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Visual Lexical Access Is Initially Phonological: 1. Evidence From Associative Priming by Words, Homophones, and Pseudohomophones

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In 9 experiments, a target word (e.g., frog) was named following an associate (TOAD), or a word (e.g., TOWED) or nonword (e.g., TODE) homophonic with the associate. At brief (e.g., 50 ms) stimulus onset asynchronies (SOAs), the 3 primes produced equal associative priming. At a long SOA (250 ms), priming by TOAD was matched by TODE but not by TOWED. Equal priming at brief SOAs by the 3 primes and no priming by orthographic controls (TOLD, TORD) suggests that lexical access is initially phonological. TOWED priming less than TODE at SOA = 250 ms suggests that phonologically activated representations whose input orthography does not match the addressed spelling (available only for words) are eventually suppressed. Phonological constraints on lexical access precede and set the stage for orthographic constraints.

Ever since the inception of research on reading, the issue of phonology's role has been a topic of debate (e.g., Huey, 1908/1968). Does a printed word contact its representation in the internal lexicon on the basis of how it looks or on the basis of how it sounds? The visual route would seem most direct, because the sound route necessarily entails a conversion from the word's visual form to the phonology that it transcribes. The requirement of a conversion would seem to add time to lexical access, rendering recognition by how a printed word sounds, a potentially slower process than recognition by how a printed word looks. From a different perspective, however, phonological mediation is the only sensible option. How words sound and how they are spoken presage experience with how they look, suggesting that the challenge of visual word recognition is met by linking the visual forms of words to their phonological forms so as to exploit the word memory established by speaking and hearing.

As models of word recognition developed, room for both routes to the internal lexicon was found, with theoretical preference given to the visual route partly on the grounds that it seemed to express the intuitive notion of fluency. The more skilled a reader, the more inclined he or she would be to recognize a printed word on the basis of how it looked. As framed in the original version of dual-route theory (Coltheart, 1978), the direct visual route is the principal route for exceptional spellings, and the phonological route is the principal route for new words and nonwords. Familiar words can be processed by both routes, but the faster visual route is preferred by the skilled reader (as noted), and the phonological route is considered as often occurring too slowly to influence the reading of familiar words in the normal time course of word identification.

Although the phonological route's status within dual-route theory has been relegated to that of second fiddle, many students of word recognition have been disinclined to assign any role to the phonological route, feeling that it could be discarded from theoretical considerations with no loss of generality (e.g., Aaronson & Ferres, 1983; Kolers, 1970; McClelland & Rumelhart, 1981; Paap, Newsome, McDonald, & Schvaneveldt, 1982; Smith, 1971). Humphreys and Evett (1985) offered a major proposal along such lines, their review of the available data on visual word recognition suggested to them that there was no substantial evidence for an independent phonological route. They stated that all variants of word recognition could be accommodated by a word-specific strategy and that an appeal to a process engaging orthography-to-phonology conversion rules was unwarranted.

A large body of data on word recognition in the Serbo-Croatian language has stood against the conclusion of Humphreys and Evett (1985); for recent summaries see Carello, Turvey, & Lukatela, 1992; Lukatela & Turvey, 1990a, 1991). Results from a wide variety of experiments that exploited the two partially overlapping and phonetically precise alphabets (Roman and Cyrillic) of the Serbo-Croatian language, and that were conducted with readers who were competent in both alphabets, have resisted a consistent interpretation in terms of a visual access code. They have tended to suggest instead that the access is strictly phonological. Said differently, with the Serbo-Croatian language, providing a demonstration of direct access distinguishable from phonologic mediation has been difficult, if not impossible.

The Serbo-Croatian results can be looked at in two ways. One way is to see them as indicative of outcomes peculiar to the transcription of the language and its implementation of two partially overlapping but phonemically precise alphabets. The other way is to see them as the outcomes of experimental procedures, made possible by the special fea-

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tures of transcribed Serbo-Croatian, that are uniquely able to reveal the dominant role of phonology. Whereas the first way of looking at the results emphasizes the differences among languages in terms of orthographic depth or the simplicity of the orthography-to-phonology mapping (Lukatela & Turvey, 1980), the second way emphasizes the common dependence of word recognition in all alphabetic writing systems on phonologically mediated lexical access (Carello et al., 1992; Lukatela & Turvey, 1993).

There has been an ever-increasing number of results in English that reinforce the second perspective on the Serbo-Croatian data (e.g., Lukatela, Lukatela, & Turvey, 1993; Lukatela & Turvey, 1991, 1993; Perfetti, Bell, & Delaney, 1988; Van Orden, Johnston, & Hale, 1988). These results stem from novel procedures (e.g., rapid semantic categorization of homophones, homophonic backward masking) that reveal a significant role for phonology, one that is manifest very early in the word recognition process. To an important degree, rejections of phonological mediation in English have been empirically reinforced by evidence that phonological manipulations prove significant only when the recognition responses are slow. The implication has been that phonological influences arise subsequent to the usual time course of word recognition and are, therefore, ancillary at best to the recognition process (e.g., McCusker, Hillinger, & Bias, 1981).

Not surprisingly, the dual-route perspective can be relatively easily adjusted to incorporate the new evidence for a rapidly available phonological code in English word recognition. One major adjustment is to permit phonologically mediated access (rule-based or otherwise) to occur at a pace close to that of direct visual access for familiar words when there is a consistent orthography–phonology mapping (Paap & Noel, 1991; Paap, Noel, & Johansen, 1992). An important experimental finding that provides a supportive context for this adjustment is an interaction between the regularity of a word's spelling and the frequency of a word's occurrence (e.g., Seidenberg, Waters, Barnes, & Tanenhaus, 1984). Inconsistency affects word recognition latencies most when word frequency is low.

In the present research, we take the implications of our prior research in Serbo-Croatian very seriously and press an interpretation of English word recognition that is in keeping with the interpretation of Serbo-Croatian word recognition (e.g., Lukatela, Turvey, Feldman, Carello, & Katz, 1989). That is, we take the primary and initial source of lexical activation in English to be phonological. The role of orthographic codes is then taken to be that of refining the lexical activation begun by phonology. Phonologically activated representations inform us about how a word is spelled, and, in combination with the visually presented form (the input orthographic pattern), these "addressed" spellings help reduce the number of lexical representations to one when more than one has been activated.

The present investigations expand on the original intuition of Rubenstein, Lewis, and Rubenstein (1971) that nonwords that sound like words (i.e., pseudohomophones), and words that sound like words (i.e., homophones), collectively constitute a powerful empirical tool for unearthing phonological processes in English word recognition. In the present research, this intuition is implemented in the context of the associative priming task with prime-to-target delays equal to or very much less than 250 ms. It would seem that the successful demonstration of lexical access codes requires experiments that probe the time domain in which such codes are assumed to operate "reflexively" and "irresistibly" (Fodor, 1983). If two processes are hypothesized to operate within overlapping time scales, then distinguishing between them, evaluating their separability, and determining their roles (singly and in combination) demands a detailed examination of their common temporal domain. In the experiments that follow we repeatedly focus on the questions "How fast is phonologically mediated lexical access?" and "Can an independent visual access be distinguished from phonological access?"

Experiment 1

If phonological codes are assembled rapidly and automatically for use in lexical access, then printed words that sound alike should induce similar activity within the internal lexicon. Lukatela et al. (1993) examined this hypothesis in a priming-of-naming task in which words that were homophonous (e.g., TOWED) with associates (TOAD) of target words (FROG) preceded the targets at a stimulus onset asynchrony (SOA) of 100 ms. The results revealed that relative to spelling controls (e.g., TROD), homophonic primes reduced target naming latencies. In Experiment 1, the Lukatela et al. (1993) experiment was repeated with the addition of TOAD–frog pairs, and with more refined orthographic controls for the homophones, to determine whether associative priming by homophones at brief SOAs is comparable to that by words.

Method

Subjects. Thirty-nine undergraduates at the University of Connecticut served as subjects. Each subject was assigned to one of three groups, according to the time he or she arrived at the laboratory, yielding 13 subjects per group.

Materials. Before we ran the experiment, we presented 168 printed words to 47 undergraduate students. These words comprised 84 pairs of yoked English homophones (e.g., TOWED and TOAD, DOUGH and DOE). The two members of a given pair of yoked homophones were presented on separate sheets of paper in a random order. Each of the 47 students was requested to write down in line with each printed test word three associates as they came to mind. Each student was urged to respond quickly and to not make corrections. An experimental list of 60 visually related pairs was assembled using the most frequently and reliably associated pairs generated by the 47 students (e.g., TOAD–FROG, DOE–DEER). The selected pairs (see Appendix A) were not fully identical with those that Lukatela et al. (1993) had used previously.

Each prime in the TOAD–FROG, DOE–DEER list was replaced by its yoked homophone to produce a second experimental list of 60 homophonically related prime–target pairs (e.g., TOWED–FROG, DOUGH–DEER). The latter list implicitly comprised two sublists of 30 pairs each. In Sublist A, for a given target word (e.g., DEER), the homophonically related prime (DOUGH) was higher in frequency than its yoked counterpart (DOE). Specifically, DOUGH-type primes had a frequency of 253.21 ± 647.03; DOE-type primes had a frequency of 24.30 ± 33.46. In Sublist B, for a given target word (e.g., FROG), the homophonically related prime (TOWED) was lower in frequency than its yoked counterpart (TOAD). Specifically, TOWED-type primes had a frequency of 11.24 ± 15.70; TOAD-type primes had a frequency of 79.36 ± 165.56. Consequently, the mean frequency of the homophonically related primes in Sublist A was higher than that of the homophonically related primes in Sublist B (253.21 vs. 11.24), and, conversely, the mean frequency of appropriate primes in Sublist A was lower than that of the appropriate primes in Sublist B (24.30 vs. 79.36). Averaged over the two sublists, appropriate primes had a mean frequency of 51.83 and homophonically related primes had a mean frequency of 132.13. Averaged over both prime types, the mean frequencies of Sublist A primes and Sublist B primes were 178.64 and 35.8, respectively, and the mean frequencies of Sublist A targets and Sublist B targets were 76.10 and 91.33, respectively. All frequencies were determined from Kucera and Francis (1967). The purpose of including the sublist variable was to determine the contribution of prime frequency to the degree of priming. If prime frequency was important, then we might expect a Prime Type × Sublist interaction.

A third list, a spelling control list of 60 unrelated prime–target pairs, was also created in which the word targets were the same as those in the experimental pairs. Each spelling control was a word more or less similar in form and frequency to the homophone that it was a control for (e.g., TOLLED for TOWED) and not a prominent associate of the corresponding target. The overall mean frequency of spelling controls was 137.61, which is close to the mean frequency of homophonic primes (132.13, as noted above). Finally, a foil list was assembled that comprised 60 unrelated prime–target pairs. The foil words were nonhomophonic regular words selected with no specific constraints. For all stimuli pairs the prime stimuli were written in uppercase letters and the target stimuli were written in lowercase letters.

Design. The major constraint on the design was that a given subject never encountered a given word more than once. There were three prime types (appropriate associative, homophonic associative, and unrelated control). Each subject was presented with 20 experimental word–word stimulus pairs from each of the three types, with the prime in uppercase letters and the target in lowercase letters, to ease discrimination. For example, if the first subject received NUN–priest, KNOWS–ears, BELL–buy, MEDAL–gold, BARON–dry, and WORMS–flower; then the second subject would receive NONE–priest, KNEES–ears, SELL–buy, MEDDLE–gold, BANJO–dry, and ROSE–flower; and the third subject would receive NINE–priest, NOSE–ears, CELL–buy, MEDLEY–gold, BARREN–dry, and ROWS–flower. In addition, each subject saw a foil set (the same for all subjects) of 60 unrelated word–word pairs. In total, each subject saw 120 stimulus pairs. The experimental sequence was divided into five subsets, with a brief rest after each subset. Stimulus types were ordered pseudorandomly within each subset. The experimental sequence was preceded by a practice sequence of 36 word–word pairs, 16 of which were associatively related.

Procedure. Subjects were run one at a time. Each subject sat in front of the monitor of a Macintosh Apple IIe computer in a dimly lit room. Each trial consisted of an auditory warning signal, followed by a 40-ms presentation of an uppercase letter string (i.e., the context). After an interstimulus interval (ISI) of 60 ms, a lowercase letter string appeared at the fixation point for 400 ms. These exposure durations are nominal rather than exact, because in reality display changes occurred within the standard 16-ms scan rate of the Apple IIe monitor. This means that all actual durations of nominal exposures in the present experiment—as well as in all other experiments reported in this article—varied in a random manner with a uniform probability between 8 ms and −8 ms around the statistical mean exposure. For example, the nominal 100-ms exposure in reality varied between 100 and 116 ms, whereby the statistical mean exposure was 108 ms.

Each subject was told that he or she would view on each trial a sequence of two words, with the first word in uppercase letters and the second word in lowercase letters, and that his or her task was to attend to both words and to name out loud the lowercase word that came second as quickly and as accurately as possible. In all conditions, latencies from the onset of the target to the onset of the response were measured by a voice-operated trigger relay. Naming was considered erroneous when the target word was mispronounced or preceded by any other sound, the pronunciation was not smooth (i.e., subject hesitated after beginning to name), or the response was not loud enough to trigger the voice key. To ensure that subjects were attending to the primes, a computer message was given immediately after a trial that asked subjects to report orally the prime on that trial. This prompt to recall the prime was restricted to 10% of the unrelated (foil) trials. If the naming latency was longer than 1,200 ms, a message appeared on the screen requesting the subject to respond more quickly. All latencies, including those longer than 1,200 ms, were stored in the computer memory.

Results and Discussion

For each subject, naming latencies more than two standard deviations above or below the mean in all conditions were considered errors. For the error analysis, these latency errors were combined with the pronunciation errors described in the preceding paragraph. (We applied this two-standard deviation criterion and the combination of error kinds to all of the reported experiments.) The results are summarized in Table 1.

We conducted a 3 × 2 (Prime Type × Sublist) analysis of variance (ANOVA) on naming latencies, with subjects and stimuli as the error terms, which revealed a main effect of prime type (TOAD = 583 ms vs. TOWED = 588 ms vs. TOLLED = 603 ms) that was significant for subjects, $F1(2, 76) = 11.79, p < .001$, and for stimuli, $F2(2, 116) = 9.18, p < .001$. The main effect of sublist (Sublist A = 594 ms vs. Sublist B = 589 ms) was significant by subjects but not by stimuli,

Table 1
Mean Naming Latencies (in Milliseconds) and Percentage Error Rate, With the Corresponding Standard Deviations by Subjects and by Items in Experiment 1

	TOAD–frog		TOWED–frog		TOLLED–frog	
Measure	L	ER	L	ER	L	ER
Sublist A						
M	588	4.10	589	2.56	603	4.87
Subject *SD*	88	5.49	83	4.42	84	6.01
Item *SD*	38	5.24	29	5.47	33	6.54
Sublist B						
M	577	1.54	586	2.56	603	4.10
Subject *SD*	81	3.66	85	4.98	98	6.37
Item *SD*	34	3.13	30	4.21	40	6.62

Note. L = latency; ER = error rate.

$F1(1, 38) = 5.66$, $p < .05$, $F2 < 1$. The interaction between prime type and sublist, and the partial interactions, were not significant ($Fs < 1$). There were no significant effects in the error analysis.

Turning to the planned comparisons, TOAD–frog differed from TOLLED–frog by 21 ms, $F1(1, 38) = 27.19$, $p < .001$, and $F2(1, 58) = 16.05$, $p < .001$, respectively; TOWED–frog differed from TOLLED–frog by 15 ms, $F1(1, 38) = 8.44$, $p < .01$, and $F2(1, 58) = 9.82$, $p < .01$, respectively; TOWED–frog was 6 ms slower than TOAD–frog, which was not significant for either subjects or stimuli, $F1(1, 38) = 2.03$, $p > .05$, and $F2(1, 58) = 1.39$, $p > .05$, respectively.

In sum, the results of the present experiment substantiate and extend Lukatela et al.'s (1993) results in that they show that (a) naming frog was faster following TOWED than following TOLLED, (b) naming frog following TOWED was as fast as naming frog following TOAD, and (c) the priming by homophonic (e.g., TOWED) and appropriate (TOAD) primes was indifferent to their frequency.

Experiment 2

In Experiment 1, subjects had to report occasionally on the identity of the prime following the naming of the target. This requirement would have encouraged subjects to code the prime phonologically for purposes of short-term retention. In Experiment 2, we eliminated the instruction of "be prepared to report the first word when asked" from the design. If the results of Experiment 1 were an artifact of the requirement to attend to the prime for possible future reporting, then a difference should be seen in Experiment 2 in the magnitudes of priming frog by TOAD and TOWED.

Method

Subjects. Thirty-nine undergraduates at the University of Connecticut served as subjects. These students had not participated in Experiment 1. Each subject was assigned to one of three groups, according to the time he or she arrived at the laboratory, yielding 13 subjects per group.

Materials and design. These were the same as in Experiment 1.

Procedure. The procedure was identical to that of Experiment 1, except that subjects never expected to have to report the prime verbally on any trial in the experiment and were never asked to make such a report.

Results and Discussion

Table 2 summarizes the results. A 3 × 2 (Associativeness × Sublist) ANOVA on naming latencies, with subjects and stimuli as the error terms, revealed a significant main effect of associativeness (TOAD = 517 ms vs. TOWED = 521 ms vs. TOLLED = 532 ms), $F1(2, 76) = 14.94$, $p < .001$, $F2(2, 116) = 4.50$, $p < .01$, respectively. The main effect of sublist (Sublist A = 527 ms vs. Sublist B = 519 ms) was significant by subjects but not by stimuli, $F1(1, 38) = 32.98$, $p < .001$, $F2(1, 58) = 2.34$, $p < .05$, respectively. The interaction between associativeness and sublist was not significant (both $Fs < 1$). There were no significant effects in the error analysis.

Table 2
Mean Naming Latencies (in Milliseconds) and Percentage Error Rate, With the Corresponding Standard Deviations by Subjects and by Items in Experiment 2

	TOAD–frog		TOWED–frog		TOLLED–frog	
Measure	L	ER	L	ER	L	ER
Sublist A						
M	522	0.51	524	1.03	536	1.54
Subject *SD*	56	3.20	50	3.07	62	4.89
Item *SD*	37	1.95	30	3.34	44	3.72
Sublist B						
M	511	1.03	518	0.00	527	2.05
Subject *SD*	50	3.07	54	0.00	67	8.33
Item *SD*	25	3.34	36	0.00	41	4.01

Note. L = latency; ER = error rate.

Considering the important planned comparisons, the 15-ms difference between TOAD–frog and TOLLED–frog was significant, $F1(1, 38) = 23.77$, $p < .001$, and $F2(1, 58) = 7.59$, $p < .01$, respectively; the 11-ms difference between TOWED–frog and TOLLED–frog was significant, $F1(1, 38) = 11.80$, $p < .001$, and $F2(1, 58) = 4.42$, $p < .05$, respectively; and the 4-ms difference between TOWED–frog and TOAD–frog failed to attain significance by both analyses, $F1(1, 38) = 3.94$, $p > .05$, and $F2 < 1$, respectively.

The results of Experiment 2 show that, in the absence of a prompt to recall the prime, which might have encouraged an explicit phonological coding of the prime, TOWED continued to be an effective prime of frog. Aside from this corroboration of Experiment 1 and of Lukatela et al. (1993), the results of Experiment 2 were characterized by (a) an overall smaller associative priming effect than in Experiment 1 and Lukatela et al. (1993) and (b) a replication of the numerical difference in Experiment 1 in which the naming of frog following TOAD was faster than that following TOWED.

With respect to (a), it is apparent that the prompted prime recall, though it did not affect the overall pattern of results, did influence the magnitude of the observed effects. In Experiment 1 the total mean naming latency was 591 ms, whereas in Experiment 2 it was only 524 ms. This relatively large difference (67 ms) in mean naming latency is consistent with the hypothesis that the subjects in Experiment 1 were performing an extra task that was not present in Experiment 2. Presumably, this extra task was rehearsal of the prime in short-term memory. The latter impression is further supported by the fact that the average error rate in Experiment 1 was three times as high (3.26%) as that in Experiment 2 (1.03%). Of the naming errors in Experiment 1, about 2% consisted of the initial segment of the prime; in addition, there were errors in which the prime was merged with the pronunciation of the target. Such errors occurred more rarely in Experiment 2.

With respect to (b), the numerical superiority of TOAD over TOWED in the priming of frog is consistent with the understanding from dual-route theory of an important difference in the way in which TOAD and TOWED activate the lexical representation of frog. According to dual-route theory, a difference between the priming by TOAD and TOWED can be expected, because a task-relevant visual access code for *toad* is available in the case of TOAD and is not available in the case of TOWED. Visual access and phonologically mediated access may combine to activate the lexical representation *toad*. If this combination results in a larger degree of activation, with a resultant larger degree of intralexical activation of *frog* than that induced by phonologically mediated access alone, then naming frog ought to be faster after TOAD than after TOWED. The appropriateness of this interpretation is evaluated in the experiments that follow.

Experiment 3

In Experiment 2, we determined that homophonic priming was not an artifact of the prompted prime recall procedure used in Experiment 1 and Lukatela et al. (1993). It may have been an artifact, however, of another feature of those experiments, one shared by Experiment 2, namely, that the stimulus conditions biased the subjects to expect an associative relation between the prime and target. In Experiments 1 and 2, 44.4% (16 of 36) of the practice stimulus pairs and 16.6% (20 of 120) of the experimental stimulus pairs exhibited a proper associative relation (e.g., TOAD–frog). Considering both appropriate and homophonic (e.g., TOWED–frog) pairs, subjects in Experiments 1 and 2 encountered associativeness on 36% of the trials. If this proportion encouraged an associative expectation, then the observed priming of frog by TOWED could be attributed in part to this expectation.

Experiment 3 was similar to Lukatela et al.'s (1993) experiment in that it examined only pseudoassociative priming—TOAD–frog pairs were excluded. Experiment 3 went beyond Lukatela et al.'s (1993) experiment, however, in two important respects. First, all practice stimulus pairs were made unrelated, and all appropriate primes in Experiments 1 and 2 were replaced by a row of *X*s. In consequence, the percentage of the stimulus pairs suggesting associativeness was reduced from 32.4 in Lukatela et al.'s (1993) experiment to only 12.8 in the present experiment. Second, a forward mask was used to reduce the likelihood of expecting pseudoassociative relations. By sandwiching TOWED between a pattern mask and a target separated at an ISI of 100 ms, we hoped that the opportunity to attend to the particulars of TOWED and to infer its derivative relation to frog would be much reduced.

Method

Subjects. Fifty-four undergraduates at the University of Connecticut served as subjects. These students had not participated in Experiments 1 and 2. Each subject was assigned to one of three groups, according to the time he or she arrived at the laboratory, yielding 18 subjects per group.

Materials. These were the same as those of Experiments 1 and 2, except that each appropriately related context word (e.g., TOAD for frog) was replaced by a row of five *X*s, leaving only TOWED–frog and TOLLED–frog stimuli. All primes were preceded by a mask consisting of a row of seven #s occupying the same spatial region of the screen and covering the same extent as the word primes and the *X*s.

Design. The experimental design was the same as that in Experiment 1.

Procedure. Each subject sat in front of the computer monitor in a well-lit room (to help reduce the sharpness of the stimuli on the screen). On each trial the subject was presented with a sequence of three visual events: a 500-ms visual mask, a 100-ms prime, and a 400-ms target word. The stimuli followed one another at an ISI of 0 ms. Each subject was instructed as follows:

> First you will see a complex visual pattern consisting of a row of hash marks and various strings of uppercase letters. Then you will see a word written in lowercase letters. The word in lowercase you are supposed to read aloud as fast as you can and as accurately as you can. You should try to ignore the complex visual pattern.

Results and Discussion

Table 3 summarizes the results. We conducted a 3 × 2 (Prime Type × Sublist) ANOVA on naming latencies with subjects and stimuli as the error terms. It revealed a significant effect of prime type (xxxxx = 536 ms vs. TOWED = 542 ms vs. TOLLED = 550 ms), $F1(2, 106) = 14.11, p < .001$, and $F2(2, 116) = 7.58, p < .001$, respectively; and a significant effect of sublist (Sublist A = 548 ms vs. Sublist B = 535 ms), $F1(1, 53) = 79.27, p < .001$, and $F2(1, 58) = 4.27, p < .05$, respectively. The Prime Type × Sublist interaction was not significant, $F1(2, 106) = 1.79, p > .10$, and $F2 < 1$, respectively. With respect to the planned comparison of interest, TOWED–frog differed significantly from TOLLED–frog by 8 ms, $F1(1, 53) = 7.47, p < .01$, and $F2(1, 58) = 4.92, p < .03$, respectively. In addition, xxxxx–frog was 14 ms faster than TOLLED–frog, and this difference was significant, $F1(1, 53) = 22.83, p < .001$, and $F2(1, 58) = 13.54, p < .001$, respectively; and xxxxx–frog was 6 ms faster than TOWED–frog, a difference that was significant for subjects, $F1(1, 53) = 8.58, p < .01$; and marginally insignificant for stimuli, $F2(1, 58) = 3.27, p < .10$. There were no significant effects in the error analysis (all Fs < 1).

Table 3
Mean Naming Latencies (in Milliseconds) and Percentage Error Rate, With the Corresponding Standard Deviations by Subjects and by Items in Experiment 3

	xxxxx–frog		TOWED–frog		TOLLED–frog	
Measure	L	ER	L	ER	L	ER
Sublist A						
M	544	0.00	547	0.56	558	0.37
Subject *SD*	48	0.00	53	2.31	49	1.91
Item *SD*	29	0.00	31	1.70	35	1.41
Sublist B						
M	528	0.56	537	0.74	542	0.37
Subject *SD*	53	3.02	50	3.28	52	1.91
Item *SD*	26	1.70	27	1.92	29	1.41

Note. L = latency; ER = error rate.

The magnitude and statistical power of the TOWED–frog versus TOLLED–frog difference suggests that the expectation strategy made possible by the stimulus conditions of Experiments 1 and 2 was not a major contributing factor to the outcomes of those experiments. Collectively, Experiments 1–3 clarify that the advantage of TOWED–frog over TOLLED–frog is not attributable to methodological nor strategic factors.

The data of Table 3 suggest that the main effect of sublist was not due to the difference between the two sublists in prime frequency—the latency contrast favoring Sublist B was evident in the data of the xxxxx–frog stimuli. The two sublists also differ with respect to their targets and the mean frequencies of their targets, 76.10 versus 91.33. To test for the contribution of the targets, we ran a control experiment with 8 subjects and modified stimulus pairs. All the primes in Experiment 3 were replaced by BLANK. The 8 subjects, therefore, were presented with all of the targets but none of the primes. A main effect of sublist was revealed (Sublist A = 538 ms vs. Sublist B = 520 ms), $F1(1, 7) = 21.01$, $p < .01$, $F2(1, 54) = 7.61$, $p < .01$, suggesting that the sublist effect was primarily due to the difference between the sublists in their target stimuli.

The superiority of the xxxxx prime was an unexpected feature of this experiment. This implies that, at the time scale of 100 ms, TOWED and TOLLED must have slowed the processes of selection that result in the lexical representation of frog, with TOWED slowing the processes less so than TOLLED. In more general terms, the implication is that linguistic primes (words) relative to nonlinguistic primes (such as xxxxx) induce greater activity in the internal lexicon, activity that functions essentially as noise against which the selection of the target representation must occur. As is made apparent, the observed superior priming of xxxxx in this experiment is consistent with the dynamics of lexical access and the dependencies of those dynamics on the nature of the prime and the time scale of the prime–target sequence.

Experiment 4

Homophonic associative priming may be interpreted as follows. First, the phonological code for TOWED is assembled automatically, prior to lexical access. Second, the word representations *towed* and *toad* are activated through this phonological code. Third, these activated representations feed excitation through the lexical network to their semantic relatives. Fourth, because the representation *frog* is prominent among the lexical representations primed by *toad*, excitation from *frog* is fed back down to the level of phonological processing units. Consequently, the naming of the subsequent target frog is facilitated by the preactivation of its lexical representation and its phonological constituents.

The preceding account ignores the direct, visual route of dual-route theory. Patently, of TOAD and TOWED, only the former can access *toad* by the visual route. In a recent important variation of dual-route theory, Paap et al. (1992; see also Paap & Noel, 1991) highlighted the theory's essential commitment to two independent processes and sharpened the hypothesis about the speed difference between the two routes. They explicated the main points of their model by drawing an analogy with a horse race. A lexical horse runs the visual, direct, or lexical track, and a nonlexical horse runs the phonological mediation or the orthography-to-phonology conversion track. Naming a word by the lexical track is achieved by recognizing the word and then looking up the phonological information stored at that particular lexical entry. Naming a word on the nonlexical track is achieved by parsing a word into subword units and activating the corresponding phonological units. An unequivocal winner on either track can determine a pronunciation. It is hypothesized that finishing times on the lexical track are faster for high frequency (HF) than for low frequency (LF) words and that finishing times on the nonlexical track are faster for letter strings conforming to consistent rules than to inconsistent rules. Only the lexical horse is influenced by word frequency. Fast horses on the nonlexical track will usually beat slow horses on the lexical track. Furthermore, fast horses on both tracks—HF words and words that obey consistent rules—will finish neck-and-neck, with the lexical horse winning by a nose (Paap et al., 1992). When the two horses lead to competing pronunciations, a delay is introduced relative to when both horses deliver the same pronunciation. The stewards need time to resolve the "photo finish," and they tend to do so in favor of the lexical horse (Paap et al., 1992).

Paap et al.'s (1992) model has important implications for the present research and the interpretation of the findings of Experiments 1 and 2. Suppose that TOAD activates *toad* by the lexical route and TOWED activates *toad* by the nonlexical route. Because appropriate and homophonic primes were, on average, words of the same degree of consistency with respect to the mapping rules, they would take the same amount of time on the nonlexical track. Consequently, TOAD would activate *toad* by the lexical track and TOWED would activate *toad* by the nonlexical track on very similar time scales, with TOAD's activation of the lexical entry *toad* slightly ahead of TOWED's activation.

How might Paap et al.'s (1992) model be tested within the present experimental priming-of-naming task? In Experiment 4, the SOA between prime and target was reduced to half that used in Experiments 1–3 and in Lukatela et al. (1993). If the time for TOAD to get to *toad* by the lexical route is slightly less than the time for TOWED to get there by the nonlexical route, and if this time difference translates into a difference in the degree to which the associate *frog* is preactivated (more by TOAD than by TOWED) at the time frog is presented, then an advantage for priming by TOAD over priming by TOWED should appear at briefer SOAs. Furthermore, this expected advantage of appropriate over homophonic primes should be amplified in conditions in which the appropriate primes are of higher average frequency. In terms of the design of Experiments 1 and 2, this means that the TOAD–frog versus TOWED–frog contrast should be larger for Sublist B than for Sublist A.

An additional feature of Experiment 4 in relation to Experiments 1 and 2 was forward masking of the prime in the manner of Experiment 3 to minimize strategic options (Evett & Humphreys, 1981). If the nonlexical track of Paap et al.'s (1992) model is more optional than the lexical, and if it can be disengaged, then under forward masking of the prime, homophones such as TOWED might become ineffective. The use of a forward mask has the further virtue, as outlined in Experiment 3, of reducing the possibility that the subject notices the fact of association between certain paired stimuli and therefore is less likely to adopt the strategy of looking for associations to facilitate processing.

Method

Subjects. The participants in the experiment were 45 undergraduates at the University of Connecticut. Each subject was assigned to one of three groups, yielding 15 subjects per group. None of the subjects had participated in any of the previous experiments.

Materials and design. These were the same as those in Experiments 1 and 2.

Procedure. The procedure was identical to that of Experiment 3, with the exception that the prime–target SOA was 52 ms.

Results and Discussion

In the debriefing, subjects consistently reported difficulty in seeing the letter pattern that preceded the to-be-named target words, suggesting that there was a marked combined effect of the forward mask and the target (acting as a backward mask). The results of the experiment are summarized in Table 4. A 3 × 2 (Prime Type × Sublist) ANOVA on naming latencies revealed a significant main effect of prime type (TOAD = 560 ms vs. TOWED = 565 ms vs. TOLLED = 571 ms), $F1(2, 88) = 8.49$, $p < .001$, $F2(2, 116) = 11.70$, $p < .001$, respectively. The main effect of sublist (Sublist A = 571 ms vs. Sublist B = 559 ms) was significant by subjects and stimuli, $F1(1, 44) = 64.77$, $p < .001$, and $F2(1, 58) = 3.92$, $p < .05$, respectively. (From the control experiment reported in the *Results and Discussion* section of Experiment 3, the main effect of sublist may again be attributed to the difference between the sublists in their target stimuli.) The important interaction between prime type and sublist was not significant (both $Fs < 1$). There were no significant effects in the error analysis.

With respect to the planned comparisons of interest, TOAD–frog differed significantly from TOLLED–frog by 10 ms, $F1(1, 44) = 14.61$, $p < .001$, $F2(1, 58) = 19.03$, $p < .001$; TOWED–frog differed significantly from TOLLED–frog by 6 ms, $F1(1, 38) = 5.98$, $p < .02$, $F2(1, 58) = 6.31$, $p < .02$; TOWED–frog was 5 ms slower than TOAD–frog, which was marginally significant for subjects, $F1(1, 44) = 3.63$, $p < .06$, and reliably significant for stimuli, $F2(1, 58) = 6.92$, $p < .01$.

In sum, Experiment 4 revealed that at a much-reduced SOA (relative to Experiments 1 and 2) of 52 ms, appropriate associative priming seems to be superior to priming by a homophonic counterpart (10 ms vs. 6 ms). From the perspective of Paap et al.'s (1992) horse race analogy, the lexical horse for TOAD was able to begin the preactivation of *frog* sooner than the nonlexical horse for TOWED, and to provide thereby a more strongly activated *frog* at the time of processing frog. The failure to find an interaction of prime type and sublist however, dilutes the strength of this interpretation. To reiterate, in Sublist A, appropriate primes were of lower frequency than homophone primes, and in Sublist B the reverse was true.

The equivocality of support for the dual-route interpretation invites a reconsideration of the stimulus manipulations, giving rise to the priming superiority of TOAD over TOWED. Do the primes differ on dimensions other than that of current theoretical interest (namely, appropriate vs. homophonic)? Consistent with the present experiment, both Experiments 1 and 2 yielded a numerical difference favoring TOAD–frog. Common to all three experiments was the fact that the appropriate primes and the homophonic primes were of unequal frequency, with the homophonic primes occurring in the language 2.6 times more frequently, on the average, than the appropriate primes. Furthermore, in all three experiments average frequency was equated between the homophonic and control primes but not between the appropriate and control primes. There is a possibility therefore that these average frequency differences, together with other differences in the selection of primes, made a difference in the degree of priming.

Table 4
Mean Naming Latencies (in Milliseconds) and Percentage Error Rate, With the Corresponding Standard Deviations by Subjects and by Items in Experiment 4

	TOAD–frog		TOWED–frog		TOLLED–frog	
Measure	L	ER	L	ER	L	ER
Sublist A						
M	566	4.00	571	2.67	577	2.44
Subject *SD*	41	5.39	43	4.47	47	4.84
Item *SD*	25	8.51	28	8.68	34	4.46
Sublist B						
M	554	2.00	559	2.44	564	2.22
Subject *SD*	40	4.57	43	4.35	47	4.20
Item *SD*	25	3.57	24	4.79	29	7.74

Note. L = latency; ER = error rate.

Experiment 5

Behind the use of the significant contrasts of TOWED–frog versus TOLLED–frog and TOAD–frog versus TOWED–frog as constraints on theories of word recognition is the assumption that the primes are distinguished only phonologically and visually. There are other distinctions between the primes, however, such as frequency, word length, and relative visual similarity to the target. In addition to controlling for these differences, an improved experimental design should permit a reliable and sensitive measure of the magnitude of priming by each of the so-called appropriate, homophonic, and quasi-homographic primes.

The preceding criticisms of the design features of Experiments 1–4, and suggestions for improvements, bear directly on the interpretation of the advantage of TOAD–frog over TOWED–frog in Experiment 4. The interpretation advanced above was that TOAD activates the lexical entry of TOAD more quickly because of the simple difference that TOAD can use the typically faster lexical route, whereas TOWED cannot. Alternatively, one could argue that the superiority of TOAD in Experiment 4 was artifactual, because of uncontrolled differences among TOAD–frog, TOWED–frog, and TOLLED–frog in prime frequency, prime length, and the visual overlap of prime and target. Consequently, in Experiment 5 we introduced a change in the experimental stimuli and their controls. The experimental primes for frog were TOAD (appropriate), TOWED (homophonic with TOAD), and TOLD (quasi-homographic with TOAD), each with its own control. The respective control primes—FINK, PLASM, and GIVE—were chosen to be identical in length and frequency to TOAD, TOWED, and TOLD and to possess no letters in common with them. Because the hypothesis being tested is that visual lexical access is phonological, it was considered desirable to maximize the visual similarity between appropriate primes and their quasi-homographic counterparts (TOAD and TOLD, respectively) and to minimize the visual similarity between appropriate primes and their homophonic counterparts (TOAD and TOWED, respectively).

The use of a forward mask is conventionally considered an indispensable manipulation for revealing orthographic or form priming, that is, an influence on the target's perception, dictated by the visual structure of the prime (Forster, 1987; Humphreys, Evett, Quinlan, & Besner, 1987). Relatedly, Evett and Humphreys (1981) argued that when conditions render prime perception difficult, only automatic processes can determine word recognition. From the perspective of dual-route theory, this means that only the visual access route is usable. Experiment 5 continued the use of sandwiching the prime between a forward mask (a row of #s) and a backward mask (the target). The apparent effectiveness of this three-field masking (Michaels & Turvey, 1979) in Experiment 4 suggests that its use in the present experiment should hinder the manifestation of effects dependent on phonology, if dual-route theory is correct.

Given the experimental primes and their controls in Experiment 5, a hypothesis of no visual access independent of phonologically mediated access should predict that (a) the degree of priming by TOWED (measured by the TOWED–frog vs. PLASM–frog contrast) should equal that of TOAD (measured by the TOAD–frog vs. FINK–frog contrast), and (b) TOLD–frog should not differ from GIVE–frog, and both TOWED–frog and TOAD–frog should differ equally (in the faster direction) from TOLD–frog.

Method

Subjects. Fifty-four undergraduates at the University of Connecticut served as subjects. None of the subjects had participated in the previous experiments. Each subject was assigned to one of six groups, according to the time he or she arrived at the laboratory, yielding 9 subjects per group.

Materials. The stimuli (see Appendix B) consisted of all the 84 pairs of yoked English homophones (e.g., TOWED and TOAD, DOUGH and DOE) together with 84 associatively related target words that had been determined in the pilot study (see the *Materials* section in Experiment 1). List 1 consisted of 84 appropriate prime–target pairs (e.g., TOAD–frog, PAWS–cat). Each prime in List 1 was then replaced by its yoked homophone to produce List 2, which consisted of 84 homophonically related prime–target pairs (e.g., TOWED–frog, PAUSE–cat). List 3 consisted of 84 quasi-homographically related prime–target pairs (e.g., TOLD–frog, PAYS–cat). In List 3, each quasi-homographic prime (e.g., TOLD, PAYS) was a word similar in visual form and identical in number of letters to the appropriate prime (e.g., TOAD, PAWS), but it was not a prominent associate of the corresponding target.

There were three control lists, Lists 4–6. List 4 consisted of 84 "inappropriate" unrelated prime–target pairs (e.g., FINK–frog, FLOC–cat). Each inappropriate unrelated prime (e.g., FINK, FLOC) was a word that, in relation to its corresponding List 1 prime, (a) had no letters in common (or in rare cases, just one letter, but in a different position), (b) was of the same length (i.e., the same number of letters), (c) was of approximately the same frequency (compare TOAD with FINK, PAWS with FLOC), and (d) was not a prominent associate of the corresponding target.

List 5 consisted of 84 "nonhomophone" unrelated prime–target pairs (e.g., PLASM–frog, SCREW–cat). Each nonhomophone unrelated prime (e.g., PLASM, SCREW) was a word that (a) shared no letters with its corresponding List 2 prime, (b) was of the same length and frequency as its corresponding List 2 prime (compare PLASM with TOWED, SCREW with PAUSE), and (c) was not a prominent associate of the corresponding target.

List 6 consisted of 84 non-quasi-homograph unrelated prime–target pairs (e.g., GIVE–frog, DOME–cat). Each non-quasi-homograph unrelated prime (e.g., GIVE, DOME) was a word that (a) shared no letters with its corresponding List 3 prime, (b) was of the same length and frequency as its corresponding List 3 prime (compare GIVE with TOLD, DOME with PAYS), and (c) was not a prominent associate of the corresponding target.

Finally, we assembled a foil list consisting of 36 unrelated context–target pairs. The foil words were nonhomophonic regular words selected with no specific constraints. For all stimuli pairs the context stimuli were written in uppercase letters and the target stimuli were written in lowercase letters.

Each of Lists 1–6 was implicitly divided into two sublists (Sublist A and Sublist B) of 42 prime–target pairs. For List 1, Sublist A had a prime frequency of 16.00 ± 25.93 and Sublist B had a prime frequency of 91.50 ± 166.02. For List 2, Sublist A had a prime frequency of 198.67 ± 565.13 and Sublist B had a prime frequency of 14.59 ± 25.70. In List 1's Sublist A, for a given target word (e.g., CAT) the appropriate prime (PAWS) was lower in frequency than its homophonic counterpart (PAUSE), which was a member of List 2's Sublist A. Similarly, in List 1's Sublist B, for a given target word (e.g., FROG) the appropriate prime was higher in frequency than its homophonic counterpart (TOWED), which was a member of List 2's Sublist B. In List 3 (consisting of PAYS–cat and TOLD–frog pairs), the mean prime frequencies of Sublists A and B were 30.17 and 75.07, respectively.

Lists 4–6 duplicated the Sublist A versus Sublist B contrasts of Lists 1–3. Thus, the respective Sublist A and Sublist B mean prime frequencies were 16.00 and 88.91 for List 4, 180.01 and 14.62 for List 5, and 29.95 and 70.62 for List 6. All frequencies were determined from Kucera and Francis (1967). Averaging over the sublists yielded mean prime frequencies of 53.76 for List 1, 106.63 for List 2, 52.62 for List 3, 52.45 for List 4, 97.72 for List 5, and 50.29 for List 6. The average (over lists) Sublist A prime and target frequencies were 78.5 and 57.6, respectively, and the average

Sublist B prime and target frequencies were 59.22 and 81.70, respectively.

An estimate of visual similarity between two letter strings was computed as the average sum of two fractions: (a) number of letters ($L1$) shared in the same position (with a shared final letter always considered to be in the same position) relative to the total number of letters (L) in the longer letter string and (b) number of letters ($L2$) in and out of position relative to L. For example, for TOAD and TOWED, $L1 = 3$, $L2 = 3$, $L = 5$, and the estimate of visual similarity is $\frac{1}{2}(\frac{3}{5} + \frac{3}{5}) = 0.6$; for TOAD and TOLD, $L1 = 3$, $L2 = 3$, $L = 4$, and the estimate of visual similarity is $\frac{1}{2}(\frac{3}{4} + \frac{3}{4}) = 0.75$. The average index of visual similarity between appropriate primes (e.g., TOAD) and homophonically related primes (TOWED) was 0.63, and that between appropriate primes and quasi-homographic primes (TOLD) was .70.

Design. Again, as in Experiments 1–4, a given subject never encountered a given word more than once. This was achieved by using six groups of subjects. There were six basic prime types defined by Lists 1–6 (TOAD–, TOWED–, TOLD–, FINK–, PLASM–, GIVE–) and two sublists (Sublist A and Sublist B) providing for each subject six basic experimental situations with 14 stimuli pairs per situation. One half of the pairs from each list was from Sublist A and the other half was from Sublist B. In addition, each subject saw a foil set (the same for all subjects) of 36 unrelated word–word pairs. In total, each subject saw 120 stimulus pairs. The experimental sequence was divided into four subsets, with a brief rest after each subset. Stimulus types were ordered pseudorandomly within each subset. Experimental sequence was preceded by a practice sequence of 36 word–word pairs, 16 of which were associatively related.

Procedure. The procedure was the same as that in Experiment 4, except the prime–target SOA was 50 ms.

Results and Discussion

In the debriefing, subjects consistently reported an inability to clearly discern the letter pattern that preceded the to-be-named target words, which again suggested the effectiveness of the combined forward and backward masking. The results of the experiment are summarized in Table 5. Turning to the planned comparisons, TOAD–frog differed from FINK–frog by 10 ms, $F1(1, 53) = 20.14$, $p < .001$, $F2(1, 82) = 7.75$, $p < .01$; TOWED–frog differed from PLASM–frog by 11 ms, $F1(1, 53) = 16.36$, $p < .001$, $F2(1, 82) = 10.00$, $p < .01$; and TOLD–frog differed insignificantly from GIVE–frog by 1 ms, (Fs << 1).

Additional analyses of partial interactions were appropriate. The partial interaction between TOAD–frog versus FINK–frog (10-ms difference) and TOLD–frog versus GIVE–frog (1-ms difference) was significant for subjects, $F1(1, 53) = 6.66$, $p < .05$, $F2(1, 82) = 2.71$, $p < .10$. The partial interaction between TOWED–frog versus PLASM–frog (11-ms difference) and TOLD–frog versus GIVE–frog (1-ms difference) was significant for subjects, $F1(1, 53) = 5.32$, $p < .05$, and marginally significant for stimuli, $F2(1, 82) = 3.51$, $p < .06$. In contrast, the partial interaction between TOAD–frog versus FINK–frog (10-ms difference) and TOWED–frog versus PLASM–frog (11-ms difference) was not significant (Fs < 1).

In the error analysis, the main effect of sublist (Sublist A = 2.91% vs. Sublist B = 2.03%) was significant for subjects, $F1(1, 53) = 4.06$, $p < .05$, but not for stimuli, $F2(1, 82) = 1.84$, $p < .20$. Other main effects and all interactions in the error analysis were insignificant (all Fs < 1).

In summary, with the improvement in controls that characterizes this experiment, the priming of frog by a word homophonic with TOAD, specifically, TOWED, was identical at an SOA of 50 ms to the priming by TOAD itself. In contrast, there was no priming of frog by TOLD, which is visually similar to TOAD. The important implications of the results of Experiment 5 are that (a) lexical access is phonologically mediated, and (b) there is no visual access independent of phonological access.

Could the equivalency of priming by TOWED and TOAD have been an artifact of asymptotic associative priming? Perhaps the additional benefit of the visual access connected with TOAD added little, given the rapid achievement of complete associative priming using phonology within the temporal conditions of the experiment. The following experimental facts argue against such an interpretation. First, in Lukatela and Turvey (1991), the degree of associative and pseudoassociative priming of naming was of the order of 20 ms when the SOA was 500 ms—that is, considerably larger effects were observed than were seen in the present experiment using an SOA of 50 ms. Second, the theoretically important studies of Lorch (1982), in which SOA and

Table 5

Mean Naming Latencies (in Milliseconds) and Percentage Error Rate, With the Corresponding Standard Deviations by Subjects and by Items for the "Associated" and Control Primes of Experiment 5

	"Associated" primes						Control primes					
	TOAD–frog		TOWED–frog		TOLD–frog		FINK–frog		PLASM–frog		GIVE–frog	
Measure	L	ER	L	ER	L	ER	L	ER	L	ER	L	ER
Sublist A												
M	572	1.59	578	2.38	583	3.97	583	3.44	588	3.17	585	2.91
Subject *SD*	59	4.53	59	5.37	58	8.96	59	7.31	63	8.17	63	5.81
Item *SD*	37	3.94	35	5.23	38	9.12	44	5.75	46	6.15	39	5.52
Sublist B												
M	565	1.85	567	1.85	571	2.12	575	2.12	578	2.12	571	2.12
Subject *SD*	58	5.58	60	5.58	62	5.83	58	5.83	63	5.83	59	5.12
Item *SD*	27	4.86	37	4.86	37	4.42	33	4.42	37	5.05	36	5.05

Note. L = latency; ER = error rate.

the strength of the prime–target association were manipulated, found that the priming effects on naming increased to an asymptotic level that depended on the association strength and did so at a rate that was independent of association strength. Asymptotic levels were not achieved until 600 ms. A continuous and gradual buildup in associative priming over time is a core assumption of contemporary models of the process (e.g., Masson, 1991). In brief, the answer to the above question must be "no."

Experiment 6

Recent experiments by Lesch and Pollatsek (1993) and Fleming (1993) failed to find homophonic priming at long SOAs. One interpretation of this failure is that at longer SOAs cleanup processes that are constrained by nonphonological information obscure the phonologically based processes by which lexical access is achieved.

To elaborate, Experiments 1–5 suggest that the visual presentation of TOWED activates *towed* and *toad* using prelexically computed phonology. This activation makes available automatically semantic information about the two words and information about how they are spelled. It is now hypothesized that information about spelling is the basis of a cleanup process that reduces the equivocality at the lexical level engendered by "noisy" phonological codes. As soon as addressed spellings become available, they are automatically compared with the pattern temporarily preserved in the orthographic level of processing units. If the spelling check is positive, then the patterns of lexical activity corresponding to word representations other than that of the representation with the appropriate addressed spelling are suppressed. With respect to TOWED, the spelling check confirms that only the word with the semantic interpretation of *towed* fits. The word with the semantic interpretation of *toad* does not conform to the orthographic pattern of TOWED and as a consequence is suppressed.

Because the cleanup process depends on the retrieval of lexical information about a word's spelling, the process and its effects are necessarily subsequent to the intralexical process by which activity in *toad* because of access by TOWED leads to activity in *frog*. At shorter SOAs between the visual presentations of TOWED and frog, the cleanup process will not have time to suppress *toad*, and lexical access by frog will be able to benefit from a high level of preactivation of *frog* by *toad*. At longer SOAs, however, the cleanup process will have time to suppress *toad*. The resultant lower level of preactivation of *frog* by *toad* means reduced priming of frog by TOWED relative to the priming of frog by TOAD. For the latter, the cleanup process based on addressed spellings will suppress activity in *towed* with no consequence for the preactivation of *frog* by *toad*. The expectation, therefore, is that with the lengthening of SOA, the ability of TOWED to prime frog as effectively as TOAD primes frog should decline.

A further expectation can be developed with respect to the role of frequency. The cleanup process based on a spelling check will begin as soon as addressed spellings become available, and they will presumably become available sooner for HF primes than LF primes. Furthermore, the spelling check and, as a result, the cleanup process, should finish sooner with HF primes given the greater strengths of their internal orthographic codes. The expectation, therefore, is that with the lengthening of SOA, HF homophone primes should prime less well than LF homophone primes.

In Experiment 6, the SOA was increased to 250 ms. We expected that at this time scale: (a) pseudoassociative priming by homophones would be less reliable than associative priming by appropriate words, and (b) prime type and prime frequency would interact to determine the naming latency to targets.

Method

Subjects. Sixty undergraduates at the University of Connecticut served as subjects. Each subject was assigned to one of six groups, according to the time he or she arrived at the laboratory, yielding 10 subjects per group. None of the subjects had participated in any of the previous experiments. Two subjects were discarded from the analysis because of inadequate measurement (one subject was suffering from a bad cold and coughed repeatedly into the microphone, the other subject's voice was too soft and often failed to trigger the voice key).

Materials and design. Materials and design were the same as those in Experiment 5.

Procedure. The procedure was the same as that of Experiment 5, except the SOA between prime and target was 250 ms.

Results and Discussion

Table 6 summarizes the results. Considering the planned comparisons, TOAD–frog differed from FINK–frog by 14 ms; this planned comparison was significant by both subjects and stimuli, $F1(1, 57) = 27.94$, $p < .001$, and $F2(1, 82) = 9.25$, $p < .01$, respectively. In contrast, the 7-ms difference between TOWED–frog and PLASM–frog was significant only by subjects, $F1(1, 57) = 9.85$, $p < .01$, $F2(1, 82) = 2.43$, $p > .05$. The mean latencies of TOLD–frog and GIVE–frog were identical.

Because of the importance of the prediction concerning the dependence of homophonic priming on SOA, we conducted an additional planned (and one might say "direct") comparison on TOWED–frog versus TOAD–frog (a difference favoring TOAD of 9 ms), $F1(1, 57) = 10.15$, $p < .01$, $F2(1, 82) = 5.57$, $p < .05$. In Experiment 5, this contrast (of 4 ms) was insignificant in both analyses, $F1(1, 53) = 1.89$, $p > .05$, $F2(1, 82) < 1$.

A preliminary 3 × 2 × 2 (Prime Type × Associativeness × Sublist) ANOVA conducted on naming latencies revealed a significant Prime Type × Sublist interaction by the stimulus analysis. (In this ANOVA, *prime type* refers to a list and its control; thus, List 1 and List 4, List 2 and List 5, and List 3 and List 6 are the three prime types, and *associativeness* refers to the contrast between Lists 1–3 and their controls, Lists 4–6. In this omnibus ANOVA, prime type and associativeness are quasi-variables and sublist is a real variable. This ANOVA provides useful indicators of interactions

Table 6
Mean Naming Latencies (in Milliseconds) and Percentage Error Rate, With the Corresponding Standard Deviations by Subjects and by Items for the "Associated" and Control Primes of Experiment 6

	"Associated" primes						Control primes					
	TOAD–frog		TOWED–frog		TOLD–frog		FINK–frog		PLASM–frog		GIVE–frog	
Measure	L	ER	L	ER	L	ER	L	ER	L	ER	L	ER
Sublist A												
M	540	0.00	547	0.49	553	0.25	557	0.25	552	0.00	549	0.74
Subject *SD*	61	0.00	58	2.63	66	1.88	60	1.88	57	0.00	56	4.16
Item *SD*	47	0.00	44	2.28	46	1.71	44	1.40	32	0.00	40	2.73
Sublist B												
M	528	0.74	538	0.99	541	0.25	539	0.25	548	0.74	545	0.49
Subject *SD*	57	3.19	62	3.65	63	1.88	57	1.88	63	3.19	65	2.63
Item *SD*	34	2.71	35	3.06	40	1.40	31	1.54	45	2.80	39	2.19

Note. L = latency; ER = error rate.

involving sublist.) The significance of Prime Type × Sublist in the omnibus ANOVA, given that it involved all three prime types, encouraged an examination of the interaction limited to the List 1–List 4 versus List 2–List 5 contrast. The outcome was $F1(1, 57) = 3.23$, $p < .07$, $F2(1, 82) = 5.23$, $p < .05$. For Sublist A (i.e., higher frequency homophonic primes), the List 2 versus List 5 difference was 5 ms, in contrast to the 17-ms difference between List 1 and List 4. For Sublist B (i.e., lower frequency homophonic primes), the List 2 versus List 5 difference was 11 ms, and the List 1 versus List 4 difference was 10 ms.

In summary, this experiment, using a comparatively long time scale of SOA = 250 ms, departed from the results of Experiment 5 in two important respects. First, TOWED–frog did not differ from PLASM–frog as strongly in Experiment 6 (in Experiment 5, the difference reached significance by both subjects and items), and TOWED–frog was associated with longer latencies by both the subjects and items analyses than TOAD–frog in Experiment 6 (in Experiment 5, this comparison was insignificant by both subjects and items). The reduced effectiveness of homophonic priming evidenced in the long SOA condition examined in Experiment 6 corroborates the observations of Lesch and Pollatsek (1993) and Fleming (1993). Second, there was a strong suggestion that the degree of homophone priming was frequency dependent. The results of Experiment 6, therefore, are consistent with the hypothesis that at longer SOAs (≥ 250 ms), a cleanup process based on addressed spellings can exert an influence on target naming. The hypothesis is that it does so through a suppression of patterns of lexical activity that do not correspond to the lexical item passing the spelling check. In the case of TOWED, this means that *toad* is suppressed and, accordingly, so is the degree to which it preactivates *frog*. The likelihood of this suppression occurring within the SOA depends on the homophone's frequency, with HF homophones associated with a faster occurring suppression than LF homophones.

The understanding that phonologically based lexical access retrieves information about spelling and that this information constrains a cleanup process lends itself to an appreciation of why TOAD–frog was often numerically faster than TOWED–frog in the present series of experiments. Simply put, even at brief SOAs (e.g., 50 ms) the addressed spellings of some homophones will be checked against their visual forms. A relatively small number of such completed checks within the course of an experiment would be enough to introduce a temporal difference, on average, between appropriate and homophonic primes favoring the appropriate primes.

Experiment 7

The outcome of Experiment 6 suggests that at longer SOAs a cleanup process constrained by how words look may be strongly involved in the rapid word naming task that is fundamentally constrained by how words sound. The cleanup process's involvement may be credited with washing out the associative priming with homophonic primes, especially those from Sublist A (higher frequency homophonic primes). The same arguments might apply to the potentially puzzling observation—in light of homophone priming results such as those of Experiment 6 and those of Lesch and Pollatsek (1993)—that English pseudohomophones at SOAs ≥ 250 ms produce a reliable associative priming of the same strength as their source words (Lukatela & Turvey, 1991, 1993). With a pseudohomophone such as TODE, there would be no addressed spellings consistent with its orthographic form. The inability to achieve a positive spelling check means that there would be no suppression of lexical activity, the representation *toad* activated by TODE would continue to preactivate *frog* at a high level. The important prediction is that, with the lengthening of SOA, a pseudohomophone such as TODE, unlike a homophone such as TOWED, should continue to prime frog as reliably as TOAD primes frog.

There were methodological differences between Experiments 1–6 and Lukatela and Turvey's (1991, 1993) pseudohomophonic priming experiments. In the present experiments, (a) all primes were words, (b) all to-be-named targets were words, (c) awareness of the prime was not probed for (with the exception of Experiment 1), (d) primes were forward masked (in Experiments 3–6), and (e) SOAs were considerably less than 250 ms (with the exception of Experiment 6). In contrast, in Lukatela and Turvey's (1991, 1993) pseudohomophonic priming experiments, (a) the majority of trials were nonword–nonword pairs and pseudohomophone–nonword pairs, (b) on approximately 4% of the trials the subjects were requested to orally report the prime, (c) there was no forward masking of the primes, and (d) SOAs were greater than 250 ms, as noted.

Each of the above differences identifies a possibility for an uncontrolled bias or optional strategy in Lukatela and Turvey's (1991, 1993) pseudohomophonic priming experiments. For example, one could argue that the subjects, under the requirement to process primarily nonwords and pseudohomophones, adopted special (irregular) word-access mechanisms to perform the task. It would be important, therefore, to replicate pseudohomophonic associative priming in the setting of the present experimental series. Moreover, it would be important to repeat the pseudohomophonic priming experiments with a systematic control of prime frequencies for all source words and derived pseudowords, as well as with a substantially improved control for graphemic similarity. Therefore, the experimental conditions for the target word frog consisted of word primes TOAD and LEASE, pseudohomographic primes TORD and LESSE, pseudohomophonic primes TODE and LEESE, and pseudoword primes PESK and RACOR. TOAD–, TORD–, TODE–, and PESK– constitute the associative contexts, and LEASE–, LESSE–, LEESE–, and RACOR– constitute the nonassociative contexts. A verification of Lukatela and Turvey (1991, 1993) would be the demonstration of a significant effect of TODE (relative to its nonassociative control LEESE and relative to its pseudohomographic and pseudoword controls TORD and PESK, respectively) that is not different in magnitude from the effect of TOAD (relative to LEASE, TORD, and RACOR).

Method

Subjects. The participants in the experiment were 64 undergraduates at the University of Connecticut. Each subject was assigned to one of eight groups, yielding 8 subjects per group. None of the subjects had participated in any of the previous experiments.

Materials. There were eight word sets (see Appendix C). The first set (also the base set) consisted of 80 associatively related word pairs, of which one half had an LF word acting as the prime, and the other half had an HF word acting as the prime. Sublist 1 (LF primes) had the following frequencies: 19.42 ± 35.14 for prime source words and 43.50 ± 80.99 for target words. On the other side, Sublist B (HF primes) had the following frequencies: 144.60 ± 137.70 for prime source words and 128.85 ± 136.87 for target words. All frequencies were determined from Kucera and Francis (1967). Averaging over sublists, frequencies were 82.01 ± 118.06 for primes and 86.17 ± 119.71 for target words.

LF pairs were grouped to make 20 LF-related quadruples (e.g., TOAD–frog, LEASE–hire); similarly, HF pairs were grouped to make 20 HF-related word quadruples (e.g., PIECE–pie, WHITE–black). Seven additional sets of 80 pairs were generated from the base set (Set 1).

Set 2: Within each related quadruple, the mutual substitution of context words produced a new unrelated word quadruple of two associatively unrelated pairs (e.g., LEASE–frog, TOAD–hire).

Set 3: In each related context–target pair, the context word was replaced by its pseudohomophone to produce 80 pseudohomophone–word related pairs (e.g., TODE–frog, LEESE–hire).

Set 4: In each unrelated context–target pair, the context word was replaced by its pseudohomophone to produce 80 pseudohomophone–word unrelated pairs (e.g., LEESE–frog, TODE–hire). In Set 3 and Set 4, the pseudohomophone that replaced a given word had the same word length and shared the same initial letter or letters and phoneme with its source word.

Set 5: In each related pseudohomophone–target pair, the context was replaced by its pseudohomograph to produce 80 pseudohomograph–word related pairs (e.g., TORD–frog, LESSE–hire).

Set 6: In each unrelated pseudohomophone–target pair, the context was replaced by its pseudohomograph to produce 80 pseudohomograph–word unrelated pairs (e.g., LESSE–frog, TORD–hire). In Set 5 and Set 6, the pseudohomograph replacing a given pseudohomophone shared the same initial letter or letters and same initial phoneme with its source word and its yoked pseudohomophone; the pseudohomograph had the same index of visual similarity with its source word as it had with its yoked pseudohomophone.

Set 7: In each related word–target pair, the context was replaced by a pseudoword to produce 80 pseudoword–word related pairs (e.g., PESK–frog, RACOR–hire).

Set 8: In each unrelated word–target pair the context was replaced by a pseudoword to produce 80 pseudoword–word unrelated pairs (e.g., RACOR–frog, PESK–hire). In Set 7 and Set 8, the pseudoword replacing a given word had the same number of letters as the word, but none of the pseudoword's letters were shared in the same position with the source word, its yoked pseudohomophone, or its yoked pseudohomograph.

Finally, a foil set of 46 unrelated word–word pairs was created. The foil set was used to counter the development of biases, such as always looking for an associative relation or making predictions about targets on the sound of the prime.

Design. Eight counterbalanced experimental lists were prepared for eight groups of subjects. Each subject saw 5 stimulus pairs of 16 prime types (LF-related word, HF-related word, LF-unrelated word, HF-unrelated word, LF-related pseudohomophone, HF-related pseudohomophone, LF-unrelated pseudohomophone, HF-unrelated pseudohomophone, LF-related pseudohomograph, HF-related pseudohomograph, LF-unrelated pseudohomograph, HF-unrelated pseudohomograph, LF-related pseudoword, HF-related pseudoword, LF-unrelated pseudoword, and HF-unrelated pseudoword), resulting in 80 experimental stimulus pairs. The frequency designation LF or HF for a given prime was always in accordance with the word in Set 1 from which it was derived or to which it was related by the requirements for producing control stimuli. In addition, each subject saw 46 unrelated word–word pairs, resulting in 126 stimulus pairs per session. The experimental sequence was preceded by a practice sequence of 24 stimulus pairs.

Procedure. The procedure was the same as that in Experiment 6.

Results and Discussion

Table 7 summarizes the results. The omnibus ANOVA described in Experiment 6, with the quasi-variables of prime type and associativeness and the real variable of sublist, revealed no significant interactions with sublist by either

Table 7
Mean Naming Latencies (in Milliseconds) and Percentage Error Rate, With the Corresponding Standard Deviations by Subjects and by Items for the "Associated" and "Nonassociated" Primes of Experiment 7

	"Associated" primes								"Nonassociated" primes							
	TOAD–frog		TORD–frog		TODE–frog		PESK–frog		LEASE–frog		LESSE–frog		LEESE–frog		RACOR–frog	
Measure	L	ER	L	ER	L	ER	L	ER	L	ER	L	ER	L	ER	L	ER
Low frequency																
M	515	0.00	534	0.31	523	0.00	541	0.00	534	0.63	537	0.63	534	0.31	540	0.00
Subject *SD*	42	0.00	48	2.50	51	0.00	55	0.00	60	3.51	52	3.51	49	2.50	48	0.00
Item *SD*	29	0.00	28	1.98	34	0.00	43	0.00	38	2.76	38	2.76	33	1.98	37	0.00
High frequency																
M	510	0.31	529	0.63	522	0.31	534	0.63	519	0.63	531	0.00	532	0.31	531	1.25
Subject *SD*	53	2.50	48	3.51	49	2.50	48	3.51	52	3.51	51	0.00	48	2.50	48	4.88
Item *SD*	47	1.98	40	2.76	45	1.98	30	2.76	30	2.76	32	0.00	36	1.98	39	4.74

Note. L = latency; ER = error rate.

subjects or stimuli. With respect to the planned comparisons, the 14-ms difference between TOAD–frog and LEASE–frog was significant, $F1(1, 63) = 22.95$, $p < .001$, $F2(1, 78) = 9.73$, $p < .01$; the 2-ms difference between TORD–frog and LESSE–frog was insignificant (*F*s < 1); the 11-ms difference between TODE–frog and LEESE–frog was significant, $F1(1, 63) = 17.30$, $p < .001$, $F2(1, 78) = 5.32$, $p < .05$; and the 2-ms difference between PESK–frog and RACOR–frog was insignificant (*F*s < 1).

Turning to the partial interactions, the one between TOAD versus LEASE (14 ms) and TORD versus LESSE (2 ms) was significant, $F1(1, 63) = 8.77$, $p < .01$, $F2(1, 78) = 6.94$, $p < .01$; the partial interaction between TOAD versus LEASE (14 ms) and TODE versus LEESE (11 ms) was not significant (both *F*s < 1); the partial interaction between TOAD versus LEASE (14 ms) and PESK versus RACOR (2 ms) was significant, $F1(1, 63) = 19.20$, $p < .001$, $F2(1, 78) = 5.41$, $p < .05$; the partial interaction between TODE versus LEESE (11 ms) and TORD versus LESSE (2 ms) was significant for subjects, $F1(1, 63) = 4.12$, $p < .05$, and marginally insignificant for stimuli, $F2(1, 78) = 2.85$, $p < .10$; and finally, the partial interaction between TODE versus LEESE (11 ms) and PESK versus RACOR (2 ms) was significant, $F1(1, 63) = 8.02$, $p < .01$, $F2(1, 78) = 5.33$, $p < .05$.

Two other subanalyses are of interest. First, both TOAD–frog and TODE–frog differed from TORD–frog. TOAD–frog differed by 19 ms, $F1(1, 63) = 73.82$, $p < .001$, $F2(1, 78) = 30.36$, $p < .001$; and TODE–frog differed by 9 ms, $F1(1, 63) = 15.82$, $p < .001$, $F2(1, 78) = 9.91$, $p < .01$. Second, TOAD–frog differed from TODE–frog by 10 ms, and LEASE–frog differed from LEESE–frog by 6 ms. This partial interaction (of association and lexicality) was not significant (*F*s < 1), but the 8-ms main effect of word primes (TOAD and LEASE) versus pseudohomophone primes (TODE and LEESE) was significant, $F1(1, 63) = 18.89$, $p < .001$, $F2(1, 78) = 17.69$, $p < .001$.

This experiment demonstrates that, at an SOA of 250 ms, TODE primes frog to the same degree that TOAD primes frog. In sum, the present results, obtained with superior controls, provide a successful replication of Lukatela and Turvey's (1991, 1993) demonstration of associative priming by pseudohomophones and highlights a contrast of potential theoretical import between pseudohomophones and homophones. As Experiment 6 showed, homophonic priming at SOA = 250 ms is unreliable. The reliability of pseudohomophonic priming and the unreliability of homophonic priming at SOA = 250 ms can be attributed to a cleanup process based on addressed spellings. A positive spelling check on the prime in the case of TOWED–frog leads, at the longer SOA, to a suppression of the representation *toad* and a decline in the preactivation of *frog* relative to the TOAD–frog case. In contrast, a negative spelling check in the case of TODE–frog means that, at the longer SOA, there is no induced suppression of *toad* and that the level of preactivation of *frog* continues to be equal to that in the TOAD–frog case.

In further agreement with Lukatela and Turvey's (1991, 1993) research, there was a main effect of prime lexicality in the absence of a Prime Lexicality × Prime Type interaction: Naming frog was faster to the same degree following each of the two word primes, TOAD and LEASE, than following each of the two pseudohomophone primes, TODE and LEESE. Clearly, this faster naming after word primes is not a reflection of an automatic associative priming. Rather, it must be a consequence of the cleanup process based on addressed spellings. With TOAD and LEASE, the positive spelling check leads to suppression of all lexical activity not corresponding to that of the lexical representations *toad* and *lease*, respectively. This suppression constitutes a reduction in the overall lexical noise against which the resolution of the pattern for *frog* must subsequently occur. No such overall noise reduction occurs in the cases of TODE and LEESE. The consequence is a faster naming of frog following TOAD and LEASE than following TODE and LEESE that is independent of the processing advantages of TOAD and TODE over LEASE and LEESE, respectively.

The preceding discussion of lexical noise provides the basis for understanding the observation in Experiment 3 that XXXXX–frog was faster than TOLLED–frog and TOWED–frog. When the prime is nonlinguistic, such as XXXXX, the induced lexical activity is minimal in comparison to when the prime is linguistic, such as TOLLED or TOWED. At brief SOAs, well under the time scale of suppression by the cleanup process, the degree of activity in the lexicon induced by linguistic primes will constitute noise against which pattern selection of *frog* must occur. The considerably lower noise level following xxxxx means that the resolution of *frog* on presentation of frog can be achieved more quickly. There is a further understanding that follows from this notion of lexical noise. With increasing SOA there is an increasing opportunity for the cleanup process to exert its contrast-enhancement effect on the patterns of lexical activity induced by a word prime with a resultant lessening of lexical noise. The consequence should be a systematic decline in the average latency of naming a target with increasing temporal separation of prime and target. A comparison of the average target latencies from Experiment 5 (SOA = 50 ms) and Experiment 6 (SOA = 250 ms) reveals a longer average latency for Experiment 5 consistent with the expectation from the notion of lexical noise.

Experiment 8

We had three goals in Experiment 8. First, we wanted to determine that associative priming by pseudohomophones occurs within the same small time scale (SOA $\leq$ 100 ms) as the priming by words and homophones demonstrated in Experiments 1–5. The second goal was to determine that there is no visually constrained associative priming independent of phonologically constrained associative priming when the vehicle for the latter is a pseudohomophone. The third goal was to determine that the naming latency for a target (e.g., frog) following a word prime (TOAD, LEASE) is indistinguishable from that following a pseudohomophone prime (TODE, LEESE) when the SOA is very small. At very small SOAs (e.g., 50 ms), the reduction in lexical noise consequent to a positive spelling check is ruled out. Positive spelling checks would occur only for word primes (TOAD and LEASE). Consequently, the potential advantage that accrues to word primes through the cleanup process is nonrealizable at very small SOAs. In the TOAD–frog and TODE–frog cases, the lexical representation *frog* will be primed by *toad* to the same degree, and its activity following the presentation of frog will be resolved against a background of lexical noise that is roughly equivalent for the two cases.

Method

Subjects. The participants were 56 undergraduates at the University of Connecticut. Each subject was assigned to one of eight groups, yielding 7 subjects per group. None of the subjects had participated in any of the previous experiments.

Materials and design. These were the same as those in Experiment 7.

Procedure. The procedure was the same as that in Experiment 7, except the SOA was five times shorter (50 ms).

Results and Discussion

Table 8 provides a summary of the results. The omnibus ANOVA described in Experiment 6 with the quasi-variables of prime type and associativeness and the real variable of sublist revealed no significant interactions involving sublist by either subjects or stimuli. Turning to the planned comparisons, TOAD–frog differed significantly from LEASE–frog by 12 ms, $F1(1, 55) = 14.11$, $p < .001$, $F2(1, 78) = 11.37$, $p < .001$; TORD–frog differed insignificantly from LESSE–frog by 3 ms ($Fs < 1$); TODE–frog differed significantly from LEESE–frog by 11 ms, $F1(1, 55) = 12.02$, $p < .001$, $F2(1, 78) = 6.83$, $p < .01$; and PESK–frog differed insignificantly from RACOR–frog by 3 ms ($Fs < 1$).

With respect to the important planned comparisons between related prime pairs, TOAD–frog differed significantly from TORD–frog by 8 ms, $F1(1, 55) = 6.27$, $p < .05$, $F2(1, 78) = 4.76$, $p < .05$; TOAD–frog differed insignificantly from TODE–frog by 1 ms, $F1(1, 55) < 1$, $F2(1, 78) < 1$; TODE–frog differed from TORD–frog by 7 ms, which was significant by subjects, $F1(1, 55) = 3.90$, $p < .05$, and almost significant by stimuli, $F2(1, 78) = 3.02$, $p < .08$; and LEASE–frog and LEESE–frog were identical.

Table 8
Mean Naming Latencies (in Milliseconds) and Percentage Error Rate, With the Corresponding Standard Deviations by Subjects and by Items for the "Associated" and "Nonassociated" Primes of Experiment 8

	"Associated" primes								"Nonassociated" primes							
	TOAD–frog		TORD–frog		TODE–frog		PESK–frog		LEASE–frog		LESSE–frog		LEESE–frog		RACOR–frog	
Measure	L	ER	L	ER	L	ER	L	ER	L	ER	L	ER	L	ER	L	ER
Low frequency																
M	559	1.43	564	3.21	557	2.5	570	2.14	571	2.50	568	3.57	569	1.43	568	1.79
Subject *SD*	62	5.20	62	7.41	60	6.67	60	7.31	59	6.67	57	9.43	57	5.20	59	5.75
Item *SD*	43	4.34	39	7.58	38	6.38	36	6.10	35	6.38	44	7.76	42	4.34	38	4.78
High frequency																
M	546	5.00	556	2.50	550	3.57	560	3.57	558	3.93	559	2.86	561	4.29	557	1.43
Subject *SD*	52	8.74	56	6.67	58	7.73	55	8.62	52	8.02	59	7.06	51	9.12	54	5.20
Item *SD*	41	8.89	42	7.85	44	6.26	39	9.57	40	9.14	40	7.38	36	7.38	35	5.41

Note. L = latency; ER = error rate.

One may conclude, therefore, that at SOA = 50 ms (a) the pseudohomophone TODE primed frog as well as TOAD primed frog, (b) TORD failed to prime frog, and (c) the speeds with which frog was named following TODE and TOAD were identical, as were the speeds with which frog was named following LEASE and LEESE. These outcomes strongly suggest that there is no visual access of the lexicon by TOAD that is independent of phonologically mediated access. They also suggest that at time scales too small for the cleanup process based on addressed spellings, the intralexical processes induced by TOAD and TODE relative to the activation of *frog* are the same.

Experiment 9

In the context of dual-route models, an equivalency of the priming of frog by TODE and TOAD at an SOA of 50 ms presents a particularly significant challenge, because for TODE there is no lexical horse. TODE should, therefore, be at a disadvantage relative to TOAD, which has horses on both tracks. The assumption that lexical horses are generally faster (Coltheart, 1978; Paap et al., 1992) suggests that certain benefits should accrue to appropriate associative primes simply because they can initiate the preactivation of their targets that much sooner. This expected benefit for appropriate primes such as TOAD should be manifest more clearly when the primes are HF rather than LF. No evidence was found in Experiment 8, however, for an interaction between prime type and prime frequency. Furthermore, the assumption that the lexical and nonlexical routes reinforce one another (Carr & Pollatsek, 1985) suggests that, contrary to what was observed, TOAD should prime more effectively than TODE.

The results of Experiment 8 contradict dual-route theory in both its classical or contemporary forms. More specifically, the results counter the hypothesis of an orthographically based lexical access. Experiment 8 and the preceding experiments of the present series show that TOAD accesses *toad* and preactivates *frog* not because of how it looks but because of how it sounds. No evidence has been forthcoming that a word or nonword that looks like TOAD (e.g., TOLD, TORD) is able to initiate the automatic associative process within the internal lexicon. In marked contrast, evidence has been found repeatedly that a word or nonword that sounds like TOAD (e.g., TOWED, TODE) can initiate this process as readily as TOAD itself.

The final experiment was designed to provide a direct evaluation of the equivalency of both degree of priming and naming latency when a target word is preceded by (a) an associate and (b) a nonword homophonic with the associate. It was also designed to provide a systematic replication of Experiment 8 in that it sought the same basic pattern of results over different stimuli, a different range of frequencies, and a different SOA. The experiment compared priming and absolute naming latencies under the following conditions: word–word (DOOR–knob), pseudohomograph–word (DORN–knob), pseudohomophone–word (DORE–knob), and nonoverlapping pseudoword–word (CHAS–knob).

Method

Subjects. Forty undergraduates at the University of Connecticut served as subjects. These subjects had not participated in the previous experiments. Each subject was assigned to one of four groups, according to the time he or she arrived at the laboratory, yielding 10 subjects per group.

Materials. The stimuli (see Appendix D) were generated from the same list that was used in Experiments 7 and 8, though not all of the stimulus pairs were necessarily identical to those previously used. A basic set of 40 associatively related word pairs with LF primes (e.g., TROOP–army) was selected, as was a set of 40 associatively related HF primes (e.g., DOOR–knob). The frequency of the LF word primes was 8.55 ± 5.82, whereas the frequency of the HF word primes was 232.3 ± 231.4. In each prime–target pair the prime was replaced by a pseudohomograph (e.g., TRAPE–army, DORN–knob) to produce a set of 40 LF and 40 HF associated pseudohomograph–word pairs. A third set of 40 LF and 40 HF associatively related pseudohomophone–word pairs (e.g., TRUPE–army DORE–knob) was generated. It was desirable that a pseudohomophone and the corresponding pseudohomograph would share all letters in the same position except one, such that they would be maximally similar visually yet sound as different as possible. Finally, a set of 80 unrelated pseudoword–word pairs (e.g., CLINF–army, CHAS–knob) was obtained by replacing each word prime by a graphemically and phonemically nonoverlapping pseudoword.

A set of 30 unrelated word–word pairs (e.g., MUTE–sail) was also generated to be used as foil stimulus pairs. All primes were written in uppercase letters and all target words were in lowercase letters.

Design. The design was similar to those of the previous experiments, except we assembled four counterbalanced lists of stimuli for four groups of subjects. There were eight (4 × 2) stimulus types (Prime Type × Prime Frequency). Each subject was presented with 10 experimental stimulus pairs from each of the eight types and 50 foils, yielding 110 stimulus pairs. A practice sequence of 32 stimulus pairs, of which one quarter were associatively related, preceded each experimental sequence.

Procedure. The procedure was the same as that in Experiment 8, with SOA = 70 ms.

Results and Discussion

Table 9 summarizes the results. A 4 × 2 (Prime Type × Prime Frequency) ANOVA on naming latencies revealed a main effect of prime type (DOOR = 534 ms vs. DORN = 545 ms vs. DORE = 533 ms vs. CLINF = 546 ms), which was significant for subjects, $F1(3, 117) = 12.53$, $p < .001$, and for stimuli, $F2(3, 234) = 6.16$, $p < .001$. The main effect of prime frequency (LF = 546 ms vs. HF = 533 ms) was significant by subjects, $F1(1, 39) = 93.30$, $p < .001$, and it was marginally insignificant by stimuli, $F2(1, 78) = 3.77$, $p < .06$. The interaction between prime type and prime frequency was not significant (both Fs < 1). There were no effects of significance in the error analysis.

With respect to the theoretically important comparisons, DOOR–knob differed significantly from CHAS–knob by 12 ms, $F1(1, 39) = 16.73$, $p < .001$, $F2(1, 78) = 7.36$, $p < .01$; and DORE–knob differed significantly from CHAS–knob by 13 ms, $F1(1, 39) = 27.93$, $p < .001$, $F2(1, 78) = 9.89$, $p < .01$. Subjects named DORE–knob 11 ms faster than DORN–

Table 9
Mean Naming Latencies (in Milliseconds) and Percentage Error Rate, With the Corresponding Standard Deviations by Subjects and by Items in Experiment 9

	TOAD–frog		TORD–frog		TODE–frog		PESK–frog	
Measure	L	ER	L	ER	L	ER	L	ER
Low frequency								
M	543	0.75	550	1.75	540	0.25	553	1.75
Subject *SD*	43	2.67	45	3.85	45	1.58	50	4.46
Item *SD*	33	2.80	40	4.65	34	1.44	33	6.14
High frequency								
M	525	1.25	539	0.75	527	1.50	539	1.25
Subject *SD*	42	3.35	43	2.67	40	3.62	45	4.04
Item *SD*	28	3.33	41	2.42	28	4.45	38	3.33

Note. L = latency; ER = error rate.

knob, $F1(1, 39) = 16.64, p < .001$, $F2(1, 78) = 7.26, p < .01$; and named DOOR–knob 11 ms faster than DORN–knob, $F1(1, 39) = 13.23, p < .001$, $F2(1, 78) = 5.86, p < .02$. The 1-ms advantage of DORE–knob over DOOR–knob was not significant, nor was the 1-ms advantage of DORN–knob over CHAS–knob.

The results of Experiment 9 corroborate those of Experiment 8: At a brief SOA, a nonword homophonic with a word can prime an associate of the word as well as the word itself, but a nonword homographic with the homophone cannot prime at all. Once again there seems to be no evidence that lexical access is constrained by how a word looks, only evidence that lexical access is constrained by how a word sounds.

General Discussion

The model of word recognition for English words that has evolved in the research of this article possesses a number of features that are novel in regard to the conventional interpretation of recognition proceeding by two independent routes and primarily by a route that is closely related to how words look. At the same time, the model brought to light by the present series of experiments is in fundamental agreement with that which has evolved over many years to accommodate the experimental findings on recognizing Serbo-Croatian words (e.g., Lukatela et al., 1989; Lukatela & Turvey, 1990a). The important implication, therefore, is that word recognition is essentially identical in alphabetic orthographies that differ markedly in the precision with which they transcribe the sounds (phonology) and family resemblances (morphology) of words.

The outcomes of the present series of experiments leave little room for any hypothesis other than that which identifies a word's phonology as the initial, and perhaps solitary, code by which a word accesses its representation in the internal lexicon. As to the role of a word's orthographic structure, the present results rule out its ability to function as a primary lexical access code and highlight its responsibility in those processes that reduce the noise in the lexicon following activation by the word's phonological code. Simply put, lexical noise is the degree to which there are competing patterns of activity corresponding to a few or many lexical representations active to the same degree. Because semantically and syntactically different English words can be of similar phonology, a given word's phonological code can bring more than one lexical representation to a significant level of activation. Herein lies the critical importance of the visual nature of a printed or written word—it reduces the number of competing representations. Lexical representations activated by phonological codes inform about how their respective words are spelled. Consequently, a cleaning up process can be engaged once a fit between the spelling retrieved by a phonological code and the presented visual form has been achieved. The competing patterns of lexical activity other than the patterns whose addressed spellings fit the actual spelling are suppressed. Importantly, in the preceding scheme, orthographic input codes can affect the internal lexicon only after a particular kind of information (the addressed spelling) has been made available by phonological access codes. This is perhaps a new kind of dual-route theory, one in which access by phonological codes is more aptly termed *direct,* and access by input orthographic codes is more aptly termed *mediated,* given the critical role of retrieved orthography in implementing access by input orthographic codes.

In simple terms, the present research suggests that how a word sounds is what is important to activating its lexical representation, and how a word looks is what is important to selecting the word's activated representation from other, simultaneously activated representations. Why has the role of phonology as the initial access code been generally hidden in past investigations with the English language? To an important degree, the experimental time scale relative to the time scales of the underlying processes seems to have been the critical factor. When letter strings are presented in isolation for lexical decision or naming, either the presentation time, the time to respond, or both are essentially unrestricted. This temporal freedom allows visually constrained cleanup to run its course with a consequent obscuring of the leading role of phonology. Similarly, when letter strings are presented as targets subsequent to a context, with the independent manipulations carried by the targets, the technically unrestrained response time again permits the visually governed cleanup to obscure the phonologically governed lexical access. The key methodological feature of the present research, which allowed the study of initial access free of subsequent cleanup, was the exploitation of the highly automated and rapid intralexical associations. In prime–target sequences, we made the prime the carrier of the theoretically important independent variables, and the manifestation of an associative influence by the prime on the target was taken as the measure of the independent variables' effect. Reducing the delay of the target relative to the prime brought the experimental time scale below the time scale of postaccess processes. Then, and only then, was the role of phonology as the access code observable and uncontaminated in the measure of associative priming.

Of particular importance to the success of the associative priming method is the manipulation of homophony through words and nonwords. The manipulation provides a new understanding of the distinction between words and nonwords. Nonwords are letter strings for which a cleanup process based on addressed spellings cannot occur. Classically, in dual-route terms, the word versus nonword contrast is a difference in lexical access, with nonwords restricted to the phonological, or nonlexical, route. In the present view, all letter strings, regardless of lexical status, proceed through one and the same network and all activate lexical patterns. They do so, however, to different degrees. Each word and each nonword homophonic with a word is able to bring about the full activation of a lexical entry, including its spelling. A nonword that is not homophonic with a word generally differs from words in that it cannot fully activate any entry and cannot retrieve any spelling. Nonwords that are homophonous with words contrast with words in a different way. Though they can retrieve spellings, they cannot satisfy the spelling check and thereby cannot benefit, as words can, from the contrast-enhancing cleanup process. Experiments 7 and 9, when contrasted with Experiment 8 and Lukatela and Turvey's (1991) Experiment 4, reveal that at time scales too short for cleanup words and nonwords homophonous with words are indistinguishable. In this vein, one can expect conditions in which nonwords will prove to be more effective associative primes than the words with which they are homophonous. Those conditions would come about if the "rules" subserving the encoding of the pseudohomophone happened to be stronger than the pseudohomophone's word counterpart (Rosson, 1985).

Of additional importance to the success of the associative priming method is the careful equating and contrasting of the control primes with the theoretically significant primes for which they function as baseline controls. In Experiments 5 and 6, in which appropriate (TOAD), homophonous (TOWED), and quasi-homographic (TOLD) word primes were of theoretical significance, the controls (FINK, PLASM, and GIVE, respectively) were equated to the primes in frequency and number of letters and maximally distinguished from them in respect to orthographic composition. For an SOA of 50 ms in Experiment 5, the effects of appropriate and homophonic associative primes were very strong (all subjects and stimuli analyses were significant at either the 1% level or 0.1% level) and the effect of the quasi-homographic prime was nonexistent (*Fs* << 1). In Lesch and Pollatsek's (1993) related experiment, which used less precisely regulated control primes for the appropriate and homophonic primes, the observed effect of the important homophonic priming with a 50-ms exposure and an SOA of 250 ms, limited to the subjects' analysis, was comparatively weak. In Experiments 7–9 of the present series (experiments directed at associative priming by pseudohomophones), the controls were again carefully chosen to ensure that they mirrored the contrasts among the theoretically significant primes. Thus, the contrasts in source word frequency and in visual form among TOAD, TORD, and TODE were matched by the contrasts among their respective controls LEASE, LESSE, and LEESE. Again, the effects of appropriate and "sound-alike" associative primes were very strong (all subjects and stimuli analyses significant at either the 5%, 1%, or 0.1% level), and the effect of the quasi-homographic prime (TORD) was nonexistent (*Fs* << 1).

The inability of the nonword TORD and the word TOLD to prime frog in the face of the evident ability of the nonword TODE and the word TOWED to prime frog indicates, on the one hand, a general indifference of the mechanisms of lexical access to a word's orthographic structure and, on the other hand, the low tolerance and high precision of the spelling check. If the orthographic pattern figured prominently in lexical access, then at short SOAs the close visual similarity of TORD and TOLD to TOAD should have sufficed to activate *toad* partially and preactivate *frog*. If the spelling check was accepting of closely approximate matches, as when addressed spelling and actual spelling differ by a single letter in a given position, then at long SOAs the cleanup process connected with TORD and TOLD should have left *toad* more distinguished from other competing representations than would have been the case with their controls, LESSE and GIVE. The failures of TORD and TOLD to prime frog contradict both of the preceding hypotheses.

It has been suggested that phonological effects, such as those that have figured prominently in the present research, are more probable for LF words (e.g., Jared & Seidenberg, 1991); specifically, a phonological code is not likely to be a significant contribution to HF words, given the essentially greater speed of access afforded by the visual code available to HF words. Experiments 5 and 6 provide insight into how one might get the impression (perhaps mistakenly) of a frequency restriction on phonological coding. With less severe constraints on prime processing time (e.g., the 250-ms SOA of Experiment 6), the effect on naming of a phonological manipulation was more pronounced for LF than for HF words. With more severe constraints on prime processing time (e.g., the 50-ms SOA of Experiment 5), the effect on naming of a phonological manipulation was identical for LF and HF words. As noted, this difference between Experiments 5 and 6 is attributable not to a difference in use of the phonological code but to a difference in ease of executing the spelling check. Experiments 7 and 8 provide a further counter to the frequency-dependent hypothesis of phonological coding. An HF word such as WHITE was matched in priming efficacy (with black as the target) by its nonword partner WHYTE just as an LF word such as TOAD was matched in priming efficacy (with frog as the target) by its nonword partner TODE. The hypothesis of frequency-dependent access codes would have predicted a greater difference between WHITE and WHYTE, favoring WHITE, than between TOAD and TODE, favoring TOAD. The differences for the two contrasts, however, were nonsignificant.

In summary, the present research affirms the general conclusions Van Orden, Pennington, and Stone (1990) drew concerning the status of the theories of word recognition that grant the leading role in lexical access to visual codes. Specifically, the results reported here show that the phonological code creates the circumstances within which the role of the visual code is defined (the hypothesis of delayed phonology in classical dual-route theory is rejected), the phonological code is the access code of skilled readers (the bypass hypothesis of classical dual-route theory is rejected), and, perhaps, the phonological code is the only code through which the reader accesses his or her lexical knowledge (the independent-processes hypothesis of classical dual-route theory is seriously questioned).

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Appendix A

Stimulus Materials in Experiments 1, 2, and 4

Each row identifies, in order, the appropriate prime, the homophonic prime, the visual control for the homophonic prime, and the corresponding target.

1. ALTAR, ALTER, AJAR, CHURCH
2. BARREN, BARON, BANJO, DRY
3. BEACH, BEECH, BENCH, SAND
4. BEAR, BARE, BARK, BROWN
5. BEAT, BEET, BLEST, DRUMS
6. BRAKE, BREAK, FREAK, CAR
7. BREAD, BRED, BROOD, BUTTER
8. CREEK, CREAK, CRATE, WATER
9. DEW, DUE, DEL, MORNING
10. DOE, DOUGH, THUDS, DEER
11. FAIRY, FERRY, FARCE, TALE
12. FEET, FEAT, FATE, TOES
13. FIR, FUR, FRY, TREE
14. FLEA, FLEE, FLEX, DOG
15. GATE, GAIT, GALE, OPEN
16. GUEST, GUESSED, GUST, HOST
17. GUYS, GUISE, GUILE, GIRLS
18. HAWK, HOCK, HAUL, BIRD
19. HEEL, HEAL, HELM, BOOT
20. HOLE, WHOLE, WHOSE, GROUND
21. HORSE, HOARSE, HOSE, RIDE
22. KNIGHT, NIGHT, HIGH, ARMOR
23. MALE, MAIL, LAME, FEMALE
24. MALL, MAUL, MELD, SHOP
25. MEAT, MEET, MEAN, COW
26. MEDAL, MEDDLE, MEDLEY, GOLD
27. NOSE, KNOWS, KNEES, EARS
28. NUN, NONE, NINE, PRIEST
29. PAIL, PALE, PEAS, BUCKET
30. PASTE, PACED, CEDAR, GLUE
31. PATIENTS, PATIENCE, PATENT, DOCTOR
32. PAWS, PAUSE, PURSE, CATS
33. PEAK, PEEK, PECK, MOUNTAIN
34. PEARL, PURL, PERIL, OYSTER
35. PIECE, PEACE, PLACE, PIE
36. PLANE, PLAIN, PLANK, FLY
37. PRAY, PREY, GREY, GOD
38. RING, WRING, RINSE, DIAMOND
39. ROAD, RODE, ROLE, LANE
40. ROSE, ROWS, WORMS, FLOWER
41. ROUTE, ROOT, ROOF, HIGHWAY
42. SEAMS, SEEMS, SEEDS, STITCH
43. SELL, CELL, BELL, BUY
44. SERIAL, CEREAL, VERBAL, NUMBERS
45. SIGHT, SITE, STEP, EYES
46. SLEIGH, SLAY, SLAM, SNOW
47. STEAK, STAKE, STARK, BEEF
48. THRONE, THROWN, THROAT, KING
49. TOAD, TOWED, TOLLED, FROG
50. TOW, TOE, TIE, TRUCK
51. URN, EARN, UREA, ASHES
52. VICE, VISE, VINE, EVIL
53. WAY, WEIGH, NEIGH, TRAVEL
54. WEAK, WEEK, WALK, STRONG
55. WEAR, WHERE, THERE, CLOTHES
56. WEIGHT, WAIT, WAGE, HEAVY
57. WHALE, WAIL, WILT, OCEAN
58. WITCH, WHICH, WHEN, BROOM
59. WRITE, RIGHT, MIGHT, PAPER
60. YOLK, YOKE, YELP, EGG

Appendix B

Stimulus Materials in Experiments 5 and 6

Each row identifies, in order, the appropriate prime, the homophonic prime, the quasi-homographic prime, their respective controls, and the corresponding target.

1. ALTER, ALTER, AJAR, TEENS, SILLY, MILT, CHURCH
2. BAIT, BATE, BAST, SWAP, PUBS, DUNE, FISH
3. BALE, BAIL, BALD, SPIN, FOLD, SPIN, HAY
4. BARREN, BARON, BURDEN, TRUSTS, NECKS, LIQUOR, DRY
5. BEACH, BEECH, BENCH, DROVE, STAIN, DYING, SAND
6. BEAR, BARE, BEER, SPOT, FLED, SING, BROWN
7. BEAT, BEET, BELT, JURY, ORGY, GYRO, DRUMS
8. BLUE, BLEW, BLUR, FALL, TROT, PEEL, SKY
9. BORED, BOARD, BARRED, NAILS, CLOSE, TUMORS, TIRED
10. BRAKE, BREAK, FREAK, COLON, FIXED, HOBBY, CAR
11. BREAD, BRED, BREED, SMOKE, PALS, AMPLE, BUTTER
12. CENT, SCENT, CANT, WALL, POKER, LURK, PENNY
13. CEREAL, SERIAL, CENTRAL, SHIFTS, TYPING, FRIENDS, OATS
14. CREEK, CREAK, CROOK, UPSET, OHMIC, SALVE, WATER
15. DEW, DUE, DEL, LAG, TRY, FOX, MORNING
16. DOE, DOUGH, DYE, HAW, SLICE, HAW, DEER
17. FEET, FEAT, FRET, WORD, CLIP, VIVA, SOCKS
18. FIR, FUR, FIN, PAL, EGO, PAL, TREE
19. FLEA, FLEE, FLEX, MUGS, STUNK, SNUG, DOG
20. FLOWER, FLOUR, FLOPPER, ADULTS, KNELT, NUDGING, TULIP

(*Appendixes continue on next page*)

21. GATE, GAIT, GAT, FOOL, SLUM, MOO, FENCE
22. GUEST, GUESSED, GUST, FIFTH, OMINOUS, WAXY, HOST
23. GUYS, GUISE, GUTS, CROP, PROPS, SLAB, GIRLS
24. HARE, HAIR, HIRE, LOWN, MEET, QUIT, RABBIT
25. HAWK, HOCK, HARK, RIPE, YORE, NETS, BIRD
26. HERD, HEARD, HEED, PALM, STUDY, STAG, SHEEP
27. HORSE, HOARSE, HOUSE, LIVED, CHILLY, AGAIN, RIDER
28. KNIGHT, NIGHT, NAUGHT, FASTER, ASKED, COERCE, ARMOR
29. LADDER, LATTER, LAUDER, POLISH, MOVING, ORPHIC, CLIMB
30. LOAD, LODE, LOAF, MAMA, FESS, WICK, BURDEN
31. LOOT, LUTE, LOST, SAWS, MOAN, VIEW, MONEY
32. MAIL, MALE, MALL, COOK, PUSH, OUST, LETTER
33. MAIN, MANE, MAN, ARMS, COUD, DID, STREET
34. MALL, MAUL, MILL, DOOM, SOOT, BLOC, SHOP
35. MEDAL, MEDDLE, MEDIA, TORSO, PAJAMA, VIRUS, GOLD
36. MINER, MINOR, METER, POLKA, AVOID, WHIGS, COAL
37. MUSSEL, MUSCLE, MISSILE, OATNUT, WEAPON, TRAGEDY, CLAM
38. NOSE, KNOWS, NONE, TEXT, VISUAL, FIRM, SMELL
39. NUN, NONE, NUT, EEL, WISH, JAY, PRIEST
40. OAR, ORE, JAR, MEW, LAX, FEE, PADDLE
41. PAIL, PALE, PALL, FUSS, BUSY, VINE, BUCKET
42. PANE, PAIN, PANS, TICK, LOSS, TICK, WINDOW
43. PASTE, PACED, PESTS, ELBOW, ELBOW, ALLAY, GLUE
44. PAWS, PAUSE, PAYS, FLOC, SCREW, DOME, CAT
45. PEAK, PEEK, PECK, RAGE, PLUM, CRIB, MOUNTAIN
46. PEARL, PURL, PERIL, JOKES, FOWL, CROWN, OYSTER
47. PIECE, PEACE, PENCE, MONTH, THIRD, VALOR, PIE
48. PLANE, PLAIN, PLANK, DOUBT, SORRY, CORSO, AIRCRAFT
49. POLE, POLL, PILE, WING, DUSK, HANG, STICK
50. PRAY, PREY, PRY, BITS, STUD, JAM, GOD
51. RAIN, REIN, RUIN, DUST, OPUS, WOKE, UMBRELLA
52. RIGHT, WRITE, RIOT, AGAIN, SCENE, BANG, WRONG
53. RING, WRING, RANG, HERO, TACIT, UGLY, DIAMOND
54. ROAD, RODE, ROUND, BOOK, INCH, SHAPE, LANE
55. ROSE, ROWS, RISE, LAWS, TAXI, CLAY, THORN
56. ROUTE, ROOT, ROTTE, SKILL, FLUX, BLAIN, HIGHWAY
57. SAIL, SALE, SALT, BUTT, BOND, BOND, BOAT
58. SEA, SEE, SET, OIL, OWN, WHY, OCEAN
59. SEAMS, SEEMS, SLAMS, BLUNT, MAJOR, FROWN, STITCH
60. SELL, CELL, SILL, VICE, JULY, NAP, BUY
61. SIGHT, SITE, SIGHS, COVER, GROW, TANIN, EYES
62. SIGN, SINE, SING, LORD, USER, YARD, TRAFFIC
63. SLEIGH, SLAY, SLIGHT, ORNATE, OZON, MOTION, SNOW
64. SON, SUN, SIN, PAY, HIT, WET, DAUGHTER
65. STAIR, STARE, STAIN, MOURN, HONEY, TOWEL, STEP
66. STEAK, STAKE, STERN, MERGE, LUNGS, BELLY, BEEF
67. STEEL, STEAL, STALL, PRIME, BROWS, FADED, COPPER
68. SUITE, SWEET, SUITS, CHARM, DRAWN, CHARM, HOTEL
69. SURF, SERF, SCARF, TENS, WOLD, TROUT, WAVE
70. TALE, TAIL, TALL, SINK, ZERO, PICK, STORY
71. TEA, TEE, TER, FOG, HUM, SOP, COFFEE
72. THRONE, THROWN, THROAT, COMPLY, VISUAL, LISTEN, KING
73. TIDE, TIED, TILE, CALF, CORN, MONK, FLOOD
74. TOAD, TOWED, TOLD, FINK, PLASM, GIVE, FROG
75. TOW, TOE, TAW, ALE, SPY, YIP, TRUCK
76. URN, EARN, UREA, BIB, CLUE, POMP, ASHES
77. VANE, VEIN, VASE, BROS, STAR, FLIP, WEATHER
78. WAIST, WASTE, WARTS, VIOLA, URGED, PUNCH, HIPS
79. WAY, WEIGH, WRY, TOO, MUSED, COX, TRAVEL
80. WEAK, WEEK, WALK, CURT, HALF, FILM, STRONG
81. WEAR, WHERE, WARS, BOMB, AFTER, FIST, CLOTHES
82. WHALE, WAIL, WHEEL, PITHY, STUB, CROSS, MAMMAL
83. WITCH, WHICH, WATCH, ASSET, THERE, INDEX, BROOM
84. YOLK, YOKE, YELP, PUFF, RUNG, AFAR, EGG

Appendix C

Stimulus Materials in Experiments 7 and 8

Each row identifies, in order, the appropriate prime, the pseudohomographic prime, the pseudohomophonic prime, the nonword prime, their respective controls, and the corresponding target.

1. BAKE, BAWK, BAIK, FIRG, PEARL, PARL, PERL, SUBS, CAKE
2. BRAVE, BRARV, BRAIV, LUSSE, SOAP, SOPH, SOAP, HEML, COWARD
3. BREAK, BRACK, BRAIK, PETUS, HOPE, HORP, HOAP, INTE, GLASS
4. BURN, BYRN, BERN, VOAX, MEAL, MERL, MEEL, WOMA, WOOD
5. CODE, COID, COAD, ULPI, GIRL, GARL, GURL, DENF, SECRET
6. CRATE, CRAST, CRAIT, DORCO, WADE, WAID, WAID, LUMB, BOX
7. DEAF, DELF, DEFF, TRON, PASTE, PASST, PAIST, YIEND, MUTE
8. DEAL, DERL, DEEL, CHAS, MONTH, MINTH, MUNTH, FLART, BARGAIN
9. DOOR, DORN, DORE, CHAS, PHONE, PHORN, PHOAN, BLIFF, KNOB
10. EAGLE, TAGLE, EEGLE, SHERM, TROOP, TRAPE, TRUPE, CLINF, BIRD
11. FATE, FANT, FAIT, DOOG, STEAK, STREK, STAIK, DORRY, DESTINY
12. FEAR, FETR, FEER, DOWG, TAKE, TARK, TAIK, FOWD, PANIC
13. FIGHT, FITH, FITE, BARM, MINE, MENE, MYNE, HAFL, COMBAT
14. FLOOR, FLOTR, FLORE, TRASK, EAST, ERST, EEST, LOMB, CEILING
15. FRUIT, FRUST, FRUTE, THENT, SLOW, SLOK, SLOE, ACIN, APPLE
16. GALE, GAWL, GAIL, HEEN, MUSIC, MUDIC, MUZIC, DEPEL, WIND
17. GAME, GALM, GAIM, WORP, ROAD, ROND, ROED, GRUN, PLAY
18. GIRL, GARL, GURL, DENF, CODE, COID, COAD, ULPI, BOY
19. GOAT, GOOT, GOTE, NARN, ROBE, ROLB, ROAB, FIDE, HORNS
20. GRADE, GRALD, GRAID, KUELL, TEASE, TERLE, TEEZE, PIMER, SCHOOL
21. GRAPE, GRALP, GRAIP, MISEM, TIGHT, TITH, TITE, MUED, RAISIN
22. GREEN, GRELN, GREAN, EPHIM, WINE, WONE, WYNE, GAUG, GRASS
23. GRIEF, GROEF, GREEF, STONK, ROAR, ROTR, RORE, SHEG, SORROW
24. HATE, HANT, HAIT, RUDL, SMOKE, SMONK, SMOAK, WEDLY, LOVE
25. HERD, HORD, HURD, COMS, STOVE, STORV, STOAV, BENIC, CATTLE
26. HOME, HOLN, HOAM, RELP, NEAR, NEBR, NEER, FOPS, HOUSE
27. HOPE, HORP, HOAP, INTE, BREAK, BRACK, BRAIK, PETUS, DESPAIR
28. JAIL, JALL, JALE, MONG, SOAK, SOKL, SOKE, PUMS, PRISON
29. KEY, KER, KEE, FLO, STONE, STORN, STOAN, MAIFF, LOCK
30. LAKE, LASK, LAIK, GOPS, WIFE, WAFE, WYFE, BROL, RIVER
31. LAME, LARM, LAIM, RETH, ROSE, ROYE, ROZE, SHIR, LEG
32. LEAF, LAAF, LEEF, YARK, NEAT, NERT, NEET, BAFF, TREE

33. LEASE, LESSE, LEESE, RACOR, TOAD, TORD, TODE, PESK, HIRE
34. LEASH, LERSH, LEESH, WHURT, SHADE, SHALD, SHAID, HAMEL, DOG
35. LOAD, LOLD, LODE, TANN, WHITE, WHOTE, WHYTE, STREL, HEAVY
36. MAIN, MARN, MAYN, KROF, WHILE, WHELE, WHYLE, STRUP, STREET
37. MEAL, MERL, MEEL, WOMA, BURN, BYRN, BERN, VOAX, FOOD
38. MINE, MENE, MYNE, HAFL, FIGHT, FITH, FITE, BARM, YOURS
39. MUSIC, MUDIC, MUZIC, DEPEL, GALE, GAWL, GAIL, HEEN, SONG
40. NAIL, NALL, NALE, HERM, SPADE, SPALD, SPAID, OTTEM, FINGER
41. NEAR, NEBR, NEER, FOPS, HOME, HOLM, HOAM, RELP, FAR
42. NEAT, NERT, NEET, BAFF, LEAF, LAAF, LEEF, YARK, TIDY
43. OATS, ONTS, OTES, XENY, BLADE, BLARD, BLAID, PARTH, CEREAL
44. PASTE, PASST, PAIST, YIEND, DEAF, DELF, DEFF, TRON, GLUE
45. PEARL, PARL, PERL, SUBS, BAKE, BAWK, BAIK, FIRG, OYSTER
46. PHONE, PHORN, PHOAN, BLIFF, DOOR, DORN, DORE, CHAS, CALL
47. PIECE, PRECE, PEECE, KWART, GAIN, GARN, GANE, PUTL, PIE
48. RAIN, RAWN, RANE, HESS, WIRE, WURE, WYRE, SOLG, WET
49. RAPE, RALP, RAIP, MUMF, LEAN, LEYN, LEEN, STAU, ASSAULT
50. READ, WREID, WREED, CRUMM, SEEK, SEYK, SEAK, LIAF, WRITE
51. ROAD, ROND, ROED, GRUN, GAME, GALM, GAIM, WORP, HIGHWAY
52. ROAR, ROTR, RORE, SHEG, GRIEF, GROEF, GREEF, STONK, LION
53. ROBE, ROBL, ROAB, FIDE, GOAT, GOOT, GOTE, NARN, GARMENT
54. ROSE, ROYE, ROZE, SHIR, LAME, LARM, LAIM, RETH, THORN
55. SAFE, SARF, SAIF, MYTL, DREAM, DRERM, DREEM, BAKUL, SECURE
56. SAVE, SALV, SAIV, GIML, WAR, WAYR, WOAR, HEEF, MONEY
57. SEAT, SELT, SEET, LORC, TRAIN, TRANK, TRANE, MONOD, CHAIR
58. SEEK, SEYK, SEAK, LIAF, READ, WREID, WREED, CRUMM, FIND
59. SMOKE, SMONK, SMOAK, WEDLY, HATE, HANT, HAIT, RUDL, FIRE
60. SOAK, SOKL, SOKE, PUMS, JAIL, JALL, JALE, MONG, LAUNDRY
61. SOAP, SOPH, SOAP, HEML, BRAVE, BRARV, BRAIV, LUSSE, BATH
62. SPADE, SPALD, SOAID, OTTEM, NAI, NALL, NALE, HERM, SHOVEL
63. STEAK, STREK, STAIK, DORRY, FATE, FANT, FAIT, DOOG, BEEF
64. STONE, STORN, STOAN, MAIFF, KEY, KER, KEE, FLO, ROCK
65. STOVE, STORV, STOAV, BENIC, HERD, HORD, HURD, COMS, PIPE
66. TAKE, TARK, TAIK, FOWD, FEAR, FETR, FEER, DOWG, GIVE
67. TAME, TARM, TAIM, REYK, OBEY, OBLY, OBAY, CRED, WILD
68. TAPE, TALP, TAIP, ELUC, ELBOW, ELBOT, ELBOE, FRINS, VIDEO
69. TEACH, TERCH, TEECH, MUSKO, SPEAK, SPELK, SPEEK, MENOR, LEARN
70. TEASE, TERLE, TEEZE, PIMER, GRADE, GRALD, GRAID, KUELL, ANNOY
71. TOAD, TORD, TODE, PESK, LEASE, LESSE, LEESE, RACOR, FROG
72. TRAIN, TRANK, TRANE, MONOD, SEAT, SELT, SEET, LORC, TRACKS
73. TROOP, TRAPE, TRUPE, DIDYR, EAGLE, TAGLE, EEGLE, SHERM, ARMY
74. WAR, WAYR, WOAR, HEEF, SAVE, SALV, SAIV, GIML, PEACE
75. WHEAT, WHELT, WHEET, MOGAM, RAID, RAWD, RADE, SINO, FLOUR
76. WHITE, WHOTE, WHYTE, STREL, LOAD, LOLD, LODE, TANN, BLACK
77. WIDE, WODE, WYDE, HUNF, FREE, FREN, FREA, GINT, NARROW
78. WIFE, WAFE, WYFE, BROL, LAKE, LASK, LAIK, GOPS, HUSBAND
79. WINE, WONE, WYNE, GAUG, GREEN, GRELN, GREAN, EPHIM, BEER
80. WIRE, WURE, WYRE, SOLG, RAIN, RAWN, RANE, HESS, CABLE

Appendix D

Stimulus Materials in Experiment 9

Each row identifies, in order, the appropriate prime, the pseudohomographic prime, the pseudohomophonic prime, the nonword prime, and the corresponding target.

1. BAKE, BAWK, BAIK, MONT, OVEN
2. BLADE, BLARD, BLAID, PARTH, KNIFE
3. BREAK, BRACK, BRAIK, JORPH, GLASS
4. CHEAT, CHENT, CHEET, BLAIN, HOAX
5. CIDER, MIDER, SIDER, FLOOP, JUICE
6. CRATE, CRAST, CRAIT, GOSOL, BOX
7. DATE, DAST, DAIT, RUND, FRIEND
8. DEAL, DERL, DEEL, CRON, BARGAIN
9. DOME, DOLM, DOAM, PUTH, VAULT
10. DOOR, DORN, DORE, CHAS, KNOB
11. DREAM, DRERM, DREEM, BAKUL, SLEEP
12. EAGLE, TAGLE, EEGLE, SHERM, BIRD
13. EARLY, ORLY, URLY, FEUS, LATE
14. EAST, ERST, EEST, LOMB, WEST
15. FAKE, FACK, FAIK, DOOG, FALSE
16. FEAR, FETR, FEER, DINN, PANIC
17. FIGHT, FIRT, FITE, BALM, COMBAT
18. FLOOR, FLOTR, FLORE, TRASK, TILE
19. FRUIT, FRUST, FRUTE, THENG, APPLE
20. GAIN, GARN, GANE, RIAL, LOSS
21. GALE, GARL, GAIL, HEEN, STORM
22. GAME, GALM, GAIM, WORP, PLAY
23. GAPE, GARP, GAIP, TRON, YAWN
24. GLEAM, GLERM, GLEEM, QUIGE, FLASH
25. GLOBE, GLOOB, GLOAB, KUELL, WORLD
26. GOAT, GOOT, GOTE, CARN, HORNS
27. GRAPE, GRAPS, GRAIP, SOWOR, RAISIN
28. GRIEF, GROEF, GREEF, STONK, SORROW
29. GROUP, GRUSP, GRUPE, EPHIM, PEOPLE
30. HEAR, HETR, HEER, GLIS, LISTEN
31. HOPE, HORP, HOAP, CACK, DESPAIR
32. HOUSE, HOLSE, HOWSE, CRELP, HOME
33. LADY, LANDY, LAIDY, BISHT, WOMAN
34. LAKE, LASK, LAIK, GOPS, RIVER
35. LAME, LARM, LAIM, RETH, LEG
36. LEAF, LAAF, LEEF, YARK, GREEN
37. LEAP, LESP, LEEP, FROT, JUMP
38. LEASE, LESSE, LEESE, PADIO, HIRE
39. LEASH, LERSH, LEESH, WHURD, DOG
40. LIGHT, LINTH, LITE, BORD, DARK
41. MAIN, MARN, MAYN, KROE, STREET
42. MONTH, MINTH, MUNTH, FLART, YEAR

(Appendix continues on next page)

43. MOST, MOYST, MOAST, OLIRN, LEAST
44. NAIL, NALL, NALE, HIRM, FINGER
45. NEAR, NEBR, NEER, FOPS, FAR
46. NEAT, NERT, NEET, BAFF, TIDY
47. OATS, ONTS, OTES, FENY, CEREAL
48. OBEY, OBLY, OBAY, DEST, SERVE
49. PIE, POE, PYE, LUS, CREAM
50. PIECE, PRECE, PEECE, EKAUP, CAKE
51. PLEA, PLEN, PLEE, HOIM, EXCUSE
52. RAID, RAWD, RADE, SINO, POLICE
53. RAIN, RAWN, RANE, HESS, WET
54. READ, WREID, WREED, CRUM, WRITE
55. ROAD, ROND, ROED, GRUN, HIGHWAY
56. ROAR, ROTR, RORE, SHEG, LION
57. ROBE, ROBL, ROAB, FIDE, GARMENT
58. ROPE, ROSP, ROAP, MINN, HANGING
59. SAFE, SARF, SAIF, MERT, SECURE
60. SAME, SARM, SAIM, GUNT, OTHER
61. SHADE, SHALD, SHAID, BOWSA, TREE
62. SHAPE, SHALP, SHAIP, BLIDD, FRAME
63. SHAVE, SHARV, SHAIV, YIEND, HAIR
64. SNOW, SNOP, SNOE, BUDA, WINTER
65. STONE, STORN, STOAN, MAIFF, ROCK
66. TAKE, TARK, TAIK, FOTU, GIVE
67. TAME, TARM, TAIM, NELD, WILD
68. TEASE, TELSE, TEESE, PIMER, ANNOY
69. THIEF, THREF, THEEF, MONOD, STEAL
70. TOAD, TORD, TODE, PESK, FROG
71. TONE, TOON, TOAN, BLIR, SOUND
72. TRAIT, TRAPT, TRATE, FORRY, QUALITY
73. TROOP, TRAPE, TRUPE, CLINF, ARMY
74. WADE, WAAD, WAID, MILT, WATER
75. WAIT, WATH, WATE, HERR, STOP
76. WAR, WAYR, WOAR, HEED, PEACE
77. WHEAT, WHELT, WHEET, FITAN, FLOUR
78. WHILE, WHELE, WHYLE, STRUP, DURING
79. WHITE, WHOTE, WHYTE, STREL, BLACK
80. WIFE, WAFE, WYFE, BROT, HUSBAND

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