one comprehension experiment suggest that semantic and phonological processing occur simultaneously during lexical access. However, given that a rich architecture underlies the lexical access system, it is possible that some unexplored mechanism underlies the observed pattern of results without implicating cascading. Nevertheless, it is important to note that our interpretation of these results does not require any radical modification to existing models of lexical access. Specifically, to account for these results, a model of lexical access simply requires the assumptions that activation freely spreads between levels of representation in the production system—an explanation that is gaining empirical support from other research (e.g., Griffin & Bock, 1998; Jescheniak & Schriefers, 1998; Peterson & Savoy, 1998), and that some facilitatory mechanism (here, associative connections) permits related representations to facilitate one another. At this point, these results are best taken as part of an accumulating body of research that suggests that when speakers retrieve words during production, that activation is permitted to cascade from level of representation to level of representation.

Overall, this investigation provides some hints concerning the efficient nature of lexical access: Given the information processing requirements of a system designed to mediate between the rich domain of thought and the impoverished domain of sound, the system underlying lexical access uses a complex system of excitation and inhibition, allowing activation to flow freely but within limits, so that selection is as efficient as possible.

References

Badecker, W., Miozzo, M., & Zanuttini, R. (1995). The two-stage model of lexical retrieval: Evidence from a case of anomia with selective preservation of grammatical gender. *Cognition, 57,* 193–216.

Balota, D. A., & Paul, S. T. (1996). Summation of activation: Evidence from multiple primes that converge and diverge within

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

semantic memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22,* 827–845.
Bock, J. K. (1982). Toward a cognitive psychology of syntax: Information processing contributions to sentence formulation. *Psychological Review, 89,* 1–47.
Bock, J. K. (1996). Language production: Methods and methodologies. *Psychonomic Bulletin & Review, 3,* 395–421.
Brown, R., & McNeill, D. (1966). The "tip of the tongue" phenomenon. *Journal of Verbal Learning and Verbal Behavior, 5,* 325–337.
Butterworth, B. (1992). Lexical access in speech production. In W. Marslen-Wilson (Ed.), *Lexical representation and process* (pp. 108–135). Cambridge, MA: MIT Press.
Caramazza, A. (1997). How many levels of processing are there in lexical access? *Cognitive Neuropsychology, 14,* 177–208.
Carr, T. H., McCauley, C., Sperber, R. D., & Parmelee, C. M. (1982). Words, pictures, and priming: On semantic activation, conscious identification, and the automaticity of information processing. *Journal of Experimental Psychology: Human Perception and Performance, 8,* 757–777.
Cohen, J. D., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: A new graphic interactive environment for designing psychology experiments. *Behavior Research Methods, Instruments, & Computers, 25,* 257–271.
Corina, D. P., & Lostutter, T. W. (1996). Time course of semantic and phonological interference effects in picture naming. In G. W. Cottrell (Ed.), *Proceedings of the Eighteenth Annual Conference of the Cognitive Science Society* (p. 746). Mahwah, NJ: Erlbaum.
Cutting, J. C. (1997, May). *The production and comprehension lexicons: What's shared and what's not.* Paper presented at the 69th annual meeting of the Midwestern Psychological Association, Chicago.
Dell, G. S. (1986). A spreading-activation theory of retrieval in sentence production. *Psychological Review, 93,* 283–321.
Dell, G. S. (1988). The retrieval of phonological forms in production: Tests of predictions from a connectionist model. *Journal of Memory and Language, 27,* 124–142.
Dell, G. S., & O'Seaghdha, P. G. (1991). Mediated and convergent lexical priming in language production: A comment on Levelt et al. (1991). *Psychological Review, 98,* 604–614.
Dell, G. S., & Reich, P. A. (1981). Stages in sentence production: An analysis of speech error data. *Journal of Verbal Learning and Verbal Behavior, 20,* 611–629.
Ferreira, V. S., & Cutting, J. C. (1997). Ninety-three pictures and 108 questions for the elicitation of homophones. *Behavior Research Methods, Instruments, & Computers, 29,* 619–635.
Garrett, M. F. (1975). The analysis of sentence production. In G. H. Bower (Ed.), *The psychology of learning and motivation* (pp. 133–177). New York: Academic Press.
Garrett, M. F. (1988). Processes in language production. In E. F. J. Newmeyer (Ed.), *Language: Psychological and biological aspects. Linguistics: The Cambridge survey* (Vol. 3, pp. 69–96). Cambridge, England: Cambridge University Press.
Glaser, W. R., & Düngelhoff, F-J. (1984). The time course of picture–word interference. *Journal of Experimental Psychology: Human Perception and Performance, 10,* 640–654.
Glaser, W. R., & Glaser, M. O. (1989). Context effects in Stroop-like word and picture processing. *Journal of Experimental Psychology: General, 118,* 13–42.
Griffin, Z. M. (1995, May). *The locus of the word frequency effect in language production.* Paper presented at the 67th annual meeting of the Midwestern Psychological Association, Chicago.
Griffin, Z. M., & Bock, K. (1998). Constraint, word frequency, and the relationship between lexical processing levels in spoken word production. *Journal of Memory & Language, 38,* 313–338.
Hamburger, M., & Slowiaczek, L. M. (1996). Phonological priming reflects lexical competition. *Psychonomic Bulletin & Review, 3,* 520–525.
Harley, T. A. (1984). A critique of top-down independent levels models of speech production: Evidence from non-plan-internal speech errors. *Cognitive Science, 8,* 191–219.
Humphreys, G. W., Lloyd-Jones, T. J., & Fias, W. (1995). Semantic interference effects on naming using a postcue procedure: Tapping the links between semantics and phonology with pictures and words. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 961–980.
Humphreys, G. W., Riddoch, M. J., & Quinlan, P. T. (1988). Cascade processing in picture identification. *Cognitive Neuropsychology, 5,* 67–103.
Jescheniak, J. D., & Levelt, W. J. M. (1994). Word frequency effects in speech production: Retrieval of syntactic information and of phonological form. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 824–843.
Jescheniak, J. D., & Schriefers, H. (1998). Discrete serial versus cascaded processing in lexical access in speech production: Further evidence from the coactivation of near-synonyms. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24,* 1256–1274.
Kempen, G., & Huijbers, P. (1983). The lexicalization process in sentence production and naming: Indirect election of words. *Cognition, 14,* 185–209.
La Heij, W., Dirkx, J., & Kramer, P. (1990). Categorical interference and associative priming in picture naming. *British Journal of Psychology, 81,* 511–525.
Levelt, W. J. M. (1989). *Speaking: From intention to articulation.* Cambridge, MA: MIT Press.
Levelt, W. J. M., Roelofs, A., & Meyer, A. S. (in press). A theory of lexical access in speech production. *Behavioral and Brain Sciences.*
Levelt, W. J. M., Schriefers, H., Vorberg, D., Meyer, A. S., Pechmann, T., & Havinga, J. (1991). The time course of lexical access in speech production: A study of picture naming. *Psychological Review, 98,* 122–142.
Lukatela, G., & Turvey, M. T. (1994). Visual lexical access is initially phonological: I. Evidence from associative priming by words, homophones, and pseudohomophones. *Journal of Experimental Psychology: General, 123,* 107–128.
Lupker, S. J. (1979). The semantic nature of response competition in the picture–word interference task. *Memory & Cognition, 7,* 485–495.
MacKay, D. G. (1987). *The organization of perception and action: A theory for language and other cognitive skills.* New York: Springer-Verlag.
Martin, N., Dell, G. S., Saffran, E. M., & Schwartz, M. F. (1994). Origins of paraphasias in deep dysphasia: Testing the consequences of a decay impairment to an interactive spreading activation model of lexical retrieval. *Brain & Language, 47,* 609–660.
McClelland, J. L. (1979). On the time relations of mental processes: An examination of systems of processes in cascade. *Psychological Review, 86,* 287–330.
McRae, K., & Boisvert, S. (1998). Automatic semantic similarity priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24,* 558–572.
Meyer, A. S., & Bock, K. (1992). The tip-of-the-tongue phenomenon: Blocking or partial activation? *Memory & Cognition, 20,* 715–726.
Moss, H. E., Ostrin, R. K., Tyler, L. K., & Marslen-Wilson, W. D. (1995). Accessing different types of lexical semantic informa-

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

tion: Evidence from priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 863–883.
Neely, J. H. (1991). Semantic priming effects in visual word recognition: A selective review of current findings and theories. In D. Besner & G. W. Humphreys (Eds.), *Basic processes in reading: Visual word recognition* (pp. 264–336). Hillsdale, NJ: Erlbaum.
O'Seaghdha, P. G., & Marin, J. W. (1997). Mediated semantic-phonological priming: Calling distant relatives. *Journal of Memory and Language, 36,* 226–252.
Peterson, R. R., & Savoy, P. (1998). Lexical selection and phonological encoding during language production: Evidence for cascaded processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24,* 539–557.
Roelofs, A. (1992). A spreading activation theory of lemma retrieval in speaking. *Cognition, 42,* 107–142.
Roelofs, A. (1997). The WEAVER model of word form encoding in speech production. *Cognition, 64,* 249–284.
Schriefers, H., Meyer, A. S., & Levelt, W. J. M. (1990). Exploring the time course of lexical access in language production: Picture–word interference studies. *Journal of Memory and Language, 29,* 86–102.
Slowiaczek, L. M. (1994). Semantic priming in a single-word shadowing task. *American Journal of Psychology, 107,* 245–260.
Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory, 6,* 174–215.
Starreveld, P. A., & La Heij, W. (1995). Semantic interference, orthographic facilitation, and their interaction in naming tasks. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 686–698.
Stemberger, J. P. (1985). An interactive activation model of language production. In A. Ellis (Ed.), *Progress in the psychology of language* (pp. 143–186). London: Erlbaum.
Twilley, L. C., Dixon, P., Taylor, D., & Clark, K. (1994). University of Alberta norms of relative meaning frequency for 566 homographs. *Memory & Cognition, 22,* 111–126.
van Turennout, M., Hagoort, P., & Brown, C. M. (1997). Electrophysiological evidence on the time course of semantic and phonological processes in speech production. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23,* 787–806.
Vigliocco, G., Antonini, T., & Garrett, M. F. (1997). Grammatical gender is on the tip of Italian tongues. *Psychological Science, 8,* 314–317.
Wheeldon, L. R., & Monsell, S. (1994). Inhibition of spoken word production by priming a semantic competitor. *Journal of Memory and Language, 33,* 332–356.
WordNet (Version 1.5) [Computer software]. (1996). Princeton, NJ: Princeton University Cognitive Science Library.
Zwitserlood, P. (1994). Access to phonological-form representations in language comprehension and production. In C. Clifton, L. Frazier, & K. Rayner (Eds.), *Perspectives on sentence processing* (pp. 83–106). Hillsdale, NJ: Erlbaum.

(Appendixes follow)

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

Appendix A

Stimuli Used in the Experiments

Homophone picture	Distractor words: Appropriate meaning	Distractor words: Inappropriate meaning	Distractor words: Unrelated control
Experiments 1 and 2			
ball	game	dance	hammer
band	concert	rubber	message
bat	glove	cave	rubber
bow	hair	arrow	glove
cast	arm	play	treasure
check	money	mark	arrow
chest	muscle	treasure	heart
ear	sound	corn	pad
foot	shoe	yard	pig
horn	car	unicorn	arm
iron	clothes	metal	stereo
key	lock	piano	outlet
letter	mail	alphabet	king
nail	hammer	polish	famous
note	music	message	zoo
organ	church	heart	bottom
pen	ink	pig	bell
pipe	smoke	plumber	sound
plug	outlet	drain	music
pool	swim	table	clothes
ring	finger	bell	polish
ruler	measure	king	shoe
seal	zoo	close	podium
speaker	stereo	podium	ink
stamp	envelope	pad	church
star	sky	famous	money
top	spin	bottom	play

Nonhomophone picture	Distractor words: Semantic	Distractor words: Phonological	Distractor words: Unrelated control
Experiments 1 and 2			
apple	orange	anchor	close
barrel	crate	berry	table
bed	dresser	bench	corn
bus	truck	bud	mark
camel	zebra	candle	swim
castle	fort	cactus	drain
cat	mouse	cap	spin
chair	desk	cherry	metal
crown	queen	crowd	lock
cup	bowl	cuff	game
dog	fox	doll	plumber
dynamite	gunpowder	dinosaur	sky
fork	spoon	force	envelope
frog	turtle	frost	piano
hand	elbow	ham	measure
horse	cow	house	finger
knife	gun	knight	smoke
lamp	vase	land	muscle
monkey	tiger	mushroom	alphabet
pencil	crayon	penguin	mail
rake	shovel	race	dance
rope	string	road	yard
sandwich	chips	sandal	hair
sock	mitten	salt	concert
tree	bush	tray	car
window	door	windmill	cave
witch	magician	whistle	unicorn

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

Appendix A (*continued*)

Homophone picture	Distractor words: Appropriate associate	Appropriate competitor	Unrelated control
	Experiment 3A		
ball[a]	game	frisbee	racquet
band	concert	musician	screw
bat	glove	racquet	envelope
bow	hair	ribbon	volume
cat	plaster	splint	doorknob
check	account	money	cigar
chest	muscle	torso	triangle
ear	sound	nose	spin
foot	shoe	ankle	concert
horn	car	trumpet	nose
iron	clothes	dryer	church
key	lock	doorknob	car
letter	mailbox	mail	chalk
nail	hammer	screw	swim
note	melody	music	plaster
organ	church	piano	dryer
pen	ink	chalk	account
pipe	smoke	cigar	muscle
plug	electric	cord	ankle
pool[a]	swim	jacuzzi	jacuzzi
ring	finger	bracelet	electric
ruler	measure	yardstick	music
seal	zoo	walrus	hammer
speaker	volume	amplifier	walrus
stamp	envelope	postmark	ribbon
star	sky	triangle	measure
top	spin	yo-yo	bracelet

Nonhomophone picture	Distractor words: Associate	Competitor	Unrelated control
	Experiment 3A		
apple	pie	peach	mail
barrel	wine	crate	finger
bed	sheets	dresser	yo-yo
bus	charter	truck	zoo
camel	desert	zebra	splint
castle	moat	fort	amplifier
cat	meow	mouse	frisbee
chair	sit	desk	postmark
crown	queen	hat	game
cup	coffee	bowl	melody
dog	leash	fox	glove
dynamite	explosion	gunpowder	trumpet
fork	silver	spoon	shoe
frog	pond	turtle	mailbox
hand	clap	elbow	yardstick
horse	saddle	cow	smoke
knife	cut	gun	ink
lamp	lightbulb	vase	piano
monkey	banana	tiger	torso
pencil	eraser	crayon	musician
rake	leaves	shovel	sound
rope	lasso	string	sky
sandwich	baloney	chips	lock
sock	cotton	mitten	hair
tree	branches	bush	clothes
window	glass	door	money
witch	magic	magician	cord

(*Appendixes continue*)

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

Appendix A (*continued*)

Homophone picture	Distractor words: Inappropriate associate	Inappropriate competitor	Unrelated control
	Experiment 3B		
ball	formal	prom	pig
band	rubber	string	polish
bat	cave	bird	alphabet
bow	arrow	spear	rubber
cast	play	actors	famous
check	rook	mate	plumber
chest	treasure	trunk	bell
ear	stalk	corn	play
foot	measure	yard	throne
horn	unicorn	antler	stalk
iron	chain	steel	unicorn
key	piano	tune	transplant
letter	alphabet	number	close
nail	polish	claw	rook
note	paper	message	drain
organ	transplant	bones	paper
pen	pig	cage	table
pipe	plumber	tube	chain
plug	drain	stopper	measure
pool	table	billiards	formal
ring	bell	chime	podium
ruler	throne	king	piano
seal	close	glue	treasure
speaker	podium	lecturer	cave
stamp	pad	blotter	arrow
star	famous	celebrity	height
top	height	bottom	pad

[a]These items were not included in the reported analyses.

Appendix B

Simulation Details

The simple model of lexical access described in the General Discussion was implemented as an interactive activation model, a subset of which is illustrated in Figure 4. There are four kinds of connections in the model. First, strong excitatory interlevel links connect corresponding word forms to one another. For example, the *frisbee* semantic representation is connected to the *frisbee* lemma, which in turn is connected to the */frizbij/* phonological word form. Second, weak excitatory interlevel links connect lemmas to semantically similar semantic representations. For example, the *frisbee* lemma is connected to the toy *ball* semantic representation. Third, strong inhibitory within-level links connect semantically similar lemmas to one another. For example, the *frisbee* lemma is inhibitorily linked to the toy *ball* lemma. Finally, weak excitatory within-level links connect associated phonological word forms to one another. For example, the */gejm/* phonological word form is connected to the */ba:l/* phonological word form. For each of these types of connections, we provide functional and/or empirical motivations and parameter values.

Parameter values were chosen that permitted the model to work correctly, in that other sets of tested parameter values either did not permit the target */ba:l/* phonological representation to achieve threshold, or led some distractor representation to achieve threshold. A variety of parameter values that worked were tested by adding random noise to weights, as described below.

Mapping Links

The strong excitatory links between corresponding semantic, lemma, and phonological word form representations underlie the model's ability to correctly map an activated semantic representation onto its correct lemma and phonological word form representations. In all simulations, these weights were set to a mean value of 0.3.

Semantic Similarity Links

Weak excitatory links between lemmas and semantically similar semantic representations arise under the assumption that words do not map isomorphically onto semantic representations. That is, because semantic representations are continuous and graded, whereas words are discrete, words must "cut up" semantic space. Thus, a word's semantic field will cover a range of semantic possibilities, and will overlap to some extent with the semantic fields of other words. In short, the weak connection from the *frisbee* lemma to the toy *ball* semantic representation corresponds to the claim that the semantic features of the word *frisbee* overlap to a small extent with the semantic features of the word *ball*. In all simulations, these weights were set to a mean value of 0.15.

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

Competitive Links

Strong inhibitory links connect semantically similar lemmas because the just described excitatory links from lemmas to semantically similar semantic representations cause semantically similar lemmas to become simultaneously active. That is, when a speaker intends to say toy "ball," the lemma representation of *frisbee* will become active, due to *frisbee*'s overlapping semantic representation with toy *ball*. Thus, in a production situation, more than one lemma will become active when only one can be selected. The inhibitory links among representations that tend to be co-active implement a competitive mechanism among such representations, so that representations with activations close to that of other representations are selected slowly, whereas representations with activations that are much greater than that of other representations are selected more quickly. In all simulations, these weights were set at −0.45.

In the model, we assume that the two *ball* lemmas are inhibitorily linked. Lemmas corresponding to alternative homophone meanings might be inhibitorily linked if competitive relationships evolve among representations that are simultaneously active when only a single representation can be selected from that set (as would occur with lemmas that have similar semantic representations). In turn, the alternative lemma representations of a homophone would be simultaneously active if activation feeds back from phonological to lemma representations, because activation of the intended lemma representation will feed back through the shared phonological representation to the unintended lemma representation, or if the same representations, connections, and mechanisms are used for lexical access in comprehension as well as production (see Balota & Paul, 1996, for discussion of comprehension issues). Given that we have no direct evidence for such feedback or shared resources, however, this assumption is made to be conservative, because an inhibitory connection between alternative homophone lemmas can only diminish the influence of the inappropriate-meaning distractors.

Associative Links

Finally, the motivation for the weak excitatory links that connect associatively related phonological word forms is mostly empirical. The introduction described evidence showing that associates have an inconsistent but generally facilitatory effect on one another in production (La Heij et al., 1990; Wheeldon & Monsell, 1994), and Experiment 3B revealed that distractors that are associatively related to the nondepicted meaning of a pictured homophone facilitate naming time of that picture. Our modeling efforts have revealed that within the general architecture shown in Figure 4, the only mechanism for relating associates that results in adequate levels of facilitation is one where associated phonological word form representations are excitatorily connected. Excitatory associative connections cannot be at the higher (lemma or semantic) levels, because the influences exerted by the associative connections become nullified by the competitive interactions among lemmas. These weak connections were set to the same mean value of 0.15 as the semantic similarity connections described above.

Two related findings support the claim that associative effects are due to facilitatory connections among phonological word form representations. First, evidence from comprehension research suggests that facilitatory associative priming in word recognition occurs at a level involving phonological representations (e.g., Lukatela & Turvey, 1994). Although the phonological representations that underlie comprehension and production performance are likely to be distinct (e.g., Cutting, 1997; Levelt et al., in press), it is not unprecedented to claim that phonological representations can develop a mutually excitatory pattern of processing when associatively related. Second, tip-of-the-tongue (TOT) investigations have shown that speakers more successfully retrieve words and enter fewer TOT states when presented with words that are associated with the target (e.g., Meyer & Bock, 1992).[B1] Given the architecture in Figure 4 and the assumption that TOT states occur when phonological representations are not sufficiently active, such an effect follows naturally, because an associate of a target word would serve to increase the activation of that target phonological word form through the lateral excitatory connection.

Other Simulation Details

At each time step, a node's activation decayed by a factor of 0.5. Nodes' activations were updated synchronously. The activation of a node was the sum of the node's previous activation (less decay) with all weighted inputs to the node, and was constrained to always be greater than or equal to zero (i.e., the activation function was the identity function, bounded by zero at the lower end).

The model included a space of lexical items sufficient to illustrate all effects (i.e., all nodes depicted in Figure 4). In addition, the implemented model included a competitor for each simulated associate (*contest* for *game* and *proper* for *formal*), as well as for the unrelated condition (*shrub* for *tree*), so that the within-field competitive effects for these words were simulated. Note that the model only includes a limited number of items. Strictly speaking, whether such models can easily "scale up" to more realistically sized vocabularies is unclear. In this particular model, however, the model might be expected to scale up reasonably because each field of connected items (which includes a set of taxonomically and associatively related words) is quasi-isolable, having minimal influences on other fields of items.

Processing

Target processing began by clamping (fixing as "on") the toy *ball* semantic representation with an activation of 1.5. Activation then spreads until a lemma representation (which was always the target *ball* lemma) reached a threshold activation of 1.0, at which point it was selected. Upon selection, the node's activation was clamped at an increased value of 1.5. Activation then spreads until a phonological word form (which was always the */ba:l/* phonological word form) reached a threshold of 1.0, at which point processing was terminated. The number of time steps for the */ba:l/* phonological word form to reach threshold was taken to correspond to naming latency.

The effect of the distractor types was simulated by clamping the corresponding lemma representation of the distractor word with an activation of 1.0 for a total of five time steps, beginning nine time steps before the target *ball* semantic representation was clamped. For example, in the appropriate-meaning competitor condition, the *frisbee* lemma was clamped at an activation of 1.0 at Time Step 1, and was released beginning at Time Step 6 (at which point the activation of the semantic representation gradually fell to zero). Meanwhile, the target *ball*'s semantic representation was clamped with an activation of 1.5 at Time Step 10. Activation spreads through all connections during intervening time steps, permitting distractor representations to affect target item representations.

Ten simulated participants were run in each distractor condition. Each simulated participant differed in that the weight and decay

[B1] We thank Wido La Heij for suggesting this connection to us.

(*Appendix continues*)

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

parameters were initialized to a value randomly chosen from a normal distribution with the mean reported above for each parameter, and a standard deviation of 0.025. For example, all direct mapping weights were chosen from a normal distribution with a mean of 0.3 and a standard deviation of 0.025. The statistics reported in the General Discussion were taken from planned comparisons within a one-way ANOVA with simulated participant as the random variable, and with the single variable of distractor type with five levels (appropriate competitor, appropriate associat neutral, inappropriate competitor, and inappropriate associate).

Received July 31, 1996
Revision received September 2, 1998
Accepted September 7, 1998

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

New Editors Appointed, 2000-2005

The Publications and Communications Board of the American Psychological Association announces the appointment of three new editors for 6-year terms beginning in 2000.

As of January 1, 1999, manuscripts should be directed as follows:

- For **Experimental and Clinical Psychopharmacology**, submit manuscripts to Warren K. Bickel, PhD, Department of Psychiatry, University of Vermont, 38 Fletcher Place, Burlington, VT 05401-1419.
- For the **Journal of Counseling Psychology**, submit manuscripts to Jo-Ida C. Hansen, PhD, Department of Psychology, University of Minnesota, 75 East River Road, Minneapolis, MN 55455-0344.
- For the **Journal of Experimental Psychology: Human Perception and Performance**, submit manuscripts to David A. Rosenbaum, PhD, Department of Psychology, Pennsylvania State University, 642 Moore Building, University Park, PA 16802-3104.

Manuscript submission patterns make the precise date of completion of the 1999 volumes uncertain. Current editors, Charles R. Schuster, PhD; Clara E. Hill, PhD; and Thomas H. Carr, PhD, respectively, will receive and consider manuscripts through December 31, 1998. Should 1999 volumes be completed before that date, manuscripts will be redirected to the new editors for consideration in 2000 volumes.