Journal of Experimental Psychology: General
1994, Vol. 123, No. 4, 331–353

Visual Lexical Access Is Initially Phonological: 2. Evidence From Phonological Priming by Homophones and Pseudohomophones

Georgije Lukatela and M. T. Turvey

Seven experiments were conducted that examined phonological and orthographic priming of naming using three- and four-field masking procedures with prolonged targets. Experiments 1–3 found significant phonological priming by homophones (TOWED–toad) that was independent of prime identifiability and prime–target stimulus onset asynchrony (SOA; 30, 60, or 250 ms). Subsequent experiments found significant phonological priming by pseudohomophones (TODE–toad) that was similarly independent of prime identifiability and SOA. Collectively, the limited effects of orthographic control primes (TOLD–toad, TODS–toad) and the pronounced and orthographically independent effects of phonological primes suggest (a) a leading role in visual word perception for a fast-acting, automatic, assembled phonology, and (b) a phonological basis, rather than an abstract graphemic basis, for the processing equivalency of letter variations.

An important tool for unraveling the processes that underlie word recognition is the priming paradigm. Typically, two words are presented in succession, with the first word designated the *prime* and the second word designated the *target.* Of interest is whether a dimension of similarity between prime and target affects a subject's response to the target. For example, if the prime is an associate of the target, then latency to name the target or to decide on its lexical status ("is it a word?") is reduced relative to a prime that is not associatively related (e.g., Meyer, Schvaneveldt, & Ruddy, 1974).

The issue of whether the word recognition process is driven by a word's visual or phonological structure, or by both structures, can be investigated in the priming paradigm. Consider visual and phonologic priming from the perspective of classical dual-route theory (Coltheart, 1978). Visual priming could occur over the so-called lexical route—a proposed direct link between a word's visual form and the lexicon. The priming would be in the form of prior activation of (lower level) orthographic processing units, (higher level) orthographic lexical neighbors, or both. Phonological priming could occur over either the same lexical route or over a nonlexical route—a mechanism for converting orthography into phonology by rule, with the resultant phonological code used to access the internal lexicon. Where a prime is phonologically similar to its target, then processing the target can benefit, in principle, from either the prior application of grapheme–phoneme correspondence rules (priming the nonlexical route), the prior activation of phonological lexical neighbors (priming the lexical route), or both.

Humphreys, Evett, and Taylor (1982) conducted an influential examination of phonological priming in English. Their concerns were whether phonological information is made available automatically, and, if so, whether the lexical or nonlexical route is responsible. In two experiments, Humphreys et al. (1982) demonstrated an automatic priming between homophonically related words (i.e., words with identical phonological representations). The demonstration used a four-field masking procedure (Evett & Humphreys, 1981; Michaels & Turvey, 1979; Turvey, 1978)—specifically, the stimulus sequence of pattern mask, prime, target, pattern mask—and a target-identification task. Word pairs such as TOWED–toad were found to produce more correct identifications than their graphemic controls, word pairs such as TODAY–toad[1]. The inference of automaticity was based on the brevity of the target (approximately 35 ms on average) and the unlikelihood of conscious strategies (such as expecting a stimulus that sounds like the prime) given the four-field procedure. To test whether this fast, automatic priming on phonological dimensions was conveyed over the lexical or nonlexical route, Humphreys et al. (1982) applied the *pseudohomophone test.* According to classical dual-route theory, most words can be processed by either the lexical or nonlexical route, but rare words and nonwords must be processed by the nonlexical route. The lexical route is functionally a stimulus–response (S–R) association in the

---

Georgije Lukatela and M. T. Turvey, Department of Psychology, University of Connecticut, and Haskins Laboratories, New Haven, Connecticut.

This research was supported in part by National Institute of Child Health and Human Development Grant HD-01994 to the Haskins Laboratories. The experiments were designed by Georgije Lukatela in Belgrade, Yugoslavia under National Institute of Child Health and Human Development Grant HD-08495.

Correspondence concerning this article should be addressed to G. Lukatela or M. T. Turvey, Haskins Laboratories, 270 Crown Street, New Haven, Connecticut 06510.

[1] Actually, Humphreys et al. (1982) used lowercase letters for primes and uppercase letters for targets. We reversed their convention here to be compatible with the experimental convention of Lukatela and Turvey (1994) and the convention that is used in the present experiments. Throughout the present article we indicate primes by uppercase letters and targets by lowercase letters, and we use lowercase italic letters to indicate corresponding internal lexical representations.

most traditional sense: A familiar visual stimulus (S) is connected directly to a representation that when activated responds (R) by assigning a meaning and a name to the stimulus, with the strength of the connection dependent on the frequency with which it has occurred. Given that TOWED, the homophonic prime, was a word, it could have exerted its phonological priming influence on the target toad by either the lexical or nonlexical route. A pseudohomophonic prime TODE, however, would be restricted to exerting a phonological influence on the target toad only over the nonlexical route. Hence the pseudohomophone test: Does automatic phonological priming occur when the prime in the four-field procedure is a pseudohomophone? That is, does TODE–toad yield better target identification than TODS–toad? Humphreys et al. (1982) found the answer to be "no." On the basis of this negative outcome they reached two important conclusions: First, that the successful priming with TOWED–toad must have been due to automatic addressed (lexical) phonology; second, that the unsuccessful priming with TODE–toad must be indicative of an assembled (nonlexical) phonology that is either (a) strategic rather than automatic, (b) slow relative to addressed phonology, or (c) nonexistent. Acceptance of (c) leads to the rejection of dual-route theory and the promotion of a theory of word recognition that is founded solely on the lexical route (Humphreys & Evett, 1985).

Humphreys et al.'s (1982) experimental results and their interpretation reinforce a general inclination to conceive of visual word recognition as a process constrained primarily by the visual or orthographic forms of words. In keeping with interpretation (c) above, a large number of accounts of visual word recognition assume no role for phonology in the activation of word knowledge (e.g., Aaronson & Ferres, 1983; Kolers, 1970; McClelland & Rumelhart, 1981; Paap, Newsome, McDonald, & Schvaneveldt, 1982; Smith, 1971). Additionally, experimental analyses commonly exclude considerations of the phonology of a written word, focusing only on its figural characteristics, even though phonology is always (by definition) an accompaniment of orthography. A persistent reason for downplaying phonology as mediating word perception turns on the notion of "mediate" and the spatialization of the mapping from print to meaning (Van Orden & Goldinger, 1994). If "mediate" is interpreted in the sense of an intermediary agent that is in the business of conveying or transmitting, and if there is a given information-processing or neural distance to be covered from visual input to internal lexicon, then a phonological route seems logically excessive. Why would the mental capability of word recognition engage two steps (orthography-to-phonology, phonology-to-lexicon) to traverse the same distance traversible in one step (orthography-to-lexicon)? The assessment that lexical access is most logically visual tends to (a) deflect theoretical arguments from serious consideration of phonology's role even when positive evidence for phonology's role is provided, and (b) rationalize the significance attached to, and acceptance of, null phonology effects (see review by Van Orden et al., 1992). Traditionally, experimental failures to confirm the hypothesis of phonological mediation have been received as confirmations of the hypothesis that word recognition is visually constrained—that is, lexical access is direct rather than mediated (e.g., Davelaar, Coltheart, Besner, & Jonasson, 1978; Fleming, 1993).

Nonetheless, the null phonology effect of Humphreys et al. (1982), as expressed in the failed pseudohomophone test, is difficult to accept given the ease and frequency with which phonological effects have been demonstrated recently and the wide variety of tasks (semantic categorization, backward pattern masking, priming, selective attention) in which the demonstrations have taken place. There is now considerable evidence that phonology is an early source of constraint on the visual recognition of English words (e.g., Perfetti & Bell, 1991; Perfetti, Bell, & Delaney, 1988; Lukatela, Lukatela, & Turvey, 1993; Lukatela & Turvey, 1994; Peter & Turvey, 1994; Van Orden, 1987; Van Orden, Johnston, & Hale, 1988), and that it may well be the primary constraint (Lukatela & Turvey, 1991, 1993, 1994; see reviews by Carello, Turvey, & Lukatela, 1992; Van Orden, Pennington, & Stone, 1990; Van Orden et al., 1992). In Perfetti and Bell (1991), the use of Humphreys et al.'s (1982) procedure without the first (forward) mask revealed a presence of nonword phonological priming at a time scale of less than 50 ms. In Lukatela and Turvey (1994), a target word (e.g., frog) was named after an associate (TOAD), a word that was homophonic with the associate (e.g., TOWED), or a nonword that was homophonic with the associate (e.g., TODE). At brief onset asynchronies (e.g., 50 ms) between a masked prime and target, and with controls for the frequencies, orthographic forms, and lengths of primes, appropriate primes (TOAD) and homophonous primes (TOWED, TODE) facilitated naming to an equal degree. Visually similar words (e.g., TOLD) and nonwords (e.g., TORD) failed to prime, however, suggesting a general indifference of the mechanisms of lexical access to a word's orthographic structure. If a prime's orthographic pattern figured prominently in lexical access, then the close visual similarity of TORD and TOLD to TOAD should have sufficed to partially activate the internal representation toad and, by means of lexical associations, the internal representation *frog*.

The implication that words and nonwords are processed similarly is reinforced by other experiments that have demonstrated a commonality between words and pseudohomophones in their sensitivity to attentional, frequency, and associative manipulations (Lukatela & Turvey, 1993). Between the presentation and recall of one or five digits, subjects performed a secondary task of naming a visually presented letter string—a pseudohomophone (e.g., FOLE, HOAP) or its real word counterpart (FOAL, HOPE). In the analysis of the naming latencies, memory load interacted with frequency (HOPE vs. FOAL, HOAP vs. FOLE) but not with lexicality (HOPE vs. HOAP, FOAL vs. FOLE), pointing to a processing similarity rather than difference between pseudohomophones and their word counterparts. Such an outcome is unexpected from the classical understanding that nonwords are named by a slow (resource expensive) process that assembles the letter string's phonology and words are named by a fast (resource inexpensive) process that accesses lexical phonology (cf. Paap & Noel, 1991). Where an associative priming-of-naming task is made secondary to the memory task, pseudohomophone associative priming (HOAP–DESPAIR, FOLE–HORSE) equals associative priming (HOPE–DESPAIR, FOAL–HORSE) and is affected in the same way by memory load. The conclusion drawn from this research has been that assembled phonology is the basis for naming both nonwords and words (Lukatela & Turvey, 1991, 1993; see also Van Orden et al., 1992).

Taken together, the aforementioned results point to a word's phonology as the initial and primary code by which a word accesses its representation in the internal lexicon. As to the role of a word's orthographic structure, these results suggest that it figures most significantly in processes that reduce the noise in the lexicon following activation by the word's phonological code. Because of phonological similarity among words, a given word's phonological code activates more than one lexical representation, with each representation informing about how its respective word is spelled. A cleanup process (e.g., suppressing incorrect active representations) can be engaged once a fit between the spelling retrieved by a phonological code and the presented visual form has been achieved. In this view, which turns the classical dual-route model on its head, the orthographic input code affects the internal lexicon only after a particular kind of information (the addressed spelling) has been made available by the phonological access code.

Clearly, none of the possible conclusions—(a), (b), or (c)—of Humphreys et al.'s (1982) research, identified above, conforms to the present understanding of phonology's role in word perception. Accordingly, a further examination of phonological priming is warranted. Pertinent to any such reexamination is an assessment of the related notions of abstract graphemic features and abstract graphemic recognition units (Evett & Humphreys, 1981). The absence of evidence for a true phonological priming effect, and the presence of evidence for priming across upper- and lower case transcriptions, seem to warrant the hypothesis that access to the internal lexicon proceeds by letter identity information that is independent of physical format. As Evett and Humphreys (1981) remarked, this is the most important conclusion to be drawn from the conjunction of failed phonological priming and successful case-independent priming. If access to the lexicon were achieved on phonological grounds, then it would be sufficient to assume that orthographic features (subpatterns, subsymbols) map onto phonological features. The "sameness" of different forms of a letter could then be said to arise from the fact that they activate, by means of a matrix of weighted connections, the same set of phonological features. Of relevance to this point, perhaps, is research using the two, partially overlapping, alphabets (Roman and Cyrillic) of Serbo-Croatian. In contrast to the currently available results in English, phonological priming in Serbo-Croatian is well established within both the lexical decision and naming tasks (Lukatela, Carello, & Turvey, 1990a; Lukatela & Turvey, 1990a). Indeed, for the experiments in this language, there is no evidence for graphemic-based or form priming over and above phonological priming. The experiments show that a prime and target distinguished by a single phoneme but differing in alphabet (Lukatela & Turvey, 1990a), or differing in both alphabet and case (Lukatela et al., 1990a), exhibit priming to the same degree as when prime and target are transcribed in the same alphabet and same case.

The most parsimonious interpretation of the equivalency of the Roman and Cyrillic, upper- and lowercase forms of a given alphabetic character is that all the forms map to the same cluster of phonological features. Such an interpretation seems especially prudent given that the motivations for Evett and Humphrey's (1981) advocacy of abstract graphemic units are lacking in the Serbo-Croatian research. On grounds of parsimony, it would also seem prudent to assume that the processing equivalency of letter variants in English is not founded on a principle different from that governing the processing equivalency of letter variants in Serbo-Croatian. If the notions of abstract graphemic features and abstract graphemic recognition units were to be abandoned for the processing of English words, then explanations of case-independent priming (e.g., TODS–toad) couched in terms of orthography or form would have to be reappraised. For example, the phrase "orthographic priming" would not refer to a preactivation of abstract graphemic processing units but rather would refer to effects of a particular nature within the matrix of connections relating the multidimensional space of orthographic features to the multidimensional space of phonological features[2]. One important goal of the present series of experiments with English-language materials will

---

[2] The theoretical issues surrounding phonological priming (e.g., the pseudohomophone test, abstract graphemic features) have been couched traditionally in the terms of dual-process theory with its assumptions of symbolic representations, rules, and symbol transfer between modules. As will become increasingly evident, in both surveying the issues and addressing them experimentally, we have found it necessary to exploit concepts and principles from a connectionist framework. Our impression is that word recognition, word naming, and priming are more adequately accommodated within the subsymbolic paradigm (Van Orden et al., 1990). Although it is not our purpose to produce a detailed connectionist account of the reported phenomena, it is the case that certain broad connectionist assumptions shape our experimental designs and analyses. We take orthographic and phonological feature-processing units, respectively, as defining the input and output layers of a matrix of weighted connections that computes phonology (e.g., Seidenberg & McClelland, 1989). Orthographic priming is either the result of a brief persistence of activation at the input layer or of a temporary change in the weights. We assume that the former is more likely than the latter. Similarly, in respect to phonological priming, we assume that the major source of the effect is the persistence of activation in the output layer, enhanced by feedback from the level of word representations. The overwhelming superiority of phonological priming over orthographic priming in the Serbo-Croatian experiments (Lukatela et al., 1990a; Lukatela & Turvey, 1990a) points to considerably greater persistence of activation in the output layer than in the input layer.

be to ascertain the explanatory need for a notion of abstract graphemic features over and above the older idea of underlying speech-related units.

Experiment 1

The research of Humphreys et al. (1982) used accuracy of target identification as the dependent measure under conditions that were purposely designed to render target identification less than perfect. Specifically, the uppercase target was exposed briefly under (a) forward masking by the lowercase prime (itself subject to forward pattern masking), and (b) backward masking by a cluster of randomly oriented letter segments. Certain modifications to Humphreys et al.'s procedure seemed desirable. First, a dependent measure of naming latency under relatively long target exposure, rather than identification accuracy under near-threshold target exposure, would permit direct comparisons with the investigations of pseudoassociative priming by means of phonological similarity (Lesch & Pollatsek, 1993; Lukatela & Turvey, 1994; Lukatela, Lukatela, & Turvey, 1993)[3]. Eliminating masking of the target but preserving masking of the prime has been shown to yield orthographic (form) priming in the rapid naming task (Forster & Davis, 1991; unpublished experiments referred to by Humphreys, Evett, Quinlan, & Besner, 1987), suggesting that the combination of this three-field procedure and naming could yield phonological priming. Second, reversing the cases of the prime and target would facilitate comparisons with the experiments of Lukatela and Turvey (1994), who used primes in uppercase letters and targets in lowercase letters (see Footnote 1)[4]. Following the pioneering studies of Evett and Humphreys (1981), Humphreys et al. (1982) used prime–target stimuli such as maid–MADE to ensure spatial overlap of the prime by the target and, hence, enhanced masking of the prime. It is the case, however, that similarly appropriate degrees of prime masking can be attained for MAID–made stimuli simply by adjusting the figural detail of the forward mask and the temporal conditions of presentation.

Perhaps the most important modification of Humphreys et al. (1982) is in respect to the stimuli. Their Experiments 1 and 2 contrasted pairs such as TOAD–toad (identity priming), TOWED–toad (homophonic priming), TODAY–toad (graphemic control priming), and QUITE–toad (unrelated control priming). Interpretations of differences among these stimulus pairs assumed that the different primes were 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 identity, homophonic, and graphemic control primes. Consequently, in Experiment 1 of the present series, a given target word (toad) was combined in a counterbalanced manner with three different experimental primes. For example, the experimental primes for toad were TOAD (identity), 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 the same position in common with them. Because the issue is whether phonological codes are assembled automatically as opposed to retrieved automatically by the form-driven lexical route, it was considered desirable to maximize the visual similarity between identity primes and their quasi-homographic counterparts (TOAD and TOLD, respectively), and to minimize the visual similarity between identity primes and their homophonic counterparts (TOAD and TOWED, respectively).

In sum, the principal goal of Experiment 1 was to determine whether the priming between homophonically related stimuli observed by Humphreys et al. (1982) was replicable in a naming task involving the stimulus sequence of pattern mask–prime–target and in respect to more carefully controlled priming pairs.

Method

Subjects. Fifty-four undergraduates at the University of Connecticut served as subjects. Each subject was assigned to one of six counterbalancing groups according to the time he or she arrived at the laboratory, yielding a total of 9 subjects per group.

Materials. The stimuli consisted of 96 pairs of yoked English homophones (e.g., TOWED and TOAD, GUISE and GUYS). List 1 consisted of 96 identity-related prime–target pairs (e.g., TOAD–toad, PAWS–paws). Each prime in List 1 was then replaced by its yoked homophone to produce List 2, which consisted of 96 homophonically related prime–target pairs (e.g., TOWED–toad, PAUSE–paws. List 3 consisted of 96 quasi-homographically related prime–target pairs (e.g. TOLD–toad, PAYS–paws). 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 identity prime (e.g., TOAD, PAWS).

There were three control lists, Lists 4–6. List 4 consisted of 96 nonidentity (i.e., visually and phonologically unrelated) prime–target pairs (e.g. FINK–toad, FLOC–paws). Each 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

---

[3] There should be no surprises about effects of masked (unidentifiable) stimuli showing up in latency measures. Such effects have been known for some time from the studies of Fehrer and Raab (1962) and Fehrer and Biederman (1962). In metacontrast paradigms, these experimenters showed that (a) the perceiver's phenomenal experience, as expressed in verbal judgements about the presence or absence of target stimuli, was not reflected in reaction time, and (b) reaction-time responses were initiated by stimuli whose presence was not suspected.

[4] An additional reason for reversing the cases of prime and target was that Apple IIe displays in lowercase are unfamiliar. That is, the lowercase letters are of uncommon form, and we were concerned that under masking they would pose special difficulties for visual information processing. As an aside, the continued use of the Apple IIe is to facilitate comparisons with research done in Georgije Lukatela's Belgrade, Yugoslavia laboratory, where Apple IIe computers remain the essential experimental tool.

same frequency (compare TOAD vs. FINK, PAWS vs. FLOC), and (d) was not a prominent associate of the corresponding target.

List 5 consisted of 96 nonhomophone unrelated prime–target pairs (e.g., PLASM–toad, SCREW–paws). Each nonhomophone unrelated prime (e.g., PLASM, SCREW) was a word that (a) shared no letters in the same position with its corresponding List 2 prime, (b) was of the same length and frequency as its corresponding List 2 prime (compare PLASM vs. TOWED, SCREW vs. PAUSE), and (c) was not a prominent associate of the corresponding target.

List 6 consisted of 96 non-quasi-homograph unrelated prime–target pairs (e.g., GIVE–toad, DOME–paws). Each non-quasi-homograph unrelated prime (e.g., GIVE, DOME) was a word that (a) shared no letters in the same position with its corresponding List 3 prime, (b) was of the same length and frequency as its corresponding List 3 prime (compare GIVE vs. TOLD, DOME vs. PAYS), and (c) was not a prominent associate of the corresponding target.

Finally, a foil list was assembled that consisted of 24 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, with predominantly low frequency [LF] target words, and Sublist B, with predominantly high frequency [HF] target words) of 48 prime–target pairs each. Sublist A had an average target-word frequency of 15.12 ± 25.03, and Sublist B had an average target-word frequency of 88.19 ± 156.42. Needless to say, the prime frequencies of Sublist A (PAWS–paws) and Sublist B (TOAD–toad) of List 1 were identical to that of their respective targets. For List 2, Sublist A (PAUSE–paws) had a prime frequency of 183.17 ± 530.83, and Sublist B (TOWED–toad) had a prime frequency of 13.31 ± 24.28. For List 3, Sublist A (PAYS–paws) had a prime frequency of 30.94 ± 63.16, and Sublist B (TOLD–toad) had a prime frequency of 72.17 ± 198.02.

Lists 4–6 approximately duplicated the Sublist A versus Sublist B contrasts of Lists 1–3. Thus, the respective Sublist A and Sublist B mean prime frequencies were 14.94 and 85.29 for List 4, 166.17 and 13.33 for List 5, and 30.58 and 68.21 for List 6. (All frequencies were determined from Kucera & Francis, 1967).

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 shared final letters always considered to be in the same position) relative to 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 $1/2(3/5 + 3/5) = 0.6$; for TOAD and TOLD, $L1 = 3$, $L2 = 3$, $L = 4$, and the estimate of visual similarity is $1/2(3/4 + 3/4) = 0.75$. The average index of visual similarity between identity primes (e.g., TOAD) and homophonically related primes (TOWED) was .64, and that between identity primes and quasi-homographic primes (TOLD) was .70.

Design. The major constraint on the design was that a given subject never encountred 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 16 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 24 unrelated word–word pairs. Each subject saw a total of 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. The experimental sequence was preceded by a practice sequence of 36 word–word pairs.

Procedure. Subjects, who were run one at a time, sat in front of the monitor of an Apple IIe computer in a well-lit room. Each trial consisted of an auditory warning signal followed by a rapid sequence of three visual stimuli. First, a row of five hash marks appeared at the fixation point (in the center of the screen); this mask was presented for 500 ms and was immediately (i.e., with an interstimulus interval [ISI] = 0) followed by presentation of an uppercase letter string (i.e., the prime); the prime was presented for 30 ms. Finally (again with ISI = 0), a lowercase letter string appeared at the fixation point for 400 ms. These exposure durations are nominal rather than exact, because display changes in reality 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 the present article—varied in a random manner with a uniform probability between +8 ms and −8 ms around the statistical mean exposure; for example, the nominally 30-ms exposure in reality varied between 30 and 46 ms, whereby the statistical mean exposure was 38 ms[5].

Each subject was told that on each trial he or she would view a simple sequence of visual events, namely, a "complex pattern" (i.e., consisting of different uppercase letter segments and letter wholes similarly in uppercase) followed by a word in lowercase letters. The task was to name out loud the lowercase word 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 was preceded by any other sound, the pronunciation was not smooth (i.e., the subject hesitated after beginning to name), or the response was not loud enough to trigger the voice key. If the naming latency was longer than 1,000 ms, a message appeared on the screen requesting the subject to name more quickly. All latencies, including those longer than 1,000 ms, were stored in the computer memory.

Results and Discussion

In the debriefing, all subjects reported an inability to discern the letters in the complex pattern that preceded the to-be-named target words, suggesting that the combined forward and backward masking of the prime had been successful.

For each subject, naming latencies more than two standard deviations above or below his or her 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. (This two-

---

[5] Because of the lack of precise temporal control, which becomes amplified at very brief SOAs, it becomes necessary to take averages over larger numbers of subjects. Thus, Experiment 7, in which an exposure time of nominally 18 ms was used, was conducted with 64 subjects, compared with 48 in the present experiment, in which a nominal exposure duration of 30 ms was used.

standard deviation criterion and the combination of error kinds was applied in all of the reported experiments.) The results are summarized in Table 1.

A 3 × 2 × 2 omnibus analysis of variance (ANOVA) was conducted on naming latencies using the quasi variables of prime type and relatedness and the real variable of sublist or, synonymously, average target frequency (LF targets in Sublist A, HF targets in Sublist B). "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 "relatedness" refers to the contrast between Lists 1–3 and their controls, Lists 4–6. The utility of this ANOVA involving the preceding two quasi variables is that it provides indicators of the interactions involving sublist. Sublist (Sublist A = 562 ms vs. Sublist B = 554 ms) reached significance by subjects, F(1, 53) = 25.78, $p < .001$, for sublist A, but not by stimuli, F(1, 94) = 1.73, $p > .05$, for sublist B, and did not interact with either of the quasi variables (*F*s < 1). The same 3 × 2 × 2 omnibus ANOVA conducted on errors revealed a main effect of sublist (Sublist A = 3.67% vs. Sublist B = 1.97%), F(1, 53) = 4.06, $p < .05$, for sublist A, F(1, 94) = 4.58, $p < .05$, for sublist B, but found no interactions involving sublist (all *F*s < 1).

The planned comparisons yielded the following outcomes for the homophonically and orthographically similar primes: TOWED–toad differed from PLASM–toad by 28 ms, F1(1, 53) = 91.68, $p < .001$, F2(1, 94) = 31.16, $p < .001$, and TOLD–toad differed significantly from GIVE–toad by 9 ms, F1(1, 53) = 6.23, $p < .05$, F2(1, 94) = 4.52, $p < .05$. For identity priming, TOAD–toad differed from FINK–toad by 41 ms, F1(1, 53) = 286.35, $p < .001$, F2(1, 94) = 64.75, $p < .001$.

An examination of the partial interactions provides further insight into the outcome of the experiment. The theoretically important partial interaction between TOWED–toad versus PLASM–toad (28 ms difference) and TOLD–toad versus GIVE–toad (9 ms difference) was significant, *F*1(1, 53) = 16.89, $p < .001$, *F*2(1, 94) = 8.20, $p < .01$. Lending support to the preceding are the partial interactions involving the identity prime. Thus, the partial interaction between TOLD–toad versus GIVE–toad (9 ms difference) and TOAD–toad versus FINK–toad (41 ms difference) was highly significant by both analyses, F1(1, 53) = 16.89, $p < .001$, F2(1, 94) = 12.12, $p < .001$, whereas the partial interaction between TOWED–toad versus PLASM–toad (28 ms difference) and TOAD–toad versus FINK–toad (41 ms difference) was significant by subjects, F1(1, 53) = 10.81, $p < .01$, and (marginally) insignificant by stimuli, F2(1, 94) = 3.94, $p > .05$.

Although the omnibus ANOVA did not reveal any reliable List × Relatedness interaction, it remains important to consider whether the observed priming exhibited any frequency effects. With respect to orthographic priming, Table 1 shows that TOLD–toad differed from GIVE–toad by 12 ms in Sublist A (with prime frequency of 31 and target frequency of 15) and by 6 ms in Sublist B (with prime frequency of 72 and target frequency of 88). The 12-ms difference was significant, F1(1, 53) = 7.54, $p < .01$, F2(1, 47) = 4.13, $p < .05$, whereas the 6-ms difference was insignificant, F1(1, 53) = 1.82, $p > .05$, F2(1, 47) < 1. The implication is that the orthographic priming in Experiment 1 may have been restricted to LF target words. With respect to TOWED–toad versus PLASM–toad, inspection of Table 1 reveals this difference to be 29 ms in Sublist A (with prime frequency of 183 and target frequency of 15) and 27 ms in Sublist B (with prime frequency of 13 and target frequency of 88). Both differences were significant, F1(1, 53) = 37.70, $p < .001$, F2(1, 47) = 17.90, $p < .001$; and F1(1, 53) = 69.73, $p < .001$, F2(1, 47) = 13.39, $p < .001$, respectively. Apparently, phonological priming was not affected by word frequency.

The important outcome of Experiment 1 is that Humphreys et al.'s (1982) observation of phonologic priming by masked homophones (e.g., TOWED) was replicated in the three-field naming task. Moreover, because of the careful matching of control primes, Experiment 1 revealed that there was also a reliable Priming × Graphemic Controls interaction (e.g., TOLD), a fact hidden from the analyses of Humphreys et al. (1982) but with the magnitude of

Table 1

Mean Naming Latencies (In Milliseconds) and Percentage Error Rate, With the Corresponding Standard Deviations by Subjects and by Items for the "Related" and "Unrelated" Primes of Experiment 1

	"Related" primes						"Unrelated" primes					
	TOAD–toad		TOWED–toad		TOLD–toad		FINK–toad		PLASM–toad		GIVE–toad	
Measure	L	ER	L	ER	L	ER	L	ER	L	ER	L	ER
Sublist A (LF)												
M	534	3.01	549	3.47	563	2.31	574	3.47	578	5.09	575	4.63
Subject *SD*	56	5.39	62	5.65	65	5.47	57	6.15	60	7.49	58	7.40
Item *SD*	43	5.95	54	6.94	50	4.56	43	6.94	44	10.24	43	9.95
Sublist B (HF)												
M	526	1.85	542	3.70	556	0.93	568	1.39	569	2.08	562	1.85
Subject *SD*	53	4.48	61	5.76	64	3.30	54	3.97	53	4.70	52	4.48
Item *SD*	43	4.18	45	7.00	45	3.10	41	3.71	38	4.95	39	5.29

Note. L = latency; ER = error rate; LF = low frequency; HF = high frequency.

this orthographic priming significantly below that of homophonic priming.

Experiments 2 and 3

There is a well-established impression that priming based on visual form—so-called orthographic, or form, priming—is limited to conditions in which the priming stimulus is not identifiable (e.g., Forster, 1987; Forster & Davis, 1991; Humphreys et al., 1987). Those conditions were met in Experiment 1, and evidence of a priming due to visual likeness was found: TOLD–toad differed significantly from its control, GIVE–toad. Under the same conditions of unidentifiable primes, however, Experiment 1 revealed that there was homophonic priming over and above orthographic priming.

Interactive activation models of the kind McClelland and Rumelhart (1981) introduced are well suited to addressing the form priming expressed by TOLD–toad. In such models, word processing units are selectively attuned to respond to activation patterns in (abstract) letter processing units coded for position. If the unit for letter-T-in-first-position is sufficiently excited, then all the word units with *T* as the initial letter will become active. Similar processes occur for letter-O-in-second-position, and for the remaining letters in TOLD. In recognizing TOLD, therefore, the internal representation *toad* and the representations of all other words orthographically resembling TOLD are partially activated. Consequently, the occurrence of toad soon after TOLD means that the processing of toad can benefit from the prior processing of TOLD. The simplicity and straightforwardness of the preceding account hides, however, a major insufficiency: It does not lead to the expectation that orthographic priming requires unidentified primes.

One view of the restriction of orthographic priming to masked primes is that it reflects the interaction of primes and targets competing within the information-processing system for a single (abstract) orthographic description (Humphreys et al., 1987). This interaction impedes target processing when the prime and target are orthographically different (GIVE–toad) and assists target processing when the prime and target are orthographically similar (TOLD–toad). A prime that is similar on abstract orthographic dimensions to its target will support, rather than compete with, the abstract orthographic description of the target. That two stimuli may coalesce to produce a single orthographic description is consistent with a phase of dichoptic visual masking, usually found in the SOA range of 0–50 ms, in which two successively presented stimuli function as a single unit (Michaels & Turvey, 1979). This *masking by common synthesis*, as it has been called, is not energy dependent—as is the case for two monocularly or binocularly presented stimuli that coalesce over a similar SOA range (Michaels & Turvey, 1979). When referred to the interactive activation model, the preceding interpretation of the masking dependency would suggest a prelexical locus for orthographic priming (cf. Humphreys et al., 1987)[6]. If, in Experiment 1, a prime and a target interacted in the formation of the orthographic access code, then the word processing units partially activated by the resultant code would be less likely to include toad when GAVE was the prime than when TOLD was the prime.

An important prediction of the prelexical interaction interpretation of orthographic priming is that the difference between TOLD–toad and GAVE–toad, favoring the former, should decline with SOA. Experiments that have used the four-field procedure and identification as the dependent measure have revealed this inverse relation (Humphreys et al., 1987). A similar dependency on SOA would have to be expected of phonological priming if it were the case that phonological priming was the outcome of the same process that gave rise to orthographic priming. The significant difference between the two kinds of priming in Experiment 1 suggests, however, that they may not be of common origin. One form of evidence in favor of different bases to orthographic and phonological priming would be a different response of the two priming types to SOA. Does phonological priming continue to occur, and orthographic priming not occur, over SOAs that render primes identifiable? We examined this question in Experiment 2 with an SOA of 60 ms, close to the limit on masking by common synthesis (Michaels & Turvey, 1979) and which had been shown in pilot research to produce identifiable primes in most subjects for the stimulus size, duration, and illumination conditions of Experiment 1. In Experiment 3 we examined the same question with an SOA of 250 ms, that is, at the lower end of the time scale within which strategic processes are said to become applicable (Neely, 1991), and safely outside the time scale at which an aftercoming target could mask a prior prime.

Method

Subjects. Forty-two undergraduates at the University of Connecticut served as subjects in Experiment 2, and another 42 undergraduates served as subjects in Experiment 3. In each experiment, a subject was assigned to one of six counterbalancing groups, according to the time he or she appeared at the laboratory, yielding a total of 7 subjects per group. None of the subjects had participated in Experiment 1.

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

Procedure. The procedure was the same as that of Experiment 1 except that the SOA between prime and target was 60 ms in Experiment 2 and 250 ms in Experiment 3.

---

[6] It has been suggested that there is at least one experimental situation in which orthographic priming does not arise in prelexical processes but seems to depend on prime recognition (Forster, 1987). When prime and target are related both in form and morphology (e.g., SENT–send), the resultant priming matches identity priming (Forster, Davis, Schoknecht, & Carter, 1987), implying that priming occurs only after the prime has been recognized. On the basis of the present research, this effect is more legitimately understood as an instance of phonological priming that encompasses lexical and prelexical processes.

Table 2
Mean Naming Latencies (In Milliseconds) and Percentage Error Rate, With the Corresponding Standard Deviations by Subjects and by Items for the "Related" and "Unrelated" Primes of Experiment 2

	"Related" primes						"Unrelated" primes					
	TOAD–toad		TOWED–toad		TOLD–toad		FINK–toad		PLASM–toad		GIVE–toad	
Measure	L	ER	L	ER	L	ER	L	ER	L	ER	L	ER
Sublist A (LF)												
M	554	1.79	568	3.57	594	2.98	594	2.08	593	3.27	598	2.08
Subject *SD*	68	4.43	67	5.72	68	6.65	59	5.46	59	6.21	61	6.12
Item *SD*	48	4.77	50	8.59	53	5.86	43	5.89	50	7.36	47	5.89
Sublist B (HF)												
M	543	2.98	558	1.19	573	4.46	585	0.89	580	0.89	583	1.79
Subject *SD*	64	6.05	65	6.05	64	8.20	58	3.26	60	3.26	54	4.43
Item *SD*	33	7.19	45	3.99	48	8.92	39	3.49	35	3.49	40	4.77

Note. L = latency; ER = error rate; LF = low frequency; HF = high frequency.

Results and Discussion

Tables 2 and 3 summarize the results of the two experiments. The omnibus ANOVA described in Experiment 1 revealed for the data of Experiment 2 an effect of sublist (Sublist A = 583 ms vs. Sublist B = 570 ms) limited to the subjects analysis, F1(1, 41) = 40.48, $p < .001$, F2(1, 94) = 3.88, $p > .05$, and no interactions involving sublist (*F*s < 1). In the error analysis, the Prime Type × Sublist interaction was significant for subjects and for stimuli, F1(2, 82) = 3.22, $p < .05$, F2(2, 188) = 3.09, $p < .05$.

With respect to Experiment 3, sublist (Sublist A = 591 ms vs. Sublist B = 579 ms) was significant by subjects, F1(1, 41) = 32.01, $p < .001$, and insignificant by stimuli, F2(1, 94) = 3.30, $p > .05$. Prime Type × Sublist was significant by subjects, F1(2, 82) = 4.04 $p < .05$, but not by stimuli, F2(2. 188) = 1.37, $p > .05$. In the error analysis, sublist (Sublist A = 0.89% vs. ublist B = 0.30%) was significant, F1(1, 41) = 4.92, $p < .05$, F2(1, 94) = 4.95, $p < .05$, but it was involved in no interactions (all *F*s < 1).

As with Experiment 1, the important analyses are the planned comparisons and the partial interactions. These statistics are presented first for the data of Experiment 2. The planned comparisons of Experiment 2 revealed that whereas TOWED–toad differed significantly from PLASM–toad by 23 ms, F1(1, 41) = 36.99, $p < .001$, F2(1, 94) = 21.63, $p < .001$, the 7 ms difference between TOLD–toad and GIVE–toad was not significant, F1(1, 41) = 3.59, $p > .05$, F2(1, 94) = 1.53, $p > .05$. For identity priming, TOAD–toad differed from FINK–toad by 41 ms, F1(1, 41) = 120.06, $p < .001$, F2(1, 94) = 80.07, $p < .001$. The differences between phonological priming and orthographic priming were corroborated by the analysis of partial interactions: The contrast of TOWED–toad versus PLASM–toad (23 ms difference) and TOLD–toad versus GIVE–toad (7 ms difference) was significant, F1(1, 41) = 17.01, $p < .001$, F2(1, 94) = 5.25, $p < .05$. Additionally, the partial interaction between TOWED–toad versus PLASM–toad (23 ms difference) and TOAD–toad versus FINK–frog (41 ms dif-

Table 3
Mean Naming Latencies (In Milliseconds) and Percentage Error Rate, With the Corresponding Standard Deviations by Subjects and by Items for the "Related" and "Unrelated" Primes of Experiment 3

	"Related" primes						"Unrelated" primes					
	TOAD–toad		TOWED–toad		TOLD–toad		FINK–toad		PLASM–toad		GIVE–toad	
Measure	L	ER	L	ER	L	ER	L	ER	L	ER	L	ER
Sublist A (LF)												
M	566	1.49	580	0.60	602	1.19	603	0.60	596	0.89	598	0.60
Subject *SD*	62	4.10	71	2.69	65	3.71	60	2.69	65	3.26	60	2.69
Item *SD*	43	4.41	59	2.88	54	3.99	45	2.88	51	3.49	51	2.88
Sublist B (HF)												
M	553	0.00	568	0.30	594	0.60	577	0.00	592	0.30	588	0.60
Subject *SD*	58	0.00	63	1.93	63	2.69	56	0.00	60	1.93	60	2.69
Item *SD*	41	0.00	48	2.06	51	2.88	41	0.00	52	2.06	43	2.88

Note. L = latency; ER = error rate; LF = low frequency; HF = high frequency.

ference) was significant, F1(1, 41) = 15.24, $p < .001$, F2(1, 94) = 9.50, $p < .01$, as was that between TOLD–toad versus GIVE–toad (7 ms difference) and TOAD–toad versus FINK–toad (41 ms difference), F1(1, 41) = 41.31, $p < .001$, F2(1, 94) = 24.85, $p < .001$.

Considering the sublist (frequency) influence in Experiment 2 more closely, orthographic priming in Sublist A and Sublist B was 3 ms and 11 ms, respectively (see Table 2). Neither was significant: F1(1, 41) < 1, F2(1, 47) < 1, and F1(1, 41) = 6.09, $p < .05$, F2(1, 47) = 1.99, $p > .05$, respectively. With respect to phonological priming, the difference between TOWED–toad and PLASM–toad in Sublist A was 25 ms, and in Sublist B it was 21 ms. Both differences were significant, F1(1, 41) < 26.08, $p < .001$, F2(1, 47) < 13.00, $p < .001$, and F1(1, 41) = 29.39, $p < .001$, F2(1, 47) = 8.87, $p > .01$, respectively, underscoring that phonological priming did not depend on word frequency. As noted, a contribution of sublist was found in the omnibus ANOVA on errors, specifically, a Sublist × Prime Type interaction. Importantly, there was no corresponding three-way interaction involving relatedness. Table 2 shows that the error rates in Sublist A were lower for the identity and orthographic primes than for the homophonic primes, whereas in Sublist B the reverse was true. This same pattern was replicated with the unrelated primes pointing away from any particular relation between word frequency and the dimensions of priming. Apparently, the patterning of errors followed the patterning of prime frequencies. For the identical, orthographic, and homophonic primes—both experimental and control—the frequencies were 15, 31, and 183, respectively, in Sublist A; and 88, 72, and 13, respectively, in Sublist B. If this parallelism of error and the prime frequency patterns is not artifact or chance, then a notion of a frequency-constrained processing "spillover" (or mutual processing interference) when two words are visually presented at short SOAs may need to be considered. Most important, the replication of the prime frequency effect in the control stimuli underscores the significance of the controls. If they had not been used in the present experiment, with analyses limited only to TOAD, TOWED, and TOLD, as is conventional, then false conclusions would have been drawn about the dependence of the priming on frequency.

Essentially the same statistical pattern was obtained for the data of Experiment 3, with one major exception; namely, that phonological priming approached identity priming, with the proximity greater for HF targets than for LF targets (see Table 3). The planned comparisons revealed that the 20-ms difference between TOWED–toad and PLASM–toad was significant, F1(1, 41) = 30.91, $p < .001$, F2(1, 94) = 9.94, $p < .01$, but the 5-ms difference between TOLD–toad and GIVE–toad was not, F1(1, 41) = 2.10, $p > .05$, F2(1, 94) = 1.53, $p > .05$. For identity priming, TOAD–toad differed from FINK–toad by 31 ms, F1(1, 41) = 57.61, $p < .001$, F2(1, 94) = 40.23, $p < .001$. The partial interactions provided further confirmation of the marked contrast between phonological and orthographic priming. The partial interaction between TOWED–toad versus PLASM–toad (20 ms difference) and TOLD–toad versus GIVE–toad (5 ms difference) was highly significant, F1(1, 41) = 29.10, $p < .001$, F2(1, 94) = 9.90, $p < .01$. Additionally, the partial interaction between TOLD–toad versus GIVE–toad (5 ms difference) and TOAD–toad versus FINK–toad (31 ms difference) was highly significant, F1(1, 41) = 53.11, $p < .001$, F2(1, 94) = 30.05, $p < .001$, but the partial interaction between TOWED–toad versus PLASM–toad (20 ms difference) and TOAD–toad versus FINK–toad (31 ms difference) was significant only by subjects, F1(1, 41) = 7.32, $p < .01$, F2(1, 94) = 2.77, $p > .05$. The latter points to an effect of phonological primes that is not so different from that of identity primes. More specifically, identity and phonological priming were indistinguishable for HF targets (the partial Prime Type × Relatedness interaction in Sublist B was insignificant [both *F*s < 1]) but remained distinguishable for LF targets (the partial Prime Type × Relatedness interaction in Sublist A was significant, F1[1, 41] = 11.36, $p < .01$, F2[1, 47] = 5.78, $p < .05$).

Neither Experiment 2, with barely identifiable primes, nor Experiment 3, with clearly identifiable primes, provided evidence for orthographic priming in agreement with previous research that has suggested a restriction on this type of priming to masked prime conditions (e.g., Humphreys et al., 1987; Forster, 1987). The same does not seem to be the case for phonological priming. Inspection of the results of Experiments 1, 2, and 3 suggests that phonological priming is indifferent to the identifiability of the prime (or, alternatively, is relatively constant over SOA, viz., 28-, 23-, and 20-ms effects for SOAs of 30, 60, 250 ms, respectively), and that identity priming tends to converge on phonological priming as SOA increases. Phonological priming was clearly different from, and very much more pronounced than, orthographic priming. The more pronounced nature of phonological priming has to be considered in the context of the fact that the orthographic pairs (TOLD–toad) were designed to be, on average, more visually similar than the phonological pairs (TOWED–toad). On the computed index of visual similarity (see *Materials* section in Experiment 1), the contrast was .70 versus .64, respectively. As the more pervasive priming, phonological priming would seem to be the theoretically more important priming, reflecting processes more fundamental to word recognition than those reflected in orthographic priming.

Returning to the discussion of orthographic priming, which was brought up in the introduction, the dismissal of the notion of abstract graphemic processing units would focus the effects of orthographic similarity strictly within the network of connections between orthographic features and phonological features. Working within this focus leads to a new hypothesis about orthographic priming and a suitably contrasting hypothesis about phonological priming. The short-term effects associated with TOLD–toad pairs would suggest that activity within the network reflects briefly the specific encoding of orthographic features into phonological features. That is, for a brief time there is a pattern of activity over the orthographic features that reflects precisely how the phonological features were activated. The present hypothesis is that this brief encoding-specific pattern is the basis for so-called orthographic priming. In contrast, the basis for phonological priming is the states of the phonological processing units made active by that encoding and enhanced by feedback from the word processing units activated by the phonological units.

Experiments 4 and 5

It will be recalled that the departure point for the present research was the failed pseudohomophone test of Humphreys et al. (1982). In light of the successes of Experiments 1–3 in demonstrating phonological priming within a three-field naming task, the question of phonological priming by pseudohomophones can be reopened in the context of this task. If pseudohomophones are functionally similar to homophones in priming capability—as is the case in pseudoassociative priming (Lukatela & Turvey, 1994)—then the pseudohomophone test should be passed under the SOA and prime identifiability conditions of Experiments 2 and 3. In Experiment 4 we used an SOA of 60 ms, and in Experiment 5 we used an SOA of 250 ms.

The key feature of a thoroughgoing implementation of the pseudohomophone test is the graphemic control. Ideally, for a given pseudohomophone, the graphemic control should be the letter string that is most similar visually to the pseudohomophone while at the same time conforming to the phonotactic constraints of the language. In respect to a pseudohomophone such as TODE (in the pairing TODE–toad), TODF is visually similar, but the bigram DF is uncommon in English. The nonword TODS is somewhat less visually similar to TODE than TODF but has the advantage of more closely matching TODE in bigram frequency. According to the preceding criteria, TODS is the more appropriate graphemic benchmark for TODE. The pseudohomophone test then becomes: Can TODE prime toad more than TODS primes toad?

The simple inclusion of TODS and the comparison of TODE–toad with TODS–toad, however, does not fully satisfy a thoroughgoing implementation of the pseudohomophone test. Each priming pair TODE–toad and TODS–toad must be evaluated against its own control. In Experiments 4 and 5, the experimental conditions for the target word toad consisted of *word* primes TOAD and LAME, *pseudohomographic* primes TODS and LARM, *pseudohomophonic* primes TODE and LAIM, and *pseudoword* primes PESK and RETH. Thus, TOAD-, TODS-, TODE-, and PESK- constitute the related contexts, and LAME, LARM-, LAIM-, and RETH- constitute the unrelated contexts. In sum, the pseudohomophone test would be passed if TODE primed significantly relative to its unrelated control LAIM and relative to its pseudohomographic and pseudoword controls TODS and PESK, respectively.

Method

Subjects. The participants in Experiment 4 were 48 undergraduates at the University of Connecticut. A subject was assigned to one of eight groups, yielding 6 subjects per group. The participants in Experiment 5 were 40 undergraduates at the University of Connecticut, with each subject assigned to one of eight groups, yielding 5 subjects per group. None of the subjects in either experiment had participated in Experiments 1–3.

Materials. There were eight word sets (see Appendix B). The first set (also the base set) consisted of 96 identity-related word pairs (e.g., TOAD–toad), 48 of which were LF and 48 of which were HF. LF words had a mean frequency of 13.73 ± 9.63. HF words had a mean frequency of 176.08 ± 156.02. (All frequencies were determined from Kucera & Francis, 1967.) When both subgroups of words were collapsed, the mean frequency was 94.91 ± 136.93.

Two LF maximally related word–word pairs (prime and target were the same word) were paired to match in length, to mismatch (as far as possible) in visual form, and to match (as closely as possible, given the other constraints) in their respective word frequencies. This created 24 LF "identity quadruples" (e.g., TOAD–toad, LAME–lame). Twenty-four HF identity quadruples (e.g., WIFE–wife, DOOR–door) were created in similar fashion. The 48 identity quadruples defined in the preceding manner composed the 96 stimulus pairs of Set 1. From Set 1, 7 additional sets of 96 pairs were generated.

Set 2: Within each identity quadruple, the mutual substitution of primes produced a new nonidentity quadruple of two semantically, graphemically, and phonologically unrelated word–word pairs (e.g., LAME–toad, TOAD–lame).

Set 3: In each identity quadruple, each priming word was replaced by its pseudohomophone to produce phonologically related, pseudohomophone–word pairs (e.g., TODE–toad, LAIM–lame).

Set 4: In each nonidentity quadruple, each priming word was replaced by its pseudohomophone to produce phonologically unrelated, pseudohomophone–word pairs (e.g., LAIM–toad, TODE–lame). In both Set 3 and Set 4 the pseudohomophone that replaced a given word had the same word length and shared the same inital letter(s) and phoneme(s) with its source word.

Set 5: In each phonologically related pseudohomophone–word pair, the prime was replaced by its pseudohomograph to produce visually related, pseudohomograph–word pairs (e.g., TODS–toad, LARM–lame).

Set 6: In each phonologically unrelated pseudohomophone–word pair, the prime was replaced by its pseudohomograph to produce visually unrelated pseudohomograph–word pairs (e.g., LARM–toad, TODS–lame). In both Set 5 and Set 6 the pseudohomograph that replaced a given pseudohomophone shared in the same position all but one letter with its yoked pseudohomophone; hence, each pseudohomograph had the same index of visual similarity with its source word as its yoked pseudohomophone. With regard to the identity prime (and target), the pseudohomophone and its yoked pseudohomograph shared in the same position the same letters.

Set 7: In each identity quadruple, each priming word was replaced by a pseudoword to produce 48 pseudoword–word dedicated control quadruples (e.g., PESK–toad, RETH–lame). The dedicated pseudoword that replaced a given priming word had the same number of letters as the word, but none of its letters was shared in the same position with the target word, with its yoked pseudohomophone, or with its yoked pseudohomograph.

Set 8: Within each dedicated control quadruple, the mutual substitution of primes produced a new nondedicated control quadruple with two nondedicated pseudoword–word pairs (e.g., RETH–toad, PESK–lame). Sometimes (but rarely) the nondedicated pseudoword shared one letter with the target or the target's yoked pseudohomophone or yoked pseudohomograph.

Finally, a foil set of 36 unrelated word–word pairs was also created. The foil set was used to counter the development of biases such as making predictions about targets on the basis of the sound of the prime.

Design. Eight counterbalanced experimental lists were prepared for eight groups of subjects. Each subject saw 6 stimulus pairs of 16 different prime types (LF identity word, HF identity word, LF nonidentity word, HF nonidentity 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 dedicated pseudoword, HF dedicated pseudoword, LF nondedicated pseudoword, HF nondedicated pseudoword), providing for 96 different 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 36 unrelated word–word pairs to make a total of 132 stimulus pairs per session. The experimental sequence was preceded by a practice sequence of 24 stimulus pairs.

Procedure. The procedure of Experiment 4 was the same as that in Experiment 2 (SOA = 60 ms), and the procedure of Experiment 5 was the same as that in Experiment 3 (SOA = 250 ms).

Results and Discussion

Tables 4 and 5 summarize the results of the two experiments. An omnibus ANOVA of the kind first described in Experiment 1 was conducted, which involved the quasi variables of prime type and relatedness and the real variable of target frequency. As in Experiments 1–3, this ANOVA provided useful indicators of the interactions involving the frequency of the stimuli. The ANOVA revealed that, for Experiment 4, the main effect of target frequency (LF = 570 ms vs. HF = 560 ms) was significant by subjects but not by stimuli, F1(1, 47) = 30.53, $p < .001$, F2(1, 94) = 2.00, $p > .05$, and that there were no significant interactions involving frequency. In the error analysis, neither the effect of frequency (LF = 3.30% vs. HF = 3.04 %) nor any of its interactions were significant (*F*s < 1).

Similar results were found for Experiment 5: In the latency ANOVA, target frequency (LF = 554 ms vs. HF = 546 ms) was significant by subjects but not by stimuli, F1(1, 39) = 31.89, $p < .001$, F2(1, 94) = 1.87, $p > .05$, but there were no significant interactions involving frequency. In the error analysis, frequency (LF = 0.31% vs. HF = 0.73%) was insignificant as a main effect, F1(1, 39) = 2.36, $p > .05$, F2(1, 94) = 2.15, $p > .05$, and was involved in no interactions.

With respect to the planned comparisons of Experiment 4, the 26-ms difference between TODE–toad and LAIM–toad was significant, F1(1, 47) = 33.08, $p < .001$, F2(1, 94) = 21.57, $p < .001$, as was the 21-ms difference between TODS–toad and LARM–toad, F1(1, 47) = 24.20, $p < .001$, F2(1, 94) = 15.64, $p < .001$. Additionally, the 34-ms difference between TOAD–toad and LAME–toad was significant, F1(1, 47) = 68.08, $p < .001$, F2(1, 94) = 32.09, $p < .001$, and the 1-ms difference between PESK–toad and RETH–toad was insignificant (*F*s < 1).

The equality in Experiment 4 of TODE and its orthographic control TODS suggested by the planned comparisons was confirmed by the analyses of partial interactions: TODE–toad versus LAIM–toad (26 ms) and TODS–toad versus LARM–toad (21 ms) were insignificant (*F*s < 1). Relatedly, TODE–toad versus LAIM–toad (26 ms) and PESK–toad versus RETH–toad (1 ms) were significant, F1(1, 47) = 20.79, $p < .001$, F2(1, 94) = 13.08, $p < .001$, as were TODS–toad versus LARM–toad (21 ms) and PESK–toad versus RETH–toad (1 ms), F1(1, 47) = 14.47, $p < .001$, F2(1, 94) = 7.75, $p < .01$. At the same time, the possibility that there was a difference favoring TODE over TODS is suggested by the partial interactions involving the identity prime: TODE–toad versus LAIM–toad (26 ms) and TOAD–toad versus LAME–toad (34 ms) were not significant by either subjects or stimuli, F1(1, 47) = 2.35, $p > .05$, F2(1, 94) = 1.19, $p > .05$, whereas TODS–toad versus LARM–toad (21 ms) and TOAD–toad versus LAME–toad (34 ms) were significant by subjects, F1(1, 47) = 4.18, $p < .05$, and marginally significant by stimuli, F2(1, 94) = 3.37, $p < .07$.

With regard to frequency, the impression from Table 4 is that with HF words, TODS–toad produced more priming

Table 4

Mean Naming Latencies (In Milliseconds) and Percentage Error Rate, With the Corresponding Standard Deviations by Subjects and by Items for the "Related" and "Unrelated" Primes of Experiment 4

	"Related" primes								"Unrelated" primes							
	TOAD–toad		TODS–toad		TODE–toad		PESK–toad		LAME–toad		LARM–toad		LAIM–toad		RETH–toad	
Item Frequency	L	ER	L	ER	L	ER	L	ER	L	ER	L	ER	L	ER	L	ER
Low																
M	543	4.86	559	2.43	551	1.74	574	3.82	582	4.51	579	3.47	585	3.82	582	1.74
Subject *SD*	72	10.29	64	5.94	63	5.15	64	7.08	61	7.48	60	8.39	61	7.87	70	5.15
Item *SD*	55	8.39	47	6.87	41	5.15	43	8.59	52	9.56	49	6.84	48	10.45	53	5.15
High																
M	534	4.51	548	3.82	550	3.47	573	3.13	564	2.43	572	1.39	567	2.08	566	3.47
Subject *SD*	68	8.93	68	7.08	60	7.66	62	6.57	62	6.87	68	4.66	63	5.57	54	7.66
Item *SD*	48	7.48	52	7.87	46	8.39	51	7.42	51	5.94	52	4.66	49	7.39	34	7.66

Note. L = latency; ER = error rate.

Table 5

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

Item Frequency	"Related" primes								"Unrelated" primes							
	TOAD–toad		TODS–toad		TODE–toad		PESK–toad		LAME–toad		LARM–toad		LAIM–toad		RETH–toad	
	L	ER	L	ER	L	ER	L	ER	L	ER	L	ER	L	ER	L	ER
Low																
M	532	0.42	553	0.00	539	0.42	558	0.42	557	0.00	565	0.00	563	0.42	567	0.83
Subject *SD*	63	2.64	61	0.00	61	2.64	57	2.64	61	0.00	64	0.00	67	2.64	57	3.68
Item *SD*	46	2.89	48	0.00	45	2.89	38	2.89	43	0.00	43	0.00	50	2.89	40	4.04
High																
M	523	0.42	546	1.25	539	0.42	552	0.83	545	1.25	550	0.83	558	0.42	553	0.42
Subject *SD*	57	2.64	62	4.45	57	2.64	63	3.68	62	4.45	59	5.27	65	2.64	56	2.64
Item *SD*	49	2.89	52	4.89	39	2.89	48	4.04	42	6.40	35	4.04	48	2.89	39	2.89

Note. L = latency; ER = error rate.

relative to its control than did TODE–toad relative to its control (24 ms vs. 17 ms). This impression, however, was not supported statistically (the partial Prime Type × Relatedness interaction was insignificant [both *F*s < 1]). Another impression from Table 4, one that receives more substantial statistical support, is that pseudohomophone priming was stronger for LF targets than for HF targets (34 ms vs. 17 ms; Relatedness × Frequency interaction was significant by subjects, F1(1, 47) = 6.08, $p < .05$, but not by stimuli, F2(1, 94) = 2.60, $p > .05$).

Turning to Experiment 5, the planned comparisons revealed that the 22-ms difference between TODE–toad and LAIM–toad was significant, F1(1, 39) = 23.91, $p < .001$, F2(1, 94) = 20.04, $p < .001$, but the 8-ms difference between TODS–toad and LARM–toad was not, F1(1, 39) = 3.05, $p > .05$, F2(1, 94) = 1.61, $p > .05$. Additionally, the 23-ms difference between TOAD–toad and LAME–toad was significant, F1(1, 39) = 26.43, $p < .001$, F2(1, 94) = 25.13, $p < .001$, but the 5-ms difference between PESK–toad and RETH–toad was not, F1(1, 39) = 1.97, $p > .05$, F2(1, 94) = 1.06, $p > .05$.

That TODE was different in Experiment 5 from its orthographic control TODS was confirmed by the analysis of partial interactions: First, TODE–toad versus LAIM–toad (22 ms) and TODS–toad versus LARM–toad (8 ms) was significant, F1(1, 39) = 5.35, $p < .05$, F2(1, 94) = 4.32, $p < .05$. Second, TODE–toad versus LAIM–toad (22 ms) and TOAD–toad versus LAME–toad (23 ms) was not significant (both *F*s < 1), but TODS–toad versus LARM–toad (8 ms) and TOAD–toad versus LAME–toad (23 ms) was significant, F1(1, 39) = 7.50, $p < .01$, F2(1, 94) = 5.11, $p < .05$. Third, TODE–toad versus LAIM–toad (22 ms) and PESK–toad versus RETH–toad (5 ms) was significant, F1(1, 39) = 7.81, $p < .01$, F2(1, 94) = 4.73, $p < .05$, but TODS–toad versus LARM–toad (8 ms) and PESK–toad versus RETH–toad (5 ms) was not significant (both *F*s < 1). Another subanalysis, which directly compared the principal prime–target pairings, showed that both TOAD–toad and TODE–toad differed from TODS–toad: TOAD–toad differed by 22 ms, F1(1, 39) = 33.53, $p < .001$, F2(1, 94) = 17.60, $p < .001$, and TODE–toad differed by 11 ms, F1(1, 39) = 9.06, $p < .01$, F2(1, 94) = 5.41, $p < .05$.

Returning to frequency, the mean latencies in Table 5 suggest that although orthographic priming was insignificant overall, it might have occurred for LF words. The 12-ms difference in the LF case was significant by subjects but not by stimuli, F1(1, 39) = 7.18, $p < .01$, F2(1, 47) = 3.57, $p > .05$; the 4-ms difference in the HF case was significant by neither subjects nor stimuli (*F*s < 1). Relatedly, inspection of Table 5 suggests that phonological priming occurred reliably for both frequency levels (LF = 24 ms, HF = 19 ms)—for the 24-ms difference: F1(1, 39) = 24.24, $p < .001$, F2(1, 47) = 11.91, $p < .001$; for the 19-ms difference: F1(1, 39) = 8.49, $p < .01$, F2(1, 47) = 8.14, $p < .01$.

Experiments 4 and 5 were directed at the pseudohomophone test. Specifically, can a word be primed by a nonword that is homophonic with the word? The question is posed in the context of controls that assess whether the pseudohomophone's contribution is actually due to its orthographic structure rather than to its phonological structure. As Humphreys et al. (1982) remarked: "If phonological information is automatically activated via a nonlexical route, a pseudohomophone priming effect should occur. That is, target recognition should be better in the pseudohomophone condition than in the graphemic control condition. Alternatively, if only the lexical route is involved, there should be no difference between the two conditions" (p. 581). The simple summary of the two experiments is that pseudohomophones passed the test with flying colors in Experiment 5 and failed the test (with one small reservation) in Experiment 4. In that Experiment 4 used a brief SOA along with the forward mask for the prime, its outcome may be considered as replicating the failed pseudohomophone test that Humphreys et al. (1987) conducted.

The success of Experiment 5 suggests that when a word target lags a homophonically related nonword prime by 250 ms, the phonological similarity between them can reduce the latency for naming the target. Because homophonic similarity was limited to 15% of the stimuli and to only

7.5% if the identity prime conditions are excluded, it would seem that the success of Experiment 5 cannot be attributed to a general strategy of using phonological information to anticipate the target. Rather, on those trials on which TODE–toad pairs occurred, the phonology of TODE must have nonstrategically (i.e., automatically) affected the processing of toad. The assumption of dual-route theory that nonwords are processed by the nonlexical route leads to the interpretation of Experiment 5's results as evidence for an automatic nonlexical basis of phonological priming. By implication, the priming by homophonic words observed in Experiments 1, 2, and 3 was similarly based in an automatic nonlexical process. That is, the pseudohomophones of Experiment 5 and the homophones of Experiments 1–3 engaged essentially the same process. As noted in the introduction, the core argument of dual-route theory that words and nonwords are processed by different procedures has been seriously questioned by recent experiments that have revealed a commonality between words and pseudohomophones in their sensitivity to attentional, frequency, and associative manipulations (Lukatela & Turvey, 1993; see also Van Orden et al., 1992).

Experiment 5 had an additional feature of significance that needs highlighting. When evaluated relative to their respective controls, the effects of pseudohomophone primes and identity primes were not statistically different. A reduced difference between phonological and identity priming (significant only by subjects) was evident in the homophone manipulations of Experiment 3. Together, the results of Experiment 5 and Experiment 3 suggest that stimuli that are matched only in phonology can exhibit a degree of priming that is comparable to that exhibited by stimuli that are matched perfectly in phonology, orthography, and meaning. The fact that orthographic priming was nonsignificant in these two experiments leads to the important understanding that phonological and identity primes may differ only on the lexical dimension. This notion is expressed most clearly with the data of Experiment 5: Whatever advantage identity primes had over pseudohomophone primes, that advantage had to lie in the singular fact that identity primes have a lexical representation that is lacking in the case of pseudohomophone primes.

The failure to satisfy the conditions of the pseudohomophone test in Experiment 4 seems to be due simply to the significant difference between TODS–toad and LARM–toad. The effect of TODE relative to its control was approximately the same in Experiments 4 and 5 (26 ms and 22 ms, respectively, and comparable to the 28-, 23-, and 20-ms effects of TOWED relative to its control in Experiments 1, 2, and 3, respectively). In contrast, the effect of TODS relative to its control was substantially different in Experiments 4 and 5 (21 ms and 8 ms, respectively). The marked presence of orthographic priming in Experiment 4 must also be contrasted with its absence under the identical SOA and masked prime conditions of Experiment 2. Where Experiments 4 and 2 differed was in the lexical status of the orthographic prime—the nonword TODS versus the word TOLD, respectively. In terms of the hypothesis that orthographic priming is a priming of orthographic-to-phonological connections, it would have to be argued that the target word toad benefited in Experiment 4 from the overlap between its specific encoding pattern and that of TODS but did not benefit in Experiment 2 from the overlap between its specific encoding pattern and that of TOLD. Given that the presentation conditions (SOA and masking) were identical in the two experiments, adherence to this *primed connections* interpretation of orthographic priming requires that the specific encoding pattern for TODS persisted beyond that for TOLD. Perhaps the encoding activity within the orthographic–phonological matrix of weighted connections stabilizes more slowly (and thereby returns to the preactivation state at a later moment in time) when the stimulus is a nonword as opposed to a word. Perfetti and Bell (1991) suggested that the general buildup of information about nonwords may be slower than that for words because of the absence of lexical-level feedback to sublexical units.

The important methodological point of the preceding discussion is that although phonological priming and orthographic priming could have different origins (as suggested by Experiments 1–3), and could co-occur in any given experiment, a strong presence of orthographic priming would go against a successful outcome of the pseudohomophone test. The null hypothesis would be confirmed even though significant phonological priming occurred independent of orthographic priming. It seems that to demonstrate phonological priming by pseudohomophones at very brief SOAs, a further experimental innovation is needed that undercuts the conditions that give rise to orthographic priming. What is needed is some way to terminate the specific encoding pattern associated with the nonword prime at short prime–target temporal separations. This goal could be achieved, in principle, by inserting a patterned mask between the prime and the target.

Experiment 6

Experiment 6 replicated Experiment 4 in the stimuli used and in that an SOA of 60 ms was used. It differed from Experiment 4 in that it introduceda pattern mask between prime and target. The purpose of this additional mask was to perturb the conditions thought to produce orthographic priming. If the target uses (traces of) the encoding pattern of the prime, then the intervening mask might restrict that usage.

Method

Subjects. The participants in the experiment were 48 undergraduates at the University of Connecticut. Each subject was assigned to one of eight groups, yielding six subjects per group. None of the subjects had participated in any of the previous experiments.

Materials and design. These were the same as in Experiment 4.

Procedure. The procedure repeated that of Experiment 4 except for a four-field presentation with the following sequence of stimuli: a visual mask for 500 ms, the prime for 30 ms, another visual mask for 30 ms, and the target for 400 ms. Consequently, the SOA was 60 ms.

Table 6

Mean Naming Latencies (In Milliseconds) and Percentage Error Rate, With the Corresponding Standard Deviations by Subjects and by Items for the "Related" and "Unrelated" Primes of Experiment 6

	"Related" primes								"Unrelated" primes							
	TOAD–toad		TODS–toad		TODE–toad		PESK–toad		LAME–toad		LARM–toad		LAIM–toad		RETH–toad	
Item frequency	L	ER	L	ER	L	ER	L	ER	L	ER	L	ER	L	ER	L	ER
Low																
M	510	0.35	528	1.04	518	0.69	538	0.35	542	0.35	546	0.00	541	0.69	537	0.35
Subject *SD*	55	2.41	52	4.08	48	3.37	49	2.41	51	2.41	58	0.00	53	3.37	44	2.41
Item *SD*	45	2.41	33	4.08	37	2.98	37	2.41	44	2.41	44	0.00	45	3.13	36	2.41
High																
M	496	2.08	518	1.04	509	0.00	526	0.69	524	0.35	525	0.00	532	1.04	531	1.04
Subject *SD*	55	5.57	50	4.08	46	0.00	48	3.37	44	2.41	51	0.00	52	4.08	49	4.08
Item *SD*	41	5.78	33	4.37	32	0.00	40	4.81	37	2.89	44	0.00	46	4.37	35	4.37

Note. L = latency; ER = error rate.

Results and Discussion

The results are summarized in Table 6. The omnibus ANOVA revealed that target frequency (LF = 533 ms vs. HF = 520 ms) was significant by subjects and by stimuli, F1(1, 47) = 74.37, $p < .001$, F2(1, 94) = 5.11, $p < .05$. There were, however, no significant interactions involving frequency. In the error analysis, the main effect of frequency (LF = 0.48% vs. HF = 0.78%) was insignificant, F1(1, 47) = 1.85, $p > .05$, F2(1, 94) = 1.93, $p > .05$, as were its interactions.

Planned comparisons revealed that the 23-ms difference between TODE–toad and LAIM–toad was significant, F1(1, 47) = 53.49, $p < .001$, F2(1, 94) = 27.61, $p < .001$, as was the 12-ms difference between TODS–toad and LARM–toad, F1(1, 47) = 10.92, $p < .01$, F2(1, 94) = 10.10, $p < .01$. The respective min F′'s for these two contrasts were, respectively, min F′ (1, 141) = 18.21, $p < .001$, and min F′ (1, 128) = 5.25, $p < .03$. Additionally, the 30-ms difference between TOAD–toad and LAME–toad was significant, F1(1, 47) = 59.30, $p < .001$, F2(1, 94) = 51.68, $p < .001$. The 2- ms difference between PESK–toad and RETH–toad was insignificant (*F*s < 1).

Although TODE–toad and TODS–toad were both significantly different from their respective controls, the min F′ analysis and the following examination of partial interactions suggest that TODE–toad was different in larger degree: First, the partial interaction involving TODE–toad versus LAIM–toad (23 ms) and TODS–toad versus LARM–toad (12 ms) reached significance by subjects, F1(1, 47) = 7.21, $p < .01$, F2(1, 94) = 2.07, $p > .05$. Second, the partial interaction involving TODE–toad versus LAIM–toad (23 ms) and TOAD–toad versus LAME–toad (30 ms) was insignificant, F1(1, 47) = 2.32, $p > .05$, F2(1, 94) = 1.05, $p > .05$, min F′ (1, 141) < 1, whereas that involving TODS–toad versus LARM–toad (12 ms) and TOAD–toad versus LAME–toad (30 ms) was significant by both subjects and stimuli, F1(1, 47) = 13.03, $p < .001$, F2(1, 94) = 6.60, $p < .01$, min F′ (1, 141) = 4.38, $p < .05$. Third, the significance attained by the partial interaction of TODE–toad versus LAIM–toad (23 ms) and PESK–toad versus RETH–toad (2 ms)—F1(1, 47) = 25.55, $p < .001$, F2(1, 94) = 11.68, $p < .001$—exceeded that attained by the partial interaction of TODS–toad versus LARM–toad (12 ms) and PESK–toad versus RETH–toad (2 ms)—F1(1, 47) = 4.34, $p < .05$, F2(1, 94) = 3.95, $p < .05$. The corresponding min F′ analyses for the preceding comparisons were, respectively, min F′ (1, 141) = 8.02, $p < .01$, and min F′ (1, 129) = 2.07, $p > .05$. The evidence from the planned comparisons and partial interactions for a superiority of TODE over TODS is stengthened by the outcome of a subanalysis that shows the 9 ms distinguishing TODE–toad from TODS–toad to be significant, F1(1, 47) = 9.06, $p < .01$, F2(1, 94) = 3.93, $p < .05$.

One can see from Table 6 that TODS–toad-type pairings, relative to their controls, produced a larger priming difference (18 ms) when the targets were LF words than when the targets were HF words (7 ms). Indeed, for LF targets, the 18-ms orthographic priming effect was significant, F1(1, 47) = 7.67, $p < .01$, F2(1, 47) = 9.15, $p < .01$; for HF targets the 7-ms orthographic priming effect was insignificant, F1(1, 47) = 1.85, $p > .05$, F2(1, 47) = 1.99, $p > .05$. In contrast, inspection of Table 6 suggests that phonological priming was equally reliable for both LF (23 ms) and HF (23 ms) target words, F1(1, 47) = 26.91, $p < .001$, F2(1, 47) = 14.61, $p < .001$, and F1(1, 47) = 15.74, $p < .001$, F2(1, 47) = 13.15, $p < .001$, respectively.

In sum, the overall pattern of results allows the conclusion that the pseudohomophone test was satisfied. There was, in the present experiment, an effect of TODE on toad over and above the effect of TODS on toad. Presumably, the success of the present experiment in comparison with the failure of its methodological mate, Experiment 4, is because of the inclusion of a pattern mask between the prime and target. There were two major hints that the conditions of the present experiment were psychologically distinct from those of Experiment 4. Whereas in Experiment 4 the total error rate was 3.2%, and the rate of intrusion errors was 2%, in the present experiment the total error rate was below 1%;

and whereas in Experiment 4 the overall mean latency was 565 ms, in the present experiment it was 522 ms. Another noteworthy aspect of Experiment 6 was that although the exposure time of the priming stimulus was only 30 ms (compared with 60 ms in Experiment 4), the majority of subjects reported, during debriefing, a clear view of the prime and an ability to identify it.

The reading given to the results of Experiment 6 is that the prime and target produced two separate perceptual events (Humphreys, Besner, & Quinlan, 1988), with a reduction in the possibility for orthographic priming (and, relatedly, an enhancement of the experimental capability to reveal phonological priming by pseudohomophones). The present interpretation of orthographic priming is that some of the orthographic processing units used by the target are preactivated by the prime. According to this interpretation, the effect of the intervening mask was to lessen the possibility that the specific orthographic processing units encoding the prime were still active during the encoding of the target. The apparent irrelevance of the intervening mask to phonological priming is consistent with the hypothesis that phonological priming is linked to states at a level of processing beyond the input encoding stage (specifically, activity in the phonological processing units is initiated by the orthographic units and enhanced by word units).

The results of Experiment 6 encourage a further comment. As noted several times above, a common claim is that orthographic or form priming is conditioned on an efficient masking of primes, which makes the primes unidentified by most subjects. The outcomes of Experiment 6 and Experiment 4 challenge this claim. In both experiments, orthographic priming was in evidence even though the majority of subjects reported that they were aware of the primes.

Experiment 7

A natural extension of the method introduced in Experiment 6 is to the time domain at which primes become unidentifiable. Pilot research revealed that in the sequence pattern mask–prime–pattern mask–target, subjects fail to be aware of the prime's presence when the durations of the prime and its subsequent mask are reduced to 18 ms—one refreshing cycle on the monitor of the computer. Experiment 7 replicated Experiment 6 in all respects except for the use of a prime–target SOA of 36 ms filled with an 18-ms prime and an 18-ms pattern mask. We hoped that these conditions would continue to provide evidence favoring phonological priming by pseudohomophones. Opposing a successful pseudohomophone test, however, is the likelihood of diminished priming effects under the severe temporal conditions of the experiment. A lexical decision experiment by Parpaillon (reported by Grainger, 1992) involving masked priming and an SOA of 16 ms produced orthographic effects of no more than 5 ms; an experiment by Perfetti and Bell (1991) in which an identification task and backward masking were used failed to find phonological involvement earlier than 35 ms; and Ferrand and Grainger (1992), using masked primes and lexical decision, found no evidence for phonology at 32 ms. In consequence, we anticipated that the criteria for deciding on the success of the pseudohomophone test would have to be less demanding than in the preceding experiments.

Method

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

Materials and design. These were the same as in Experiment 6.

Procedure. The procedure of Experiment 6 was replicated, except that the four-field presentation used the following parameters: a pattern mask for 500 ms, the prime for 18 ms, another pattern mask for 18 ms, and the target for 400 ms. Consequently, the nominal SOA was 36 ms.

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

	"Related" primes								"Unrelated" primes							
	TOAD–toad		TODS–toad		TODE–toad		PESK–toad		LAME–toad		LARM–toad		LAIM–toad		RETH–toad	
Item Frequency	L	ER	L	ER	L	ER	L	ER	L	ER	L	ER	L	ER	L	ER
Low																
M	527	0.26	536	0.00	530	0.26	542	0.52	545	0.26	544	0.26	547	0.78	541	0.52
Subject *SD*	55	2.08	52	0.00	45	2.08	49	2.92	52	2.08	46	2.08	46	3.55	50	2.92
Item *SD*	39	1.60	40	0.00	36	1.60	43	2.98	48	1.60	37	1.60	41	3.34	35	2.98
High																
M	515	0.52	529	1.04	525	1.30	531	1.30	536	1.30	534	0.52	532	1.04	534	0.26
Subject *SD*	48	4.17	55	4.07	52	4.51	40	4.51	50	4.51	47	2.92	50	5.04	43	2.08
Item *SD*	38	2.52	45	3.40	43	4.35	32	3.84	43	4.00	42	2.39	39	3.21	40	1.60

Note. L = latency; ER = error rate.

Results and Discussion

Table 7 summarizes the results. The omnibus ANOVA found target frequency (LF = 539 ms vs. HF = 529 ms) to be significant only by subjects, F1(1, 63) = 49.10, $p < .001$, F2(1, 94) = 2.86, $p > .05$, and found no interactions involving frequency (*F*s < 1). In the error analysis, frequency (LF = 0.36% vs. HF = 0.91%) was significant as a main effect, F1(1, 63) = 5.87, $p < .05$, F2(1, 94) = 4.61, $p < .05$, but again there were no significant interactions involving frequency.

Turning to the planned comparisons, the 12-ms difference between TODE–toad and LAIM–toad was significant by both analyses, F1(1, 63) = 15.67, $p < .001$, F2(1, 94) = 7.47, $p < .01$, whereas the 7-ms difference between TODS–toad and LARM–toad was significant by only one F1(1, 63) = 7.07, $p < .01$, F2(1, 94) = 3.12, $p > .05$. Additionally, the 20-ms difference between TOAD–toad and LAME–toad was significant, F1(1, 63) = 33.92, $p < .001$, F2(1, 94) = 24.99, $p < .001$; the 2-ms difference between PESK–toad and RETH–toad was not (*F*s < 1). Importantly, the basic pattern of contrasts was replicated under the severe temporal restraints of the present experiment, suggesting that its outcomes were only quantitatively different from those of previous experiments.

The partial interactions provided support for a priming difference favoring TODE. Although the partial interaction between TODE–toad versus LAIM–toad (12 ms) and TODS–toad versus LARM–toad (7 ms) was insignificant, F1(1, 63) = 1.68, $p > .05$, F2(1, 94) < 1; the two primes were not equally different from the identity prime: TODE–toad versus LAIM–toad (12 ms) and TOAD–toad versus LAME–toad (20 ms) were insignificant, F1(1, 63) = 3.90, $p > .05$, F2(1, 94) = 2.80, $p > .05$; but TODS–toad versus LARM–toad (7 ms) and TOAD–toad versus LAME–toad (20 ms) were significant by subjects, F1(1, 63) = 8.90, $p < .01$, and was marginally significant by stimuli, F2(1, 94) = 3.64, $p < .06$. Also of importance were the partial interactions with the pseudowords. These again suggested that the effect of TODE exceeded that of TODS: TODE–toad versus LAIM–toad (12 ms) and PESK–toad versus RETH–toad (2 ms) were significant by subjects, F1(1, 63) = 6.95, $p < .01$, but not by stimuli, F2(1, 94) = 2.12, $p > .05$, whereas TODS–toad versus LARM–toad (7 ms) and PESK–toad versus RETH–toad (2 ms) were significant by neither, F1(1, 63) = 2.27, $p > .05$, F2(1, 94) < 1. Finally, subanalyses with the pseudoword controls revealed that TODE–toad and PESK–toad differed significantly, F1(1, 63) = 10.82, $p < .01$, F2(1, 94) = 4.32, $p < .05$, but TODS–toad and PESK–toad did not, F1(1, 63) = 2.62, $p > .05$, F2(1, 94) = 1.53, $p > .05$.

Orthographic and phonological priming seem to have been more efficient with LF targets than with HF targets (see Table 7). An analysis of the interaction of relatedness and frequency restricted to the orthographic and phonological conditions yielded F1(1, 63) = 3.39, $p < .07$, F2(1, 94) = 4.41, $p < .05$. This interaction was mainly due to the contrast within the phonological priming condition. The phonological priming effect with LF and HF targets was 17 ms and 7 ms, respectively; the 17-ms difference was significant, F1(1, 63) = 23.84, $p < .001$, F2(1, 47) = 10.00, $p < .01$; the 7-ms difference was not, F1(1, 63) = 1.67, $p > .05$, F2 < 1. In the orthographic priming condition, the priming effect with LF and HF targets was 9 ms and 5 ms, respectively; the 9-ms difference was significant only by subjects, F1(1, 63) = 10.02, $p < .01$, F2(1, 47) = 2.23, $p > .05$; the 5-ms difference was not significant by either analysis, F1(1, 63) = 1.48, $p > .05$, F2 < 1.

Given the reduced viewing conditions and the consequent reduction in priming magnitudes (identity priming in the present experiment was about 10 ms less than in the preceding experiments), the assessment of the overall pattern of results has to be that the pseudohomophone test was once again passed. Of particular significance to this conclusion is the fact that, by the basic measures, phonological priming occurred, min F′ (1, 153) = 5.06, $p < .03$ (TODE–toad vs. LAIM–toad), but orthographic priming did not, min F′ (1, 153) = 2.16, $p > .05$ (TODS–toad vs. LARM–toad). There was an effect of pseudohomophone primes over and above any effect attributable to their orthographic structure. Given that primes in the present experiment could not be identified, whereas those in Experiment 6 could be identified, it would seem that prime identifiability is not a factor in phonological priming by pseudohomophones. This conclusion echoes that made following the homophone priming experiments, Experiments 1–3. Additionally, it must be concluded, given the temporal conditions of the present experiment, that this phonological priming by pseudohomophones occurs at extremely fine time scales, highlighting the understanding that phonological codes are automatic, early, and primary in the processes of visual word recognition (e.g., Carello, Turvey, & Lukatela, 1992; Lukatela & Turvey, 1994; Perfetti, Zhang, & Berent, 1992; Van Orden et al., 1990). Reiterating the point of the pseudohomophone test (Humphreys et al., 1982), if pseudohomophones prime more than their orthographic (and other) controls, then it must be the case, by dual-route theory, that phonological priming occurs automatically over the nonlexical route given that the nonlexical route is the only one available for the processing of nonwords.

General Discussion

Seven experiments have been reported that have examined case-independent priming effects using three- and four-field masking paradigms similar to those first introduced by Evett and Humphreys (1981) to study such effects. The priming of major concern in the seven experiments has been that based on the phonological identity of a priming stimulus and a subsequent target stimulus in the absence of orthographic identity. In Experiments 1–3, word primes such as TOWED were compared with word primes such as TOLD in respect to their effects on the latency of naming targets such as toad. At issue was whether TOWED–toad exhibited greater priming than TOLD–toad. Experiment 1 provided evidence that priming occurred with both phonological and orthographic primes even when neither could be identified because of masking. Experiment 1 also showed that TOWED–toad primed more than TOLD–toad, implicating a priming effect that was based on how a prime sounded rather than how it looked. Experiments 2 and 3 provided important extensions and elaborations of these effects due to TOWED and TOLD. With either marginally or clearly identifiable primes, TOLD–toad no longer exhibited any special advantages over the baseline condition of GAVE–toad. In contrast, these same circumstances of prime identifiability—correlated with prime–target SOAs of 60 and 250 ms, respectively—were circumstances in which TOWED–toad was associated with significantly shorter latencies than its baseline condition, PLASM–toad. The upshot of Experiments 1–3 is that phonological priming by homophones is distinct from orthographic priming. Apparently, phonological priming is independent of prime identifiability and is both prominent and relatively unchanging across most of the range of the theoretically important time scale of SOA $\leq$ 250 ms.

Experiments 4–7 were directed at the issue of whether TODE–toad exhibited greater priming than TODS–toad. This comparison was referred to as the *pseudohomophone test*, in deference to the important studies of Humphreys at al. (1982), which pinpointed the success of pseudohomophonic priming as crucial to the claim that assembled phonology can play a key role in visual word recognition. Experiment 4 replicated, with a different task and with different stimuli, the equality in priming between a pseudohomophone and its orthographic control reported by Humphreys et al. (1982). Expressed simply, Experiment 4 failed the pseudohomophone test: Phonological priming was not greater than orthographic priming, suggesting—by the reasoning from classical dual-route theory—no (automatic) phonology over and above addressed phonology. The remaining experiments, 5–7, however, passed the test and did so either as a consequence of the expansion of SOA (from the 60-ms value of Experiment 4 to the 250-ms value of Experiment 5) or as a consequence of the introduction of a processing discontinuity between pseudohomophone and target through the procedure of interposing a pattern mask (Experiments 6 and 7). These two manipulations brought about a reduction in orthographic priming but left relatively invariant the magnitude of phonological priming. The implications of Experiments 4–7 are that phonological priming by pseudohomophones parallels that by homophones. That is to say, it is independent of prime identifiability and is both prominent and relatively unchanging across most of the range of the theoretically important time scale of SOA $\leq$ 250 ms.

For neither homophones nor pseudohomophones was there a systematic dependency of the observed priming effects on the frequency of the stimuli. There were, however, frequency effects. Orthographic priming was greater for LF targets than for HF targets in Experiment 1 but not in Experiment 2. In contrast, phonological priming in Experiments 1 and 2 was equally reliable with targets of both frequency levels. In Experiment 4, pseudohomophone priming was stronger for LF targets than for HF targets; in Experiment 5 the priming was not distinguished by target frequency. Only LF targets were primed orthographically in Experiment 6, whereas phonological priming by pseudohomophones occurred equally with both LF and HF targets. Finally, under the briefest presentation conditions of Experiment 7, priming by pseudohomophones was limited to LF targets.

The most important conclusion to be drawn from the present research is that the assessment of phonological coding by Humphreys et al. (1982) now seems unwarranted. They argued that the successful priming by homophones must have been due to automatic addressed (lexical) phonology and that the unsuccessful priming by pseudohomophones indicated that an assembled (nonlexical) phonology was, in all likelihood, not a component of skilled word recognition. If such a component did exist, it was strategic (rather than automatic) and slow relative to addressed phonology. The present results, to the contrary, point to a dominant role for a fast-acting, automatic, assembled phonology.

Allied to Humphreys et al.'s (1982) negative assessment of assembled phonology was the promotion of abstract graphemic features and abstract graphemic processing units as the underpinning for the lexical mechanism that assigns names to letter strings (Evett & Humphreys, 1981). To the extent that the hypothesis of abstract graphemes is coupled with the absence of evidence for a true phonological priming effect (and, thereby, the absence of evidence for assembled phonology and phonological processing units), the present results suggest that this hypothesis is unwarranted. A better hypothesis, it seems, is that variants of a letter in English are functionally equivalent because they map to an invariant configuration of phonological features. An emphasis on a matrix of weighted connections mapping a multidimensional orthographic space to a multidimensional phonologic space brings with it an interpretation of orthographic priming as related to the specific encodings (connections) leading to particular phonological patterns and phonological priming as related to the particular active phonological patterns themselves. Meyer, Schvaneveldt, and Ruddy (1974) suggested an encoding-bias hypothesis to address orthographic and phonological priming, and the present arguments favor a resurrection of this hypothesis in a form tailored to contemporary (network) interpretations of the mechanisms of word recognition.

The particularly compelling demonstrations of phonological priming by identifiable homophones and pseudohomophones at SOA = 250 ms in Experiments 3 and 5, respectively, stand in sharp contrast to the failure to find consistent phonological priming in English when the presentations of rhymes and targets are prolonged (meaning that the SOAs are long). In the original investigation of rhyme priming, in which lexical decision was used, facilitation was found for BRIBE–TRIBE pairs, and inhibition was found for BREAK–FREAK pairs (Meyer et al., 1974). This pattern of results, which suggested the encoding-bias hypothesis to Meyer et al. (1974), was not upheld by further investigations. Orthographically illegal nonword stimuli that required a "no" response eliminated the BREAK–FREAK effect (Hanson & Fowler, 1987; Schulman, Hornak, & Sanders, 1978) as did a delay of 250 ms between prime and target (Hillinger, 1980), suggesting different principles behind the effects of phonological similarity (BRIBE–TRIBE) and phonological dissimilarity (BREAK–FREAK). Hillinger's (1980) dismissal of the BREAK–FREAK effect was accompanied by demonstrations of rhyme priming for both orthographically similar (LATE–MATE) and dissimilar (EIGHT–MATE) stimuli and for rhymes received by ear or by eye. Attempts at replicating Hillinger's (1980) results have not been successful, however (Peter, Lukatela, & Turvey, 1990, for naming; Martin & Jensen, 1988, for lexical decision). The failure led Martin and Jensen to suggest that either (a) the connections among lexical entries do not occur on the basis of phonological similarity, or (b) assembled phonology does not contribute to visual word recognition.

The preceding suggestions are rendered moot by unequivocal demonstrations (numbering 14 experiments) of rhyme priming in Serbo-Croatian—research that is additionally important because of its disclosure of the special complexities of priming based on partially overlapping phonology. Naming latencies to Serbo-Croatian word and pseudoword targets are facilitated to the same degree by phonologically similar primes, whether they are graphemically similar or dissimilar and whether they are words or nonwords (Lukatela et al., 1990a; Lukatela & Turvey, 1990a). In contrast, for lexical decision, the direction (positive or negative) of the phonological similarity effect depends on target frequency (see also Colombo, 1986, for a similar result in Italian), whether the prime is a word or a nonword, whether the target is a word or a nonword, and the ordinal position of the distinguishing phoneme (Lukatela et al., 1990a, 1990b; Lukatela & Turvey, 1990a). When prime and target are true rhymes, that is, when they are distinguished only by the initial phoneme(s), then the priming in lexical decision is positive; when they are distinguished by the middle phoneme(s), then the priming is negative (Lukatela & Turvey, 1990a). In respect to the fit of experimental tasks to models of word perception, the Serbo-Croatian results indicate that phonological similarity effects are based on the states of phonological processing units in the naming task and on the states of the higher, word processing units in the lexical decision task (Lukatela & Turvey, 1990a). One apparent source of difference between the two classes of effects is a principle in operation at the word unit level by which active units receive inhibition from other active units in proportion to their frequency (in consequence, lexical decisions are slowed on HF targets that have been preactivated by phonologically similar primes).

The results of Experiments 3 and 5 of the present article, when considered jointly, conform to the pattern observed in Serbo-Croatian in that priming of naming was of the same magnitude for word and nonword primes. The primes of Experiments 3 and 5 shared completely the phonology of their targets and were, therefore, unlike the rhymes in failed evaluations of phonological priming in English and were unlike the primes identified above in successful evaluations of phonological priming in Serbo-Croatian. Partial phonological overlap seems to introduce its own peculiarities, which are apparently sufficient to nullify phonological priming in English experiments but not in Serbo-Croatian experiments.

Of potential significance to understanding the rhyme-versus-homophone contrast and the English-versus-Serbo-Croatian contrast is the simple fact that, in English, but not in Serbo-Croatian, different spellings can lead to the same phonology but to different meanings. In the course of becoming skilled and fluent, an English reader must develop, of necessity, a mechanism that checks the known spelling of a retrieved word against its present spelling[7]. That is, the skilled English reader must avail him- or herself of an automatic spell-checker. Given a word such as TOWED, the resultant phonological coding will activate the words *towed* and *toad* (among others) in the internal lexicon (as shown in the experiments of Lesch & Pollatsek, 1993; Lukatela et al., 1993; Lukatela & Turvey, 1991, 1993, 1994). A spelling check[8]—computable once the addressed spelling has been made available by the phonologically driven lexical access—reveals the misfit of *toad* and suppresses it (Lukatela & Turvey, 1994). The spelling check and subsequent suppression of active neighbors is suggested in part by the empirically observed absence of homophonic associative priming and presence of pseudohomophonic associative priming at longer SOAs ($\geq$ 250 ms) (Lukatela & Turvey, 1994). A positive spelling check on the prime in the case of TOWED–frog should lead to a suppression of the representation of *toad* and to a a decline in the preactivation of *frog* relative to the case of TOAD–frog. In contrast, a negative spelling check in the case of TODE–frog (nonwords have no addressed spelling) will mean that there is no induced suppression of *toad* and that the level of preactivation of *frog* continues to be equal to that in the case of TOAD–frog.

The differences in phonological priming noted above may well turn on the spelling check and its different degrees of implementation in English and Serbo-Croatian. Consider English first. In the case of TOWED–toad, the matrix of orthographic–phonological connections will produce a close approximation to the pattern /toad/ in the phonological processing units. In turn, /toad/ will activate *towed* and *toad* (again, among other phonological neighbors) in the internal lexicon and, in turn, the active lexical representations of *towed* and *toad* will feed back to the lower phonological

---

[7] It is at this phase in the word recognition process that a notion akin to the abstract graphemic feature of Evett and Humphreys (1981) seems required. The addressed spelling must be expressed in very general terms that are capable of accommodating any variant that might be registered at the orthographic processing level. Whether the constituents of an addressed spelling are in fact close to actual letters is open to debate, however. In contemporary approaches to complex systems and their achievements, "letter" would be a higher-order state that arises from the competition and cooperation among many components (at possibly several grain sizes), none of which need be like letters or graphemic features.

[8] Because the essential role of the spelling check is to pronouncedly reduce the effects of activated representations other than those that conform to the spelling of the stimulus, it is functionally analogous to the notion of intersection (Chappell & Humphreys, 1994; Wiles & Humphreys, 1993; Wiles, Humphreys, Bain, & Dennis, 1991). Intersection is considered a computational primitive of significance to modeling in a large number of paradigms (Chappell & Humphreys, 1994).

level, sharpening the phonological representation. With sufficient time between prime and target, the spelling check will eliminate *toad* as a lexical candidate. The target toad, however, can still benefit from TOWED. In both bottom-up and top-down processing, TOWED supports the relevant phonology /toad/. A similar account can be given of TODE–toad, the only difference being that, in the absence of an addressed spelling for TODE, the spelling check will fail, and both *towed* and *toad* will continue to be active and to sharpen, by means of feedback, the phonological pattern. The foregoing suggests that phonological priming at longer SOAs may be superior for pseudohomophones. It was the case in Experiment 5, more so than in Experiment 3, that phonological priming matched identity priming.

An essential change in the preceding account occurs when the prime is a rhyme, for example, LOAD–toad. To begin with, activation of *toad* by the phonological code (/load/) will be less than by /toad/. Second, the spelling check on the prime and eventual suppression of *toad* leaves *load* as the lexical representation responsible for sharpening the phonological code. That is, in the case of LOAD–toad, the phonological code /toad/ receives less support from initial activity in the orthographic–phonological network, and from subsequent activity in the lexicon, than in the cases of TOWED–toad and TODE–toad. Indeed, a common phonology with the exception of an initial phoneme (/load/ vs. /toad/) may hinder, not aid, the naming of toad. To make these latter ideas clear, it is necessary to draw the contrast with a control condition, for example, MINK–toad. Although /mink/ and *mink* do not support the phonology for toad, they do not, at the same time, have the potential to interfere with the phonology for toad. Roughly speaking, and borrowing the language of dynamics, the phonological (and lexical) attractors for toad and MINK are nonoverlapping. The encoding of toad places it into a phonological basin of attraction that is at some remove from the basin of /mink/.

As implied above, the spelling check is not of absolute necessity for the fluent visual recognition of Serbo-Croatian words. Accordingly, the skilled Serbo-Croatian reader is less inclined to develop the same kind of mechanism as that postulated for the skilled English reader. Assume, for simplicity, no spelling check. Then, in the case of primes that merely rhyme, such as the Serbo-Croatian equivalent of LOAD–toad, the partially activated *toad* (and all other phonological neighbors of *load*) will remain active. Where in English the target's phonology /toad/ would be strongly contested by /load/ for the initial phoneme, in Serbo-Croatian, /toad/ would find top-down support that could counteract load's selective influence on the initial phoneme. Although it provides only an approximate response to the differential data sets on rhyme priming in English and Serbo-Croatian, the preceding argument highlights how word recognition may abide by universal principles but still exhibit marked contrasts in experimental outcomes across orthographies. The features that distinguish orthographies may require specialized processing mechanisms[9]. For the present case in point, English orthography mandates a spelling check; Serbo-Croatian orthography does not.

Returning to the main conclusion of the present article and its predecessor (Lukatela & Turvey, 1994): Phonology dominates the initial phases of visual word processing. As is well appreciated by students of the reading process, the role ascribed to phonology in theories of word recognition has covered the gamut from irrelevant to primary. A repeatedly voiced view (within both the classical symbol-manipulating perspective and the contemporary subsymbolic perspective) is that a phonological contribution to word recognition can be excluded from theoretical considerations without loss of generality (e.g., Aaronson & Ferres, 1983; Hinton & Shallice, 1991; Kolers, 1970; McClelland & Rumelhart, 1981; Paap, Newsome, McDonald, & Schvaneveldt, 1982; Smith, 1971). The most explicit proposal along such lines was that of Humphreys and Evett (1985), whose review of the literature suggested to them that there was no substantial evidence for an independent phonological route and that all variants of word recognition could be accommodated by a word-specific strategy. Perspectives on word recognition that dismiss phonology are, of course, at odds with the most influential model of word recognition: Coltheart's (1978) dual-route theory, which has been at center stage in the present article and in its predecessor. Within this model, the two hypothesized independent processes by which a word's representation is accessed by print—the direct, visual process and the mediated, phonological process—are assigned unequal responsibilities. Whereas the mediated route might dominate word identification in beginning reading, it is the direct route that characterizes reading fluency; and whereas phonological mediation is needed for reading new words and nonwords, the direct visual route is mandatory for exceptional spellings and is preferred for familiar words. Recent versions of dual-route theory, in response to evidence that phonology's contribution is not necessarily delayed relative to that of the visual route, deemphasize processing-time differences between the two routes but preserve the essential division of responsibilities (Paap, Noel, & Johansen, 1992). Eroding the contrast between the routes in their processing responsibilities has been a notable feature of recent and influential subsymbolic models. A prominent but moderate example is the distributed, developmental model of Seidenberg and McClelland (1989). It assumes a single, uniform procedure for computing the phonology of irregular words, nonwords, and regular words. At the same time, this subsymbolic account preserves the general idea that accessing semantic codes by means of phonology is slower than accessing them by orthography, and that certain conditions must hold if phonological

---

[9] Because the Serbo-Croatian language uses two orthographies, and because (until recently) both were learned and in use within any given Yugoslavian community, fluent readers would need a mechanism to inhibit the phonemic interpretation according to alphabet A of a shared and ambiguous letter when the letter string of which it was a part was evidently transcribed in alphabet B. This inhibitory mechanism has been studied in experiments in which techniques of alphabet priming and alphabet masking have been used (Lukatela, Lukatela, Carello, & Turvey, 1993; Lukatela & Turvey, 1990b; Lukatela, Turvey, Feldman, Carello, & Katz, 1989; Lukatela, Turvey, & Todorivic, 1991).

access is to have an observable effect (e.g., poor readers, unfamiliar spelling patterns).

An unequivocally central and leading role for phonology is defined within the subsymbolic model of Van Orden et al. (1990) and Van Orden and Goldinger (in press). Pursuing the dynamical notions of adaptive resonance and self-consistency (e.g., Grossberg, 1980; Grossberg & Stone, 1986; Smolensky, 1986), Van Orden and colleagues contended that visual–phonological resonances of printed word perception cohere before the phonological–semantic and visual–semantic resonances. The resonance of orthographic–phonological subpatterns is primary because the self-consistency between orthographic subpatterns and phonological subpatterns tends to be greater than the self-consistency between either orthography and meaning or phonology and meaning. Furthermore, covariant learning renders a word's orthographic–phonological attractor considerably stronger than the complementary attractors defined by phonological–semantic and visual–semantic mappings. In consequence, it is argued that the resonance that emerges between orthographic and phonological subpatterns provides a coherent foundation for assembling other higher order linguistic resonances (Van Orden & Goldinger, in press; Van Orden et al., 1990). According to the preceding argument, early coherence would be the basis for the observation—in the present article and in its predecessor (Lukatela & Turvey, 1994)—of phonology's leading role in visual word perception.

In summary, the present research echoes the general conclusions drawn by Van Orden et al. (1990) and ourselves (Lukatela & Turvey, 1994) concerning the classical dual-route theory of word perception and the leading role assigned to the orthographic code; namely, that the phonological code seems to be (a) the earliest constraint on word recognition, creating the circumstances within which the role of orthographic codes is defined (the hypothesis of delayed phonology in classical dual-route theory is rejected), (b) used automatically by skilled readers for naming HF and LF words and nonwords (the bypass hypothesis of classical dual-route theory is rejected), and (c) more pervasive and more empirically demonstrable as the lexical access code than the orthographic code (the independent-processes hypothesis of classical dual-route theory is seriously questioned).

References

Aaronson, D., & Ferres, S. (1983). A model for coding lexical categories during reading. *Journal of Experimental Psychology: Human Perception and Performance, 9,* 700–725.

Carello, C., Turvey, M. T., & Lukatela, G. (1992). Can theories of word recognition remain stubbornly nonphonological? In R. Frost & L. Katz (Eds.), *Orthography, phonology, morphology, and meaning* (pp. 211–226). Amsterdam: Elsevier.

Chappell, M., & Humphreys, M. S. (1994). An auto-associative neural network for sparse representations: Analysis and application to models of recognition and cued recall. *Psychological Review, 101,* 103–128.

Coltheart, M. (1978). Lexical access in simple reading tasks. In G. Underwood (Ed.), *Strategies of information processing* (pp. 151–216). San Diego, CA: Academic Press.

Colombo, L. (1986). Activation and inhibition with orthographically similar words. *Journal of Experimental Psychology: Human Perception and Performance, 12,* 226–234.

Davelaar, E., Coltheart, M., Besner, D., & Jonasson, J. T. (1978). Phonological recoding and lexical access. *Memory & Cognition, 6,* 391–402.

Evett, L. J., & Humphreys, G. W. (1981). The use of abstract graphemic information in lexical access. *Quarterly Journal of Experimental Psychology, 33,* 325–350.

Fehrer, E., & Biederman, I. (1962). A comparison of reaction time and verbal report in the detection of masked stimuli. *Journal of Experimental Psychology, 64,* 126–130.

Fehrer, E., & Raab, D. (1962). Reaction time to stimuli masked by metacontrast. *Journal of Experimental Psychology, 63,* 143–147.

Ferrand, L., & Grainger, J. (1992). Phonology and orthography in visual word recognition: Evidence from masked nonword priming. *Quarterly Journal of Experimental Psychology, 45A,* 353–372.

Fleming, K. K. (1993). Phonologically mediated priming in spoken and printed word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19,* 272–284.

Forster, K. (1987). Form-priming with masked primes: The best match hypothesis. In M. Coltheart (Ed.), *Attention and performance* (Vol. XII, pp. 127–146). Hillsdale, NJ: Erlbaum.

Forster, K., & Davis, C. (1991). The density constraint on form-priming in the naming task: Interference effects from a masked prime. *Journal of Memory and Language, 30,* 1–25.

Forster, K., Davis, C., Schoknecht, C., & Carter, R. (1987). Masked priming with graphemically related forms: Repetition of partial activation? *Quarterly Journal of Experimental Psychology, 39,* 211–251.

Grainger, J. (1992). Orthographic neighborhoods and visual word recognition. In R. Frost & L. Katz (Eds.), *Orthography, phonology, morphology, and meaning* (pp. 131–146). Amsterdam: North-Holland.

Grossberg, S. (1980). How does a brain build a cognitive code? *Psychological Review, 87,* 1–51.

Grossberg, S., & Stone, G. O. (1986). Neural dynamics of word recognition and recall: Priming, learning, and resonance. *Psychological Review, 93,* 46–74.

Hanson, V. L., & Fowler, C. A. (1987). Phonological coding in word reading: Evidence form hearing and deaf readers. *Memory & Cognition, 15,* 199–207.

Hillinger, M. L. (1980). Priming effects with phonemically similar words: The encoding bias hypothesis reconsidered. *Memory & Cognition, 8,* 115–123.

Hinton, G. E., & Shallice, T. (1991). Lesioning an attractor network: Investigations of acquired dyslexia. *Psychological Review, 98,* 74–95.

Humphreys, G. W., Besner, D., & Quinlan, P. T. (1988). Event perception and the word repetition effect. *Journal of Experimental Psychology: General, 117,* 51–67.

Humphreys, G. W., Evett, L. J., & Taylor, D. E. (1982). Automatic phonological priming in visual word recognition. *Memory & Cognition, 10,* 576–590.

Humphreys, G. W., & Evett, L. J. (1985). Are there independent lexical and nonlexical routes in word processing? An evaluation of the dual-route theory of reading. *Behavioral and Brain Sciences, 8,* 689–740.

Humphreys, G. W., Evett, L. J., Quinlan, P. T., & Besner, D. (1987). Orthographic priming: Qualitative differences between priming from identified and unidentified primes. In M. Coltheart (Ed.), *Attention and performance* (Vol. XII, pp. 105–125). Hillsdale, NJ: Erlbaum.

Kolers, P. (1970). Three stages of reading. In H. Levin & J. P. Williams (Eds.), *Basic studies on reading* (pp. 90–118). New York: Basic Books.

Kucera, H., & Francis, W. N. (1967). *Computational analysis of present-day American English.* Providence, RI: Brown University Press.

Lesch, M. F., & Pollatsek, A. (1993). Automatic access of semantic information by phonological codes in visual word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19,* 285–294.

Lukatela, G., Carello, C., & Turvey, M. T. (1990a). Phonemic priming by words and pseudowords. *European Journal of Cognitive Psychology, 2,* 375–394.

Lukatela, G., Carello, C., & Turvey, M. T. (1990b). Phonemic, associative, and grammatical context effects with identified and unidentified primes. *Language and Speech, 33,* 1–18.

Lukatela, G., Lukatela, K., Carello, C., & Turvey, M. T. (1993). Delay and degradation reduce alphabet priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition.*

Lukatela, G., Lukatela, K., & Turvey, M. T. (1993). Further evidence for phonological constraints on visual lexical access: TOWED primes FROG. *Perception & Psychophysics, 53,* 461–466.

Lukatela, G., & Turvey, M. T. (1990a). Phonemic similarity effects and prelexical phonology. *Memory & Cognition, 18,* 128–152.

Lukatela, G., & Turvey, M. T. (1990b). Automatic and prelexical computation of phonology in visual word identification. *European Journal of Cognitive Psychology, 2,* 325–343.

Lukatela, G., & Turvey, M. T. (1991). Phonological access of the lexicon: Evidence from associative priming with pseudohomophones. *Journal of Experimental Psychology: Human Perception and Performance, 17,* 951–966.

Lukatela, G., & Turvey, M. T. (1993). Similar attentional, frequency, and associative effects for pseudohmophones and words. *Journal of Experimental Psychology: Human Perception and Performance, 19,* 166–178.

Lukatela, G., & Turvey, M. T. (1994). Visual lexical access is initially phonological: 1. Evidence from associative priming by words, homophones, and pseudohomophones. *Journal of Experimental Psychology: General, 123,* 107–128.

Lukatela, G., Turvey, M. T., Feldman, L. B., Carello, C., & Katz, L. (1989). Alphabetic priming in bi-alphabetical word perception. *Journal of Memory and Language, 28,* 237–254.

Lukatela, G., Turvey, M. T., Todorovic, D. (1991). Is alphabet biasing in bialphabetical word perception automatic and prelexical? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17,* 653–663.

Martin, R. C., & Jensen, C. R. (1988). Phonological priming in the lexical decision task: Failure to replicate. *Memory & Cognition, 16,* 505–521.

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: Part 1. An account of basic findings. *Psychological Review, 88,* 375–407.

Michaels, C., & Turvey, M. T. (1979). Central sources of visual masking: Indexing structures supporting seeing at a single brief glance. *Psychological Research, 41,* 1–61.

Meyer, D. E., Schvaneveldt, R. W., & Ruddy, M. G. (1974). Functions of graphemic and phonemic codes in visual word recognition. *Memory & Cognition, 2,* 309–321.

Neely, J. H. (1991). Semantic priming effects in visual word recognition: A selective review of current fidnings and theories. In D. Besner & G. Humphreys (Eds.), *Basic processes in reading: Visual word recognition* (pp. 264–336). Hillsdale, NJ: Erlbaum.

Paap, K. R., Newsome, S. L., McDonald, J. E., & Schvaneveldt, R. W. (1982). An activation–verification model for letter and word recognition: The word superiority effect. *Psychological Review, 89,* 573–594.

Paap, K. R., & Noel, R. W. (1991). Dual-route models of print to sound: Still a good horse race. *Psychological Research, 53,* 13–24.

Paap, K. R., Noel, R. W., & Johansen, L. S. (1992). Dual-route models of print to sound: Red herrings and real horses. In R. Frost & L. Katz (Eds.), *Orthography, morphology, and meaning* (pp. 293–318). Amsterdam: North-Holland.

Perfetti, C. A., & Bell, L. C. (1991). Phonemic activation during the first 40 ms of word identification: Evidence from backward masking and masked priming. *Journal of Memory and Language, 30,* 473–485.

Perfetti, C. A., Bell, L. C., & Delaney, S. (1988). Automatic (prelexical) phonetic activation in silent word reading: Evidence from backward masking. *Journal of Memory and Language, 27,* 59–70.

Perfetti, C. A., Zhang, S., & Berent, I. (1992). Reading in English and Chinese: Evidence for a "universal" phonological principle. In R. Frost & L. Katz (Eds.), *Orthography, phonology, morphology, and meaning* (pp. 227–248). Amsterdam: North-Holland.

Peter, M., Lukatela, G., & Turvey, M. T. (1990). Phonological priming: Failure to replicate in the rapid naming task. *Bulletin of the Psychonomic Society, 28,* 389–392.

Peter, M., & Turvey, M. T. (1994). Phonological codes are early sources of constraint on visual semantic categorization. *Perception & Psychophysics, 55,* 497–504.

Schulman, H., Hornak, R., & Sanders, E. (1978). The effect of graphemic, phonetic, and semantic relationships on access to lexical structures. *Memory & Cognition, 6,* 115–123.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review, 96,* 523–568.

Smith, F. (1971). *Understanding reading: A psycholinguistic analysis of reading and learning to read.* New York: Holt, Rinehart & Winston.

Smolensky, P. (1986). Formal modeling of subsymbolic processes: An introduction to harmony theory. In N. E. Sharkey (Ed.), *Advances in cognitive science* (Vol. 1, pp. 204–235). New York: Wiley.

Turvey, M. T. (1978). Visual processing and short-term memory. In W. K. Estes (Ed.), *Handbook of learning and cognitive processes* (Vol. 5, pp. 91–140). Hillsdale, NJ: Erlbaum.

Van Orden, G. C. (1987). A ROWS is a ROSE: Spelling, sound, and reading. *Memory & Cognition, 15,* 181–198.

Van Orden, G. C., & Goldinger, S. D. (1994). The interdependence of form and function in cognitive systems explains perception of printed words. *Journal of Experimental Psychology: Human Perception and Performance, 20.*

Van Orden, G. C., Johnston, J. C., & Hale, B. L. (1988). Word identification in reading proceeds from spelling to sound to meaning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14,* 371–385.

Van Orden, G. C., Pennington, B. F., & Stone, G. O. (1990). Word identification in reading and the promise of subsymbolic psycholinguistics. *Psychological Review, 97,* 488–522.

Van Orden, G. C., Stone, G. O., Garlington, K., Markson, L., Pinnt, G., Simonfy, C., & Brichetto, A. (1992). "Assembled" phonology and reading: A case study in how theoretical perspective shapes empirical investigation. In R. Frost & L. Katz (Eds.), *Orthography, morphology, and meaning* (pp. 249–290). Amsterdam: North-Holland.

Wiles, J., & Humphreys, M. S. (1993). Using artificial neural nets

(*Appendixes follow on next page*)

to model implicit and explicit memory test performance. In P. Graf. & M. E. J. Masson (Eds.), *Implicit memory: New directions in cognition, development, and neuropsychology* (pp. 141–165). Hillsdale, NJ: Erlbaum.

Wiles, J., Humphreys, M. S., Bain, J. D., & Dennis, S. (1991). Direct memory access using two cues: Finding the intersection of two sets in a connectionist model. In R. P. Lippman, J. E. Moody, & D. Touretzky (Eds.), *Advances in neural information processing systems* (Vol. 3, pp. 635–641). San Mateo, CA: Morgan Kaufmann.

Appendix A

Stimulus Materials in Experiments 1–3

Each row identifies, in order, the identity prime (which is also the target word), the homophonic prime, the quasi-homographic prime, and their respective controls.

1. ALTAR, ALTER, AJAR, TEENS, SILLY, MILT
2. BAIT, BATE, BAST, SWAP, PUBS, DUNE
3. BALE, BAIL, BALD, SPIN, FOLD, SPIN
4. BALL, BAWL, BILL, POOR, CLAP, HOUR
5. BARREN, BARON, BURDEN, TRUSTS, NECKS, LIQUOR
6. BEACH, BEECH, BENCH, DROVE, STAIN, DYING
7. BEAR, BARE, BEER, SPOT, FLED, SING
8. BEAT, BEET, BELT, JURY, ORGY, GYRO
9. BLUE, BLEW, BLUR, FALL, TROT, PEEL
10. BORED, BOARD, BARRED, NAILS, CLOSE, TUMORS
11. BRAKE, BREAK, FREAK, COLON, FIXED, HOBBY
12. BREAD, BRED, BREED, SMOKE, PALS, AMPLE
13. CENT, SCENT, CANT, WALL, POKER, LURK
14. CEREAL, SERIAL, CENTRAL, SHIFTS, TYPING, FRIENDS
15. CORD, CHORD, CARD, PINS, SWELL, DISK
16. CREEK, CREAK, CROOK, UPSET, OHMIC, SALVE
17. DEW, DUE, DEL, LAG, TRY, FOX
18. DOE, DOUGH, DYE, HAW, SLICE, HAW
19. FEET, FEAT, FRET, WORD, CLIP, VIVA
20. FIR, FUR, FIN, PAL, EGO, PAL
21. FLEA, FLEE, FLEX, MUGS, STUNK, SNUG
22. FLOWER, FLOUR, FLOPPER, ADULTS, KNELT, NUDGING
23. FOWL, FOUL, FOLK, BRAN, BRAN, RICE
24. GATE, GAIT, GAT, FOOL, SLUM, MOO
25. GUEST, GUESSED, GUST, FIFTH, OMINOUS, WAXY
26. GUYS, GUISE, GUTS, CROP, PROPS, SLAB
27. HARE, HAIR, HIRE, LOWN, MEET, QUIT
28. HAWK, HOCK, HARK, RIPE, YORE, NETS
29. HEAL, HEEL, HELL, RUSE, ACRE, PARK
30. HERD, HEARD, HEED, PALM, STUDY, STAG
31. HOLE, WHOLE, HELM, SKIN, STUDY, ACHE
32. HORSE, HOARSE, HOUSE, LIVED, CHILLY, AGAIN
33. KNIGHT, NIGHT, NAUGHT, FASTER, ASKED, COERCE
34. LADDER, LATTER, LAUDER, POLISH, MOVING, ORPHIC
35. LENS, LENDS, LEGS, ECHO, SPOIL, JURY
36. LOAD, LODE, LOAF, MAMA, FESS, WICK
37. LOAN, LONE, LOIN, SHUT, BIAS, FEUD
38. LOOT, LUTE, LOST, SAWS, MOAN, VIEW
39. MAIL, MALE, MALL, COOK, PUSH, OUST
40. MAIN, MANE, MAN, ARMS, COUD, DID
41. MALL, MAUL, MILL, DOOM, SOOT, BLOC
42. MEDAL, MEDDLE, MEDIA, TORSO, PAJAMA, VIRUS
43. MINER, MINOR, METER, POLKA, AVOID, WHIGS
44. MUSSEL, MUSCLE, MISSILE, OATNUT, WEAPON, TRAGEDY
45. NOSE, KNOWS, NONE, TEXT, VISUAL, FIRM
46. NUN, NONE, NUT, EEL, WISH, JAY
47. OAR, ORE, JAR, MEW, LAX, FEE
48. PAIL, PALE, PALL, FUSS, BUSY, VINE
49. PANE, PAIN, PANS, TICK, LOSS, TICK
50. PASTE, PACED, PESTS, ELBOW, ELBOW, ALLAY
51. PAWS, PAUSE, PAYS, FLOC, SCREW, DOME
52. PEAK, PEEK, PECK, RAGE, PLUM, CRIB
53. PEAR, PAIR, PEER, ROBE, TEXT, BUGS
54. PEARL, PURL, PERIL, JOKES, FANG, CROWN
55. PIECE, PEACE, PENCE, MONTH, THIRD, VALOR
56. PLANE, PLAIN, PLANK, DOUBT, SORRY, CORSO
57. POLE, POLL, PILE, WING, DUSK, HANG
58. PORE, POUR, PURE, DENT, WEPT, WILD
59. PRAY, PREY, PRY, BITS, STUD, JAM
60. RAIN, REIN, RUIN, DUST, OPUS, WOKE
61. RIGHT, WRITE, RIOT, AGAIN, SCENE, BANG
62. RING, WRING, RANG, HERO, TACIT, UGLY
63. ROAD, RODE, ROUND, BOOK, INCH, SHAPE
64. ROSE, ROWS, RISE, LAWS, TAXI, CLAY
65. ROUTE, ROOT, ROTTE, SKILL, FLUX, BLAIN
66. SAIL, SALE, SALT, BUTT, BOND, BOND
67. SEA, SEE, SET, OIL, OWN, WHY
68. SEAMS, SEEMS, SLAMS, BLUNT, MAJOR, FROWN
69. SELL, CELL, SILL, VICE, JULY, NAP
70. SIGHT, SITE, SIGHS, COVER, GROW, TANIN
71. SIGN, SINE, SING, LORD, USER, YARD
72. SLEIGH, SLAY, SLIGHT, ORNATE, OZON, MOTION
73. SOLE, SOUL, SOLO, TRAY, MERE, TWIN
74. SON, SUN, SIN, PAY, HIT, WET
75. STAIR, STARE, STAIN, MOURN, HONEY, TOWEL
76. STEAK, STAKE, STERN, MERGE, LUNGS, BELLY
77. STEEL, STEAL, STALL, PRIME, BROWS, FADED
78. SUITE, SWEET, SUITS, CHARM, DRAWN, CHARM
79. SURF, SERF, SCARF, TENS, WOLD, TROUT
80. TALE, TAIL, TALL, SINK, ZERO, PICK
81. TEA, TEE, TER, FOG, HUM, SOP
82. TEAM, TEEM, TERM, EDGE, INKS, EDGE
83. THRONE, THROWN, THROAT, COMPLY, VISUAL, LISTEN
84. TIDE, TIED, TILE, CALF, CORN, MONK
85. TOAD, TOWED, TOLD, FINK, PLASM, GIVE
86. TOW, TOE, TAW, ALE, SPY, YIP
87. URN, EARN, UREA, BIB, CLUE, POMP
88. VANE, VEIN, VASE, BROS, STAR, FLIP
89. WAIST, WASTE, WARTS, VIOLA, URGED, PUNCH
90. WAY, WEIGH, WRY, TOO, MUSED, COX
91. WEAK, WEEK, WALK, CURT, HALF, FILM
92. WEAR, WHERE, WARS, BOMB, AFTER, FIST
93. WHALE, WAIL, WHEEL, PITHY, STUB, CROSS
94. WINE, WHINE, WANE, BOAT, DOLLS, BROS
95. WITCH, WHICH, WATCH, ASSET, THERE, INDEX
96. YOLK, YOKE, YELP, PUFF, RUNG, AFAR

Appendix B

Stimulus Materials in Experiments 4–7

Each row identifies, in order, the identity prime (which is also the target word), the pseudohomographic prime, the pseudohomophonic prime, the nonword prime, and their respective controls.

1. BAKE, BALK, BAIK, FIRG, ROAR, RORT, RORE, SHEG
2. BEAM, BELM, BEEM, POUC, ROPE, ROSP, ROAP, KNEX
3. BIRD, BORD, BERD, NANX, FATE, FANT, FAIT, DOOG
4. BLADE, BLARD, BLAID, MOOTH, WHEAT, WHELT, WHEET, KORCH
5. BOAT, BOTS, BOTE, GEEF, GAIN, GAND, GANE, PUTH
6. BREAK, BRACK, BRAIK, GITES, GREEN, GREWN, GREAN, TAULM
7. BURN, BYRN, BERN, VOAX, DOME, DOLM, DOAM, JEGS
8. CHEAT, CHENT, CHEET, BLAIN, EAGLE, TAGLE, EEGLE, HORMS
9. CRATE, CRAST, CRAIT, GOONS, THIEF, THREF, THEEF, MOOGS
10. DATE, DAST, DAIT, RUND, SEAT, SELT, SEET, LORK
11. DEAL, DERL, DEEL, NITH, SAME, SARM, SAIM, GUNT
12. DOME, DOLM, DOAM, JEGS, BURN, BYRN, BERN, VOAX
13. DOOR, DORN, DORE, PLEX, WIFE, WAFE, WYFE, CRED
14. DREAM, DRERM, DREEM, SWALS, STONE, STORN, STOAN, MAIPH
15. EAGLE, TAGLE, EEGLE, HORMS, CHEAT, CHENT, CHEET, BLAIN
16. EAST, ERST, EEST, LOMB, FREE, FREM, FREA, BOGH
17. FAKE, FASK, FAIK, HOIM, LEAF, LERF, LEEF, YONG
18. FAME, FALM, FAIM, PLUD, SOUP, SUPS, SUPE, DEMS
19. FATE, FANT, FAIT, DOOG, BIRD, BORD, BERD, NANX
20. FEAR, FEDR, FEER, NAWG, GAME, GALM, GAIM, WORP
21. FLOOR, FLORN, FLORE, GRAXT, WHITE, WHOTE, WHYTE, STREL
22. *FOAM*, *FOMP*, *FOME*, THYG, *KNEE*, *KNEP*, *KNEA*, *GIRS*
23. FRAME, FRALM, FRAIM, WHURT, SPEAK, SPERK, SPEEK, HALGE
24. FREE, FREM, FREA, BOGH, EAST, ERST, EEST, LOMB
25. FRUIT, FRUTH, FRUTE, THENT, GRADE, GRALD, GRAID, KIELL
26. GAIN, GAND, GANE, PUTH, BOAT, BOTS, BOTE, GEEF
27. GALE, GAWL, GAIL, HEEN, SOAK, SOKS, SOKE, GIML
28. GAME, GALM, GAIM, WORP, FEAR, FEDR, FEER, NAWG
29. GIRL, GARL, GURL, POPH, NAME, NALM, NAIM, PUNG
30. GOAT, GOTS, GOTE, FULP, RAIL, RALS, RALE, HEPH
31. GRADE, GRALD, GRAID, KIELL, FRUIT, FRUTH, FRUTE, THENT
32. GREEN, GREWN, GREAN, TAULM, BREAK, BRACK, BRAIK, GITES
33. GRIEF, GROEF, GREEF, QUALS, STOVE, STOOV, STOAV, KAUTH
34. GROUP, GRUPH, GRUPE, YIEND, HOUSE, HOLSE, HOWSE, KNALL
35. HATE, HANT, HAIT, RUDL, LEAP, LESP, LEEP, FOTH
36. HEAR, HEDR, HEER, GLIS, WIDE, WODE, WYDE, GUNF
37. HOME, HORM, HOAM, RELP, TAKE, TARK, TAIK, FULB
38. HOPE, HORP, HOAP, TIGS, RATE, RANT, RAIT, THOF
39. HOUSE, HOLSE, HOWSE, KNALL, GROUP, GRUPH, GRUPE, YIEND
40. JAIL, JALD, JALE, FING, NEAT, NERT, NEET, BOPH
41. JOKE, JONK, JOAK, RAUM, LEAN, LEWN, LEEN, TATH
42. KNEE, KNEP, KNEA, GIRS, FOAM, FOMP, FOME, THYG
43. LAKE, LASK, LAIK, GOPS, MINE, MENE, MYNE, HOYT
44. LAME, LARM, *LAIM*, RETH, *TOAD*, TODS, *TODE*, *PESK*
45. LATE, LANT, LAIT, GING, NEAR, NEWR, NEER, FOPS
46. LEAF, LERF, LEEF, YONG, FAKE, FASK, FAIK, HOIM
47. LEAK, LECK, LEEK, DYMS, TAME, TARM, TAIM, REYK
48. LEAN, LEWN, LEEN, TATH, JOKE, JONK, JOAK, RAUM
49. LEAP, LESP, LEEP, FOTH, HATE, HANT, HAIT, RUDL
50. MINE, MENE, MYNE, HOYT, LAKE, LASK, LAIK, GOPS
51. MONTH, MINTH, MUNTH, FLART, PIECE, PRECE, PEECE, GLOPH
52. NAIL, NALS, NALE, SPEM, ROBE, ROOB, ROAB, DIEP
53. NAME, NALM, NAIM, PUNG, GIRL, GARL, GURL, POPH
54. NEAR, NEWR, NEER, FOPS, LATE, LANT, LAIT, GING
55. NEAT, NERT, NEET, BOPH, JAIL, JALD, JALE, FING
56. NOSE, NOGE, NOZE, DANX, RAIN, RANS, RANE, YERT
57. OATS, OTLS, OTES, XEPH, RAPE, RALP, RAIP, NIFL
58. OBEY, OBLY, OBAY, TRUN, RAKE, RASK, RAIK, VEGS
59. PAIN, PARN, PAYN, THEB, ROSE, ROYE, ROZE, SHIR
60. PHONE, PHORN, PHOAN, BLIFF, TRAIN, TRANK, TRANE, MEWDS
61. PIECE, PRECE, PEECE, GLOPH, MONTH, MINTH, MUNTH, FLART
62. RAIL, RALS, RALE, HEPH, GOAT, GOTS, GOTE, FULP
63. RAIN, RANS, RANE, YERT, NOSE, NOGE, NOZE, DANX
64. RAKE, RASK, RAIK, VEGS, OBEY, OBLY, OBAY, TRUN
65. RAPE, RALP, RAIP, NIFL, OATS, OTLS, OTES, XEPH
66. RATE, RANT, RAIT, THOF, HOPE, HORP, HOAP, TIGS
67. ROAD, ROND, ROED, SENE, WAIT, WATH, WATE, HUMB
68. ROAR RORT, RORE, SHEG, BAKE, BALK, BAIK, FIRG
69. ROBE, ROOB, ROAB, DIEP, NAIL, NALS, NALE, SPEM
70. *ROPE, ROSP, ROAP, KNEX, BEAM, BELM, BEEM, POUC*
71. ROSE, ROYE, ROZE, SHIR, PAIN, PARN, PAYN, THEB
72. SAFE, SARF, SAIF, MYDR, WINE, WONE, WYNE, GAUG
73. SAME, SARM, SAIM, GUNT, DEAL, DERL, DEEL, NITH
74. SEAT, SELT, SEET, LORK, DATE, DAST, DAIT, RUND
75. SEEK, SECK, SEAK, TURS, TONE, TOON, TOAN, DUAR
76. SOAK, SOKS, SOKE, GIML, GALE, GAWL, GAIL, HEEN
77. SOUP, SUPS, SUPE, DEMS, FAME, FALM, FAIM, PLUD
78. SPADE, SPALD, SPAID, LEEMS, TROOP, TREPE, TRUPE, DEITH
79. SPEAK, SPERK, SPEEK, HALGE, FRAME, FRALM, FRAIM, WHURT
80. STEAK, STANK, STAIK, BROLE, TEASE, TEALE, TEAZE PIMES
81. STONE, STORN, STOAN, MAIPH, DREAM, DRERM, DREEM, SWALS
82. STOVE, STOOV, STOAV, KAUTH, GRIEF, GROEF, GREEF, QUALS
83. TAKE, TARK, TAIK, FULB, HOME, HORM, HOAM, RELP
84. TAME, TARM, TAIM, REYK, LEAK, LECK, LEEK, DYMS
85. TEASE, TEALE, TEAZE, PIMES, STEAK, STANK, STAIK, BROLE
86. THIEF, THREF, THEEF, MOOGS, CRATE, CRAST, CRAIT, GOONS
87. TOAD, TODS, TODE, PESK, LAME, LARM, LAIM, RETH
88. TONE, TOON, TOAN, DUAR, SEEK, SECK, SEAK, TURS
89. TRAIN, TRANK, TRANE, MEWDS, PHONE, PHORN, PHOAN, BLIFF
90. TROOP, TREPE, TRUPE, DEITH, SPADE, SPALD, SPAID, LEEMS
91. WAIT, WATH, WATE, HUMB, ROAD, ROND, ROED, SENE
92. *WHEAT, WHELT, WHEET, KORCH, BLADE, BLARD, BLAID, MOOTH*
93. WHITE, WHOTE, WHYTE, STREL, FLOOR, FLORN, FLORE, GRAXT
94. WIDE, WODE, WYDE, GUNF, HEAR, HEDR, HEER, GLIS
95. WIFE, WAFE, WYFE, CRED, DOOR, DORN, DORE, PLEX
96. WINE, WONE, WYNE, GAUG, SAFE, SARF, SAIF, MYDR

Received January 20, 1994
Revision received May 10, 1994
Accepted May 20, 1994 ■