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# Phonological Priming by Masked Nonword Primes in the Lexical Decision Task

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The pseudohomophone test is whether the processing of a word target can be facilitated by a masked homophonic nonword prime independent of the visual similarity between them. The significance of the test is in respect to the hypothesized contributions of phonological and orthographic codes within dual-route theories. Using the mask–prime–target presentation sequence and prime durations typical of form priming experiments (e.g., 57 ms), we found that pseudohomophone primes (e.g., KLIP) reduced lexical decision times to targets in dense neighborhoods (e.g., *clip*) relative to visually similar control primes (e.g., PLIP). We also found superior pseudohomophonic priming at a prime duration (29 ms) previously considered too brief for the emergence of phonological codes. The basis for these successful pseudohomophone tests in English was overall phonological similarity of prime and target rather than common onsets, rimes, or number of overlapping letters. Discussion focused on the need for models of visual word recognition in which phonology assumes the leading role. © 1998 Academic Press

It was suggested some years ago by Humphreys, Evett, and Taylor (1982) that if a visually presented target word could be primed by a masked (unidentifiable) homophonic nonword, then one would have to assume that visual word recognition involves the automatic and rapid assembly of phonological codes. We have referred to the proposal of Humphreys et al. (1982) as the *pseudohomophone test* (Lukatela & Turvey, 1994b). The context for the test was the dual-route theory of Coltheart (1978). According to that theory, nonwords are processed on a nonlexical route over which graphemes are converted into phonemes in contrast to most words which are processed on a lexical, visually direct route. In Humphreys et al.'s study with English, assembled phonology failed the pseudohomophone test, bringing into question the contribution of phonology to visual word recognition (e.g., Humphreys & Evett, 1985).

Recently, we repeated the pseudohomophone test in English using naming latency as the dependent measure (Humphreys et al. had used accuracy of identification) and a four-field procedure of mask–prime–mask–target (Humphreys et al. had used mask–prime–target–mask) (Lukatela & Turvey, 1994b). Additionally, we used a design in which each of the test primes could be compared to its own individualized control as well as being compared to each other and to a common control (Humphreys et al. had used only a comparison with a visual control). The outcome of our investigation was positive. Naming *toad*, for example, was found to benefit from the prior presentation of TODE relative to the prior presentation of TODS (see also Lukatela & Turvey, submitted for publication). Our results with a prime duration of 30 ms and a prime–target SOA of 60 ms complemented those of Perfetti and Bell (1991) obtained in an experiment using a prime–target–mask sequence and percentage target identification as the response measure. In that experiment, the pseudohomophone test was successful for prime exposures above 45 ms (Humphreys et al. had limited their evaluation of the test to prime exposures/SOAs of 35 ms).

The theoretical significance of the pseudohomophone test encourages further evaluations. Most particularly it encourages evaluations that use more conventional designs and conditions of presentation. What we have in

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mind are the designs and conditions that have led to experimental results suggestive of visual or orthographic effects of masked nonword primes rather than phonological effects. Notable in this regard are the studies on so-called form priming with naming or lexical decision as the response to the target (e.g., Forster, 1987; Forster & Davis, 1984, 1991). The presentation conditions are mask–prime–target with exposures, for example, of 500–60–500 ms, respectively, and interstimulus intervals of zero. A reliable perceptual consequence of this three-field paradigm is the unidentifiability of the prime which is, reportedly, a necessary condition for the demonstration of form priming (Forster, 1987; but see Forster & Veres, 1998). In the contrasting mask–prime–mask–target presentation conditions used in our experiments, the mask intervening between prime and target was introduced to minimize the carryover of visual activity from prime to target processing and to maximize the processing of these two stimuli as separate perceptual events (e.g., Humphreys, Evett, Quinlan, & Besner, 1987). One reading of the perceptual effect of the postprime pretarget mask within a model of visual word processing such as the dual-route cascade (e.g., Coltheart & Rastle, 1994) is that it perturbs prime-induced activation in the orthographic input lexicon restricting, thereby, the prime's influence on the target to the phonological output lexicon (Paap, personal communication). In short, a possible criticism of our use of an intervening mask is that it may act to bias the experimental outcome away from ordinarily dominant orthographic effects toward secondary phonological effects.

If it is more conventional to consider presentation conditions that exclude a postprime pretarget mask (e.g., Forster & Davis, 1991; Humphreys et al., 1982), it is also more conventional to emphasize in the design and analysis the direct comparison of a prime such as TODE with its visual control TODS rather than the indirect comparison afforded by, for example, the priming difference between TODE and LAIM relative to the priming difference between TODS and LARM. In this indirect comparison, a word of the same frequency and length as TOAD is chosen as the control for the identity prime TOAD and appropriate derivatives of this word are chosen as the controls for the pseudohomophone TODE and its quasihomograph TODS. Thus, given the control word LAME, the pseudohomophone control is LAIM and the pseudohomograph control is LARM. In our original experiments (Lukatela & Turvey, 1994b), the argument for a successful pseudohomophone test was based primarily on indirect comparisons although a direct comparison (a 9-ms difference favoring TODE over TODS as a prime for *toad* in Experiment 6) was found to be reliable by both items and subjects. There is an impression, however, that evidence from the direct comparison is more compelling and, for purposes of theory building and simulations, more convenient (Coltheart, personal communication). If one's theory is that lexical access is fundamentally visual, then the issue becomes simply whether any effect of TODE other than that due to its optical form is demonstrable: Is there any difference between TODE and TODS in accessing the memory for *toad?*

In the present series of experiments we use the conditions of presentation employed in the form priming experiments and determine pass or failure on the pseudohomophone test by the method of direct comparison. In order to ensure that the methodological differences and analyses differences between the present experiments and form-priming experiments would be minimized, the mask–prime–target sequences in the present experiments were controlled by the computer program used in the form-priming studies of Forster and colleagues (by courtesy of Forster) and the statistical analyses of the data followed the factorial design (which includes a group factor) typical of those studies. Further, in order to ensure that the pseudohomophone test was as difficult as possible, the response to the target in the present experiments was lexical decision rather than naming. A common sentiment is that naming a word necessarily entails phonology at some point and, therefore, phonological priming effects in the naming task are not especially surprising; there are a variety of ways in which one can imagine them arising, not all of which are theoretically interesting (Paap, personal communication). In contrast, to perform a lexical decision does not entail, in any necessary fashion, the evocation of a letter string's phonology. Consequently, evidence of a successful pseudohomophone test in lexical decision would be both more surprising and theoretically compelling. Such evidence has been provided in French (Ferrand & Grainger, 1992, 1994; Grainger & Ferrand, 1994, 1996) and in Serbo-Croatian (Lukatela & Turvey, 1990)[1]. Ferrand and Grainger (1994) and Grainger and Ferrand (1996) found that within mask–prime–target sequences that rendered the primes unidentifiable, pseudohomophone primes in lowercase (such as *nert* pronounced in French [nɛːr]) facilitated lexical decisions to target words in uppercase (such as NERF pronounced [nɛːr]) relative to orthographically similar, nonhomophonic control primes in lowercase (such as *nerc* pronounced in French as [nɛrk]). In nearly identical conditions of presentation, Lukatela and Turvey (1990, Experiment 10) found that lexical decisions on word targets were facilitated by phonologically similar nonword primes that differed from their targets in both case and alphabet (e.g., lowercase Cyrillic versus uppercase Roman). Although valuable, such demonstrations in orthographies other than English tend to have little impact on the major theories and models of visual word recognition which are directed at providing a coherent account of the many and varied facts resulting from English language studies (e.g., Coltheart, Curtis, Atkins, & Haller, 1993; Plaut, McClelland, Seidenberg, & Patterson, 1996).

In sum, the present research is directed at the question: Can an English word be primed automatically by a homophonic nonword? The question is posed in the context of (a) controls that assess whether the pseudohomophone's contribution is actually due to its orthographic rather than its phonological structure, (b) a mask–prime–target procedure in which the prime is nonidentifiable and the use of conscious strategies thereby minimized, and (c) lexical decision on the target—a task that need not, in principle, require phonology at any stage. The importance of the question and its answer from the perspective of dual-route theory is summarized by Humphreys et al. (1982, p. 581): "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."

The question and its answer are also important from the perspective of the *phonological coherence hypothesis* advanced by Van Orden and colleagues (Van Orden & Goldinger, 1994; Van Orden, Pennington, & Stone, 1990). On this hypothesis, the early achievement of a stable phonological code is pivotal to the temporal unfolding of the mappings among orthographic, phonological, and semantic subpatterns. In ordinary visual word recognition, phonology plays the leading role, mediating the dynamics of multiple feedforward and feedback interactions (in the sense of resolving competitions rather than in the sense of linking components). Failing the pseudohomophone test would counter the phonological coherence hypothesis. It would also counter the closely related hypothesis that word processing proceeds initially through the successive assembly of two phonological frames, the first based on graphemic consonants and the second based on graphemic vowels (Berent & Perfetti, 1995).

Experiments are reported with, for example, *clip* as the target and PLIP as the control prime. The pseudohomophone test was conducted in Experiment 1 with the experimental prime KLIP. A positive outcome (that is, KLIP superior to PLIP) would raise the possibility that a shared onset effect, previously restricted to naming (Forster & Davis, 1991; Grainger & Ferrand, 1996), is manifest in lexical decision. If so, then the advantage of KLIP over PLIP would suggest the influence of a nonlexical process that translates print to speech in a serial (left-to-right) order at a rate such that only the first phoneme of the prime can be determined before the onset of the target (Coltheart &

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[1] Berent (1997) provides data suggestive of a similar successful demonstration in English. In the lexical decision task, pseudohomophones primed their targets better than graphemic control primes. The absence, however, of an advantage of pseudohomophones over primes that shared no letters in common with the target undermines the demonstration.

Rastle, 1994; Forster & Davis, 1991). A shared-onset interpretation of a successful pseudohomophone test would be at odds with the phonological coherence hypothesis. For this hypothesis, it is the phonology of the whole word that matters more than the local phonology of the initial letter(s) (see also Plaut, McClelland, Seidenberg, & Patterson, 1996; Seidenberg & McClelland, 1989). Experiment 2 compared the experimental or test prime CLEP to the control prime PLIP. If the serial translation is letter-by-letter and if the initial phoneme and total number of letters shared with the target matters to a nonword prime's influence on the target word *clip* (Coltheart et al., 1993; Coltheart & Rastle, 1994), then CLEP should be superior to PLIP. Some accounts of assembled phonology assume an intermediate representational level of *onset* and *rime* (e.g., cl and ip, respectively, for the target *clip*) (e.g., Treiman & Chafetz, 1987). If the onset was more significant to assembly in its earliest stages than the rime, then CLEP (which shares the target's onset but not its rime) would be a more effective prime than PLIP (which shares the target's rime but not its onset). If, to the contrary, the rime played a more significant early role, then CLEP should be inferior to PLIP. Experiment 3 compared KLIP, CLEP, and PLIP directly under the hypothesis that if it is the overall degree of phonological similarity that matters (rather than shared onset, shared rime, or number of shared letters) then KLIP should prove most effective. The relative effectiveness of shared onsets and total number of shared phonemes in the absence of shared rimes was evaluated in Experiment 4 through comparisons of primes such as CLEP (same onset, different rime) with primes such as PREM (different onset, different rime). An advantage of CLEP over PREM would be expected if either onset identity or identity of graphemic consonants (Berent & Perfetti, 1995) is a sufficient basis for facilitating the assembly of the target's phonological code. The fifth and final experiment was designed to examine the lower temporal bound on the code's emergence. Of significance was how nonstandard manipulations of the parameters of mask, prime, and target might reveal the presence of a masked prime's phonology at time scales shorter than published estimates (e.g., Ferrand & Grainger, 1992, 1994).

## EXPERIMENT 1

The most basic form of the pseudohomophone test compares the priming efficacy of a nonword homophonic with the target word with that of a visually similar nonhomophonic nonword. For *clip* as the target, the preceding conditions are met by KLIP and PLIP, respectively. Additional basic requirements are that very little time elapses between prime and target and that the prime is unidentifiable. The significance of these latter requirements for Humphreys et al. (1982) was that if superior priming by the pseudohomophone did occur, then one could infer that the computation of phonology was fast and obligatory. In Experiment 1, the forward mask and the target were each presented for 545 ms. Within the mask–prime–target sequence with interstimulus intervals of zero, the prime was presented for 43, 57, or 72 ms. These prime durations (or, equivalently, prime–target SOAs) were selected to provide a range incorporating the prime durations typically used in form-priming experiments (e.g., Davis & Forster, 1994; Forster & Davis, 1991).

### *Method*

*Participants.* Sixty University of Connecticut undergraduates participated in the experiment in partial fulfilment of a course requirement. A participant was randomly assigned to one of six groups (10 participants per group) with two groups per prime–target SOA.

*Materials.* A base set of 48 word–word pairs was assembled (see Appendix A). In each pair the prime and the target were two identical words with the prime in uppercase and the target in lowercase (to be consistent with Lukatela & Turvey, 1994b). The initial letter of each word was C and each word was a monosyllable consisting of four or five letters (e.g., CLIP-clip, CLERK-clerk, etc.). Short, monosyllabic words were chosen because they have high neighborhood densities and they were chosen to be C-initial words because such words provide the most examples of English words with pseudohomophones that arise through a change in the first letter. The mean letter length was

4.42 and the mean number of phonemes per word was 3.96. Most of the word bodies were doubly consistent (i.e., bottom-up consistent and top-down consistent) following the terminology of Stone, Vanhoy, and Van Orden (1997). In the terminology of Berent and Perfetti (1995), the word bodies contained mostly simple, one-letter, vowel graphemes. According to Kucera and Francis (1967) the mean frequency of the target words in this base set was 44.17 ± 71.40. The neighborhood density of the target words was 8.69 and that of the word bodies was 11.19. It has been typically the case that form-priming fails when the targets are from high-density neighborhoods (Forster, 1987; Forster & Davis, 1991). The use of stimuli with high N in the present research would, presumably, eliminate form priming (assuming that such priming can occur independent of phonology) and restrict the source of any observed priming effects to shared phonology.

One test set and one control set of 48 pairs were generated from the base set. There were in addition, two foil subsets. The foil pairs were highly diverse in order to discourage the development of any specific response strategy. The diversification was motivated by our interpretation of why a previous set of experiments using a similar experimental protocol failed to get identity priming and failed to find an advantage of pseudophomophones over unrelated nonword controls (Berent, 1997). The particular stimulus pairings in these latter experiments were such as to encourage decision strategies with respect to the targets based upon the type of prime.

*The test set.* In each prime of the base set the initial letter C was replaced by the letter K (e.g., KLIP-*clip*, KLERK-*clerk*) to produce 48 phonologically matched test pairs. The mean number of letters that were shared (in the same position) between a given target word and its prime was 3.42. The mean number of phonemes that were shared (in same position) between a target word and its prime was 3.96.

*The control set.* In each prime of the base set the initial letter C was replaced by a letter representing a consonant other than /k/ (e.g., PLIP-*clip*, PLERK-*clerk*, etc.) to produce 48 phonologically mismatched control pairs. The mean number of letters that were shared (in the same position) between a given target word and its control prime was the same as in the test set (3.42 letters per word). The mean number of phonemes that were shared (in same position) between a target word and its control prime was 2.96.

*Yes-response foils.* Eighty-seven prime-target pairs were assembled in which each target was a word. The prime preceding a given target was either an identity word, an associatively related word, an unrelated word, a homophonic nonword, a nonhomophonic nonword, or a row of Xs (the number of Xs matched the number of letters in the target). All true nonword primes (that is, not rows of Xs) were orthographically legal and pronounceable.

*No-response foils.* One hundred and seventeen prime–target pairs were assembled in which each target was a nonword. Again, all true nonwords in this subset were orthographically legal and pronounceable. The prime preceding a given nonword target was a word, a nonword, or a row of Xs (the number of Xs matched the number of letters in the target).

*Design.* The major constraint of the design was that a given participant never encountered a given pair of words more than once. This was achieved within each SOA by dividing the 20 participants into two subgroups. Each participant saw one half of the pairs from the test list (KLIP-*clip*), one half of pairs from the control list (PLIP-*clip*), 87 Yes-response foil pairs, and 117 No-response foil pairs. In sum, each participant saw a total of 252 stimulus pairs. The experimental sequence was divided into three subsets with a brief rest after each. Stimulus pairs were presented to each participant in a different order. (The DMSTR program, identified below, provides a unique randomization per participant.) The experimental sequence was preceded by a practice sequence of 50 stimulus pairs. The SOA (i.e., the prime exposure duration) was a between-subject factor.

*Procedure.* Participants, who were run one at a time, sat in front of the monitor of a DIGITAL 466 computer in a dimly lit room.[2] The viewing

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[2] For unknown reasons, the dim lighting proves to be crucial. Pilot work failed to find any differences, at very brief prime durations, among full and partial phonological primes under the conditions of high illumination in our research room which had previously served as an office. It

TABLE 1

Mean Lexical Decision Latencies (L, in ms) and Percentage Error Rate (ER) with the Corresponding Standard Deviations by Participants and by Items for the Test and Control Primes in Experiment 1

| | KLIP-*clip* | | PLIP-*clip* | | |
|---|---|---|---|---|---|
| SOA (ms) | L | ER | L | ER | Effect (ms) |
| 43 | 595 | 5.2 | 599 | 5.4 | 4 |
| | 52 | 5.8 | 62 | 3.6 | |
| | 38 | 7.7 | 40 | 9.4 | |
| 57 | 597 | 4.2 | 619 | 6.5 | 22 |
| | 70 | 4.9 | 77 | 7.6 | |
| | 53 | 7.7 | 65 | 9.1 | |
| 72 | 548 | 4.4 | 567 | 3.3 | 19 |
| | 54 | 4.4 | 49 | 4.6 | |
| | 41 | 6.5 | 41 | 4.8 | |

distance was about 60 cm. The refresh rate of the VENTURIX monitor was 70 Hz making a refresh cycle (i.e., a "tick") equal to 14.3 ms. The stimuli appeared on the screen as white characters on a dark background. Each trial consisted of a sequence of three visual events in the same location on the center of the screen. First, a pattern mask consisting of a row of five hashmarks (#####) was presented for 38 ticks (545 ms); this was immediately followed by the prime stimulus for 3 ticks (43 ms), for 4 ticks (57 ms), or for 5 ticks (72 ms). Immediately following the prime, a target was presented for 38 ticks. Because the interstimulus interval was zero the prime target SOA was 43, 57, or 72 ms. (Presentation and control of stimuli were through the DMSTR software courtesy of Kenneth Forster.)

Participants were told that on each trial there would be a rapid sequence of two letter strings with the first letter string in uppercase and the second letter string in lowercase. They were warned that the first letter string would be flashed very briefly and would probably be unnoticeable. Participants were instructed to decide as quickly and as accurately as possible whether the lowercase letter string was an English word, ignoring the uppercase letter string. Their decisions were indicated by pressing a "yes" or "no" key with latencies measured from the onset of the target. If the latency was longer than 1800 ms a warning message ("TRY FASTER!") appeared on the screen and if the decision was wrong a feedback message ("WRONG") appeared on the screen.

Debriefing following the experiment revealed that almost all participants in the 43-ms SOA condition and the 57-ms SOA condition and approximately half the participants in the 72-ms SOA condition failed to see any uppercase letters.

### *Results and Discussion*

Response latencies were trimmed minimally by applying a 100-ms cut-off for fast responses and a 1800-ms cut-off for slow responses. The outliers constituted less than 0.5% of all responses (see criteria for truncation suggested by Ulrich & Miller, 1994, p. 69). The mean latencies and their standard deviations for the test and control pairs in each SOA condition are summarized in Table 1. The mean item RT for each individual prime–target pair is given in Appendix B.

A 2 × 2 × 3 (Group × Prime type × SOA) analysis of variance (ANOVA) was conducted on the correct reaction times to word targets with subjects ($F1$) and stimuli or items ($F2$) as the error terms. SOA was a between-subject variable. Prime type (Test = 580 ms, Control = 595 ms) was significant, $F1(1,54) = 12.92, p <$

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was only by reducing the room illumination to that provided by a single desk lamp at floor level that we could obtain reliable priming differences.

.001; $F2(1,92) = 12.34$, $p < .001$. The main effect of SOA was also significant, $F1(2,54) = 3.91$, $p < .05$; $F2(2,92) = 53.77$, $p < .001$, with the shortest latencies occurring in the longest SOA condition. The two-way interaction between the prime type and SOA did not reach significance, $F1(2,54) = 1.84$, $p > .05$; $F2(2,92) = 2.22$, $p > .05$. The three-way interaction was significant by items but not by subjects, $F1(2,54) < 1$; $F2(2,92) = 7.04$, $p < .001$. All other effects were insignificant. Planned comparisons revealed that the 4-ms phonological priming advantage of KLIP-*clip* over PLIP-*clip* in the 43-ms SOA condition was not significant (both *F*s < 1) but the 22-ms priming advantage in the 57-ms SOA condition and the 19-ms advantage in the 72-ms SOA condition were significant, $F1(1,18) = 10.28$, $p < .01$, $F2(1,46) = 6.25$, $p < .01$ and $F1(1,18) = 9.04$, $p < .01$, $F2(1,46) = 8.48$, $p < .01$, respectively. (There were no significant effects in the error analysis.)

In sum, the results indicate that KLIP passed the pseudohomophone test with lexical decision as the response to the target. This outcome corroborates the research of Grainger and Ferrand (1996) with French language materials and Berent (1997; but see Footnote 1) with English language materials. Both of the preceding investigations used a variant of the mask–prime–target presentation format and lexical decision as the response to the target. The outcome of Experiment 1 also corroborates our own previous research with English materials (using the mask–prime–mask–target presentation sequence) and naming as the response to the target (Lukatela & Turvey, 1994b). Additionally, the observed ineffectiveness of KLIP at the shortest SOA of 43 ms and the emergence of its superiority over PLIP at the longer SOAs of 57 and 72 ms corroborates the research of Perfetti and Bell (1991) and Ferrand and Grainger (1992, 1993, 1994), which has uniformly demonstrated a growth in phonological facilitation with increasing prime duration (see also the related findings on gaze duration in the eye movement studies of Rayner, Sereno, Lesch, & Pollatsek, 1995). The corroboration, however, should not deter the pursuit of phonological facilitation at SOAs of 43 ms and less. Implementing masking in the binocular or monocular viewing of computer displayed stimuli is problematic. Typically one's interest is in cognitive processes but the conditions of presentation (specifically, both stimuli to the same receptor surfaces, engaging the same neural paths) necessarily entail non-cognitive, energy-based and form-based interactions (e.g., Michaels & Turvey, 1979). Indeed, Berent (1997) reports successful phonological priming at an SOA/prime duration of 43 ms with mask and target durations different from the standard values of form-priming experiments (that is, those of the present experiment). We address this issue further in Experiment 5.

## EXPERIMENT 2

The clear advantage of KLIP over PLIP could have been due to the onset effect discovered by Forster and Davis (1991) in mask–prime–target sequences with the naming task. Perhaps Experiment 1 demonstrates that the onset effect is similarly true in lexical decision. As previewed in the introduction, Experiments 2 and 3 were directed at this latter possibility. In Experiment 2, CLEP was compared with PLIP. If the only reason for KLIP's superiority in Experiment 1 was shared onsets, then CLEP should be superior to PLIP. The opposite expectation follows, however, from the hypothesis that shared rimes yielded KLIP's superiority in Experiment 1. If sharing rimes is more significant than sharing onsets, then CLEP should prime less effectively than PLIP.

### *Method*

*Participants.* Twenty-two University of Connecticut undergraduates participated in the experiment in partial fulfilment of a course requirement. None had participated in Experiment 1. They were assigned randomly to one of two groups, 11 participants per group.

*Materials.* The base set of 48 word–word pairs was the same as that in Experiment 1. From this base set (e.g., CLIP-*clip*, CARD-*card*, etc.) a new test was generated. In each prime of the base set the third letter was changed to another letter, most frequently a vowel, to produce 48 test pairs (see Appendix A). The mean number of letters in the same position shared between a given target word and its test prime and between a given target word and its control prime was 3.42. In contrast, test primes shared fewer phonemes (2.60) in the same position with their targets than did the control primes (2.96). All other materials were the same as those used in Experiment 1.

*Design and procedure.* These were the same as in Experiment 1 with the exception that SOA was restricted to 57 ms.

### *Results and Discussion*

Response latencies were trimmed as in Experiment 1. The outliers constituted less than 0.5% of all responses. The mean item RT for each individual prime–target pair is given in Appendix C.

A 2 × 2 (Group × Prime type) ANOVA conducted on the correct reaction times yielded a single significant effect of Prime type with Test Primes slower than Control Primes, 617 ms versus 601 ms, respectively, $F1(1,20) = 4.93$, $p < .05$; $F2(1,46) = 5.45$, $p < .02$. There were no significant effects in the error analysis.

Although CLEP in Experiment 2, KLIP in Experiment 1 and PLIP in both experiments were equivalent form primes for *clip* (each differed by only one letter from the target), they did not exert equivalent influences on *clip*. In the 57-ms SOA condition, KLIP reduced lexical decision to *clip* by 22 ms, and CLEP increased lexical decision to *clip* by 16 ms relative to PLIP. Further, although CLEP and *clip* shared onsets (unlike PLIP and *clip*), this conferred no benefit on target lexical decision. That shared onsets do not matter in lexical decision is suggested by Forster and Davis's (1984) failure to find effective priming of PILE by *pale,* Forster and Davis's (1991) failure to find an advantage of *befora* over *defore* as a prime for BEFORE, and Grainger and Ferrand's (1996) failure in French to find an advantage of *nise* over *fise* as a prime for NERF.

## EXPERIMENT 3

The outcome of Experiment 2 suggests that the successful pseudohomophone test of Experiment 1 was not due to the onset effect and did not involve form priming. It would seem that KLIP primed *clip* better than PLIP primed *clip* (Experiment 1) because it shared the target's phonology completely. It would seem that PLIP primed *clip* better than CLEP primed *clip* (Experiment 2) because it shared the target's rime. That rimes are more influential than onsets in determining the rate at which a phonological code develops has been suggested by Kay and Bishop (1987) (see also Glushko, 1979).

In Experiment 3, the three kinds of primes were compared directly. On the understanding that it is the degree of overall phonological similarity with the target *clip* that matters, KLIP should prime more effectively than either PLIP (corroborating Experiment 1) or CLEP. On the understanding that the sharing of rimes is more influential than the sharing of onsets, PLIP should prime more effectively than CLEP (corroborating Experiment 2). In sum, the primes should order in effectiveness as KLIP, PLIP, CLEP.

### *Method*

*Participants.* Forty-five University of Connecticut undergraduates participated in the experiment in partial fulfilment of a course requirement. None had participated in either Experiment 1 or Experiment 2. They were assigned randomly to one of three groups, 15 participants per group.

*Materials.* The stimuli from Experiments 1 and 2 were used.

*Design and procedure.* These were identical to those of Experiment 1 with the SOA limited to 57 ms.

### *Results and Discussion*

Response latencies were trimmed as described in Experiment 1 and submitted to a 2 × 3 (Group × Prime type) ANOVA. There was a main effect of prime type (KLIP = 531 ms, PLIP = 546 ms, CLEP = 559 ms), $F1(2,84) = 15.53$, $p < .0001$, $F2(2,90) = 11.69$, $p < .0001$. Planned comparisons revealed that KLIP primed better than PLIP, $F1(1,42) = 6.44$, $p < .01$, $F2(1,45) = 6.18$, $p < .01$; KLIP primed better than CLEP, $F1(1,42) = 59.08$, $p < .0001$, $F2(1,45) = 19.55$, $p < .0001$; and PLIP primed better than CLEP, $F1(1,42) = 6.10$, $p < .01$, $F2(1,45) = 6.80$, $p < .01$. An ANOVA on the errors (KLIP = 4.9%, PLIP = 5.4%, CLEP =

7.6%) found a marginal effect of prime type, $F1(2,84) = 2.64, p < .08$, $F2(2,90) = 3.05, p < .05$. (The mean item RT for each individual prime–target pair is given in Appendix D.)

The expected outcome was obtained, confirming (a) the importance of overall phonological similarity, (b) the benefit of shared rimes over shared onsets, and (c) the relative insignificance of shared letters.

## EXPERIMENT 4

The ability to prime suffers when the prime does not share the rime of the target. As Experiments 1–3 have shown, KLIP and PLIP are both superior to CLEP as a prime for *clip.* The advantage of KLIP over PLIP indicates, however, that priming efficacy depends on more than the sharing of rime—it depends on the degree of phonological overlap. Accordingly, we might expect to find that CLEP, which shares the target's onset and three of its phonemes, is a more effective prime than a nonword that shares absolutely no letters or phonemes with the target, for example, PREM. This expectation is in keeping with the two-cycles model (Berent, 1997; Berent & Perfetti, 1995). Phonological priming is predicted even if the contents of assembly are limited to consonant information.

### *Method*

*Participants.* Twenty-four University of Connecticut undergraduates participated in the experiment in partial fulfilment of a course requirement. None had participated in Experiments 1 through 3. They were assigned randomly to one of two groups, 12 participants per group.

*Materials.* The materials were those of Experiment 2 with the PLIP primes replaced by PREM primes (see Appendix A).

*Design and procedure.* These were identical to those of Experiment 1 with the SOA limited to 57 ms.

### *Results and Discussion*

The mean item RT for each individual prime–target pair is given in Appendix E. A 2 × 2 (Group × Prime type) ANOVA on latencies did not find a significant effect of prime type (CLEP = 556 ms, PREM = 568 ms), $F1(1,22) = 3.13, p = .09$; $F2(1,46) = 3.02, p = .09$. Errors were fewer for PREM (4.5%) than for CLEP (7.1%), $F1(1,22) = 3.77, p = .07$; $F2(1,46) = 4.11, p < .05$, suggesting that the marginally faster responding in the CLEP-*clip* condition may have benefited from a speed–accuracy trade-off.

The lesson from Experiment 4 is that a pseudoword prime that has the same onset as the target and which differs from the target by only one letter and one phoneme is, possibly, only minimally better than a nonword prime that shares neither onset, letters, nor phonemes with the target. Said differently, when the prime's body fails to match that of the target, the contribution of number of shared phonemes between prime and target is drastically reduced. Given that PLIP is superior to CLEP (Experiments 2 and 3), one must suppose that CLEP's failure to prime significantly better than PREM is due to the missing rime.

## EXPERIMENT 5

In the fifth and final experiment we return to the stimuli of Experiment 1 and the failure, in that experiment, to find an advantage for KLIP over PLIP at the briefest SOA of 43 ms. The issue addressed in Experiment 5 was whether that failure in Experiment 1 truly reflected temporal limits on phonological processing.

The stimulus durations and type of mask typical of form-priming experiments (e.g., Forster, 1987; Forster & Davis, 1984, 1991) were essentially reproduced in the present series of experiments. The selection criterion for these presentation parameters of the mask–prime–target sequences was that they reliably produced unidentifiable primes. Patently, other presentation parameters can render primes unidentifiable. They might not, however, have the same consequences for priming. That is, success or failure of priming under one set of presentation parameters may not replicate under another with important implications for theoretical discussions that turn on issues of processing time scales.

In Experiment 5 the duration of the prime was reduced substantially from its value in Experiments 1–4. In Experiment 5, the prime duration was 29 ms. Because of this 50% reduction in prime duration, it was prudent to reduce the durations of the equally luminous mask and target displays by approximately the same amount to protect against excessive energy-based masking. Pilot work showed that these modifications (yielding mask, prime, and target durations of 286, 29, and 72 ms, respectively) satisfied the criterion of unidentifiable primes.

### *Method*

*Participants.* Twenty University of Connecticut undergraduates participated in the experiment in partial fulfilment of a course requirement. None had participated in Experiments 1 through 4. They were assigned randomly to one of two groups, 10 participants per group.

*Materials.* The materials were those of Experiment 1.

*Design and procedure.* In contrast to Experiment 1 the mask–prime–target sequence was set to 286, 29, and 72 ms or 20, 2, and 5 refreshing cycles of the computer's monitor, respectively.

### *Results and Discussion*

The mean item RT for each individual prime–target pair is given in Appendix F. A 2 × 2 (Group × Prime type) ANOVA was conducted on the correct reaction times to word targets with participants and stimuli as the error term. In the latency data, prime type (KLIP = 547 ms, PLIP = 561 ms) was significant, $F1(1,18) = 5.09$, $p < .05$; $F2(1,46) = 4.30$, $p < .05$. The error analysis revealed no significant effects (KLIP = 6.48%, PLIP = 5.85%, both $F$s $< 1$).

The success of Experiment 5 in demonstrating an advantage of KLIP over PLIP with a prime exposure of 29 ms is significant in two respects, one theoretical and one methodological. Previous investigations using prime exposures at, or close to, 29 ms have failed to find evidence for phonological priming (Ferrand & Grainger, 1992, 1994; Humphreys et al. 1982). The presence of orthographic priming in these conditions of failed phonological priming has been used to buttress arguments for the independent time evolution of two codes for lexical access with the orthographic access code evolving sooner than the phonological access code (e.g., Ferrand & Grainger, 1994). In the present experiment, the orthographic similarity of KLIP to *clip* and PLIP to *clip* is the same. Nonetheless, KLIP was the superior prime.

## GENERAL DISCUSSION

Our primary goal in the present research was to provide the most stringent and least controversial proof that fluent readers of English satisfy the pseudohomophone test. In local experimental terms, the test is whether a masked (unidentifiable) nonword prime that is homophonic with a target word exerts an influence on the processing of the target word that can be attributed to the nonword's phonological rather than visual similarity with the target word. In more global theoretical and educational terms, the test is whether fluent readers of English access their internal lexicons, automatically and rapidly, by means of phonology. We made the test stringent by using the lexical decision task rather than letter identification or naming, and we made the test uncontroversial by using the mask–prime–target stimulus sequence of form-priming experiments and the measure obtained from the direct comparison of the pseudohomophone with its visual control. Under the preceding conditions, KLIP was shown to be a better prime of *clip* than PLIP (Experiments 1 and 5) and this superiority was shown (by Experiments 2 and 3) to be due to the greater overall phonological similarity of KLIP to *clip* as opposed to number of shared letters and common initial phonemes. The conclusion we draw from the present experiments is that the pseudohomophone test has been satisfied for the reading of English words.

Our secondary goal, in conducting the present research, was to evaluate which aspects of a word's phonological structure were responsible for phonological priming. We compared the priming efficacy of whole-word phonology (using pseudohomophones) with that of onset phonology and rime phonology. The experimental evidence clearly favored the whole-word phonology with rime phonology a more significant factor than onset phonology. The latter outcome is in keeping with the view that in processing printed words rimes or word bodies (Patterson & Morton, 1985) play a more significant role than onsets (e.g., Kay & Bishop, 1987). This may not, however, be a completely general view of the relative roles of onsets and rimes. In the present research the onsets were consistent. There is evidence to suggest that when onsets are inconsistent, naming suffers (Treiman, Mullenix, Bijeljac-Babic, & Richmond-Welty, 1995).

A potentially important understanding derivable from the present results is that onset phonology combines nonlinearly with rime phonology. Shared onsets in the absence of shared rimes yield minimal priming (in Experiment 4, CLEP was not reliably better than PREM); shared rimes, however, yield substantially less priming than shared rimes *and* shared onsets (in Experiments 1, 3, and 5, PLIP was substantially less effective than KLIP).

Satisfaction of the pseudohomophone test, as noted by Humphreys et al. (1982), implicates a major role for phonology in lexical access. The contrary view of phonology's role as ancillary to orthography's leading role is adhered to by classical (Coltheart, 1978) and modern (Coltheart et al., 1993) dual-route theory and by most accounts of visual word recognition that are based on clinical case studies (e.g., Coltheart & Coltheart, 1997; Hanley & McDonnell, 1997). There seem to be no strong empirical reasons, however, for holding to the contrary view (Frost, 1998). Positive laboratory evidence for orthography's hypothesized leading role is lacking. The typical argument advanced in its favor is an argument from negative effects (failure to find a significant phonological influence) (see discussions by Grainger & Ferrand, 1996; Lukatela, Lukatela, & Turvey, 1993; Van Orden et al., 1990). Some recent efforts to go beyond the negative logic have been directed at demonstrating an orthographic contribution to lexical access over and above the contribution of phonology (Ferrand & Grainger, 1994; Grainger & Ferrand, 1996). For example, in mask–prime–target sequences, with prime in lowercase and target in uppercase, is the pseudohomophone *mert* a better prime than the pseudohomophone *mair* for the French word MÈRE? Although the experimental results have been affirmative in showing superior priming by the orthographically similar pseudohomophone, their implications for orthography's role are unclear. The present results suggest that the priming ability of a nonword's orthography depends on the degree to which it conveys the target's phonology (PLIP primed *clip* better than CLEP but worse than KLIP). The preceding impression is reinforced by the results of rapid-naming experiments using the mask–prime–mask–target presentation sequence with 60 ms prime exposure (Lukatela & Turvey, 1994b). Whereas *toad* was named faster following TOWED than PLASM (matched to TOWED in length and frequency), the naming of *toad* following TOLD was no faster than the naming of *toad* following GAVE (matched to TOLD in length and frequency). Relatedly, the advantage of TODS-*toad* over LARM-*toad* was less than the advantage of TODE-*toad* over LAIM-*toad.* Returning to the superior priming in French of orthographically similar pseudohomophones (*mert* versus *mair* as primes for MÈRE), it would seem that this result is most prudently interpreted as the finding of a contribution of number of shared letters when (and, perhaps, only when) the phonology of prime and target are identical. As Grainger and Ferrand (1996, Experiment 3) discovered, when the phonological overlap was partial rather than full (e.g., *%ert* and *%air* rather than *mair* and *mert*), priming was unaffected by the difference in number of shared letters. Apparently, for a fuller understanding of orthographic contributions beyond phonological contributions, research needs to be extended to conditions of partial phonological overlap.

Strong facilitatory effects of form primes in lexical decision have been reported to occur only when the targets have few orthographic neighbors as measured by the N metric (Forster, 1987; Forster & Davis, 1991). Examples of the kinds of data that have led to this conclusion are the inability of *bamp* to prime CAMP (Forster & Davis, 1984), a target which has multiple neighbors (e.g., RAMP, DAMP, BUMP), versus the ability of *sefa* to prime SOFA (Forster, Davis, Schoknecht, & Carter, 1987), a target which has no neighbors. In the present experiments, the targets were chosen purposely to have many neighbors (approximately nine on the average). As the results clearly indicate, a density constraint is not an essential aspect of masked priming in lexical decision. Earlier conjectures (e.g., Forster & Davis, 1991) that this constraint provides an important clue to the nature of the processes underlying word recognition need to be reconsidered. Failure to consider phonology seems to have been at the root of the conjecture. With respect to the targets CAMP and SOFA, the outcomes of the present experiments suggest that *kamp* would readily prime CAMP and do so more strongly than *sefa* primes SOFA.

As noted in the introduction, the theoretical backdrop for Humphreys et al.'s (1982) pseudohomophone test was classical dual-route theory (Coltheart, 1978). Here we consider the test and its positive consequences in the context of the contemporary form of the theory, the dual-route cascade model (Coltheart et al., 1993). In common with the original version, the cascaded processing variant is marked by the explicitness of its dual-route architecture: It has one route that can read words but cannot read nonwords and another route that can read nonwords and regular words by misreads exception words by regularizing them (Coltheart et al., 1993; Coltheart & Rastle, 1994). At the same time the revision differs in notable ways from its predecessor. For example, interactive activation common to a number of neural network models is used to accommodate that the part of the lexical route that involves the levels of letter and visual word-processing units (although discrete rules are preserved for the nonlexical route). Further, processing over both routes abides by the cascade principle of passing activation between levels as soon as activation occurs rather than awaiting the attainment of full activation (a threshold) within a level. Perhaps the most relevant aspects of the revised model are the bidirectional linkages among its several modules. On the lexical route, orthographically coded word-processing units activate a phonological output lexicon and receive, in turn, activation from them. Processing on the nonlexical route can gain access to the orthographic input lexicon via the phonological output lexicon. Assembled phonological patterns can activate stored whole-word phonological patterns (McCann & Besner, 1987), which can then activate stored whole-word orthographic patterns.

Consider the activity generated in the orthographic input lexicon by the letter identification processes corresponding to KLIP, PLIP, and CLEP. Each will generate the same high level of activity in *clip*'s representation but none will activate that representation to the level typically induced by *clip* itself. The incomplete activation arises from the interaction between the letter level and the orthographic input lexicon. The architecture of the connections between the letter processing module and the orthographic input lexicon is such that letter-to-word connections are excitatory whenever the word possesses that particular letter in that particular position and inhibitory otherwise. Each of KLIP, PLIP, and CLEP has three excitatory connections and one inhibitory connection.

On the lexical route, a nonword's ability to prime must vary simply with the number of letters it shares with its target. No differences in priming efficacy among KLIP, PLIP, and CLEP (which all share three letters with the target) can arise on this route. Such differences could arise, however, over the nonlexical route's influence on the lexical route (a nonword's phoneme pattern generated on this route would be passed to the phonological output lexicon and from there to the orthographic input lexicon). The caution is because the normal mode of operation of the dual-route cascade model entails that nonlexical processing lags lexical processing. If priming effects are constrained primarily by the faster processing over the lexical route, then any differences among the nonword primes arising over the nonlexical route would be immaterial. For sake of argument, the temporal ordering characteristic of the dual-route cascade model's normal mode can be reversed, allowing that nonlexical processing leads lexical processing. As a consequence, the pseudohomophone KLIP will activate /klIp/ in the phonological output lexicon and reinforce the activation of *clip* in the orthographic input lexicon, facilitating lexical decision. No such facilitation should occur, however, for the nonhomophonic nonwords PLIP and CLEP. Their phonemic patterns will find no matches in the phonological output lexicon. Allowing that nonlexical processing leads lexical processing yields the advantage of KLIP over PLIP, but it does not produce the observed differences between PLIP and CLEP.

Recent experiments lend support to the view that the phonological coherence hypothesis is an important step toward a more viable account of the relative contributions of orthographic and phonological codes to visual word recognition. Nonintuitive but correct predictions follow from this hypothesis. As will become evident, the experiments evaluating these predictions are logical extensions of a positive pseudohomophone test—each demonstrates that the time to assemble or resolve a single phonological code sets the lower limit on word processing time. For example, the hypothesis predicts that identity priming depends on a word's phonological consistency. For a word whose spelling can support additional nonword pronunciations, identity priming at very brief prime–target SOAs will be less effective than the priming induced by a nonword so written that it can be pronounced only as the target word (Lukatela, Savić, Urošević, & Turvey, 1997). Similarly, identity priming at very brief prime–target SOAs is superior for consistent words (e.g., BEND) than inconsistent words of the same length and frequency (e.g., BOWL) (Lukatela, Frost, & Turvey, in press). Other related predictions of the hypothesis concern rhyme priming and associative priming. In the naming task, priming by rhyming words at very brief prime–target SOAs is inhibitory and independent of orthographic similarity (HOSE and ROWS are equally inhibitory primes for *nose* because they induce strong phonological patterns that are initially similarly different from, and competitive with, the target's phonological pattern) (Lukatela & Turvey, 1996). Further, at very brief prime durations, a word prime associated with a target but pronouncable in two ways (as the word and as a nonword) proves to be a poorer prime for the target than a nonword with only one phonology—that of the associated word (Lukatela, Carello, Savić, Urošević, & Turvey, in press). Outside of the preceding results are others, obtained at relatively long lags ($\approx$250 ms) between unmasked primes and targets, that conform to expectations from the phonological coherence hypothesis with respect to the similarity of word and nonword processing. Included among these are results that show a commonality between words and pseudohomophones (e.g., HOPE, HOAP; FOLE, FOAL) in their sensitivity to frequency and attentional manipulations and in their ability to function as associative primes (Lukatela & Turvey, 1993).

In summary, the success of the pseudohomophone test and the evident significance of word-level phonological similarity call into question core aspects of the dual-route approach to visual word recognition. They also call into question the sufficiency of the idea of rapidly evolving phonological codes as a constraint on modeling visual word recognition. The more comprehensive constraint, it seems, is the idea that phonological codes assume the leading role in visual word recognition (e.g., Bosman & de Groot, 1996; Carello, Turvey, & Lukatela, 1992; Frost, 1998; Liberman, 1995; Lukatela et al., 1997; Lukatela & Turvey, 1994a,b, 1996; Van Orden 1991). The consideration of models in which phonology is foundational to the word recognition process promises a deeper understanding of the roles of orthographic codes and the interdependency of orthography and phonology. For example, a possibly more essential role for orthographic codes is within processes that reduce the noise in the lexicon following activation by a word's phonological code. Because of phonological similarity among words, a given word's phonological code activates more than one lexical representation. If each representation informs about how its respective word is typically spelled, a clean-up process (e.g., suppressing incorrect active representations) can be engaged once a fit between the spelling retrieved by a phonological code and the presented optical form has been achieved. In this view, 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 (Lukatela & Turvey, 1994a,b).

## APPENDIX A

Stimulus materials in Experiments 1–5. Each row identifies, in order, the control prime, the homophonic prime, same onset/different body prime, different onset/different body prime, and the corresponding target.

1. NORK, KORK, COUK, NAUZ, CORK
2. PORD, KORD, COOD, PLOF, CORD
3. DOINS, KOINS, COUNS, DAURG, COINS
4. TRISP, KRISP, CRASP, TEANT, CRISP
5. PLERK, KLERK, CLORK, PROWN, CLERK
6. SLOCK, KLOCK, CLECK, STEEG, CLOCK
7. PREEK, KREEK, CROEK, PLORS, CREEK
8. RATCH, KATCH, CAUCH, ROUPS, CATCH
9. PARD, KARD, CAUD, POUZ, CARD
10. WAPS, KAPS, CAUS, WOOG, CAPS
11. PLUE, KLUE, CLOE, PROY, CLUE
12. PLING, KLING, CLONG, PROOD, CLING
13. FLAM, KLAM, CLOM, FROW, CLAM
14. ZANS, KANS, CALS, ZELT, CANS
15. FREW, KREW, CRAW, FLIZ, CREW
16. ZASE, KASE, CAYE, ZOWN, CASE
17. DOST, KOST, COUT, DAUG, COST
18. TROSS, KROSS, CRUSS, THEND, CROSS
19. LAGE, KAGE, CAWE, LOWP, CAGE
20. MOACH, KOACH, COTCH, MITHS, COACH
21. DRUDE, KRUDE, CRADE, DEAGS, CRUDE
22. YARS, KARS, CAVS, YOWT, CARS
23. PRAFT, KRAFT, CRIFT, PLIRP, CRAFT
24. FLOUD, KLOUD, CLAUD, FRAFE, CLOUD
25. DOLD, KOLD, COOD, DROF, COLD
26. WROWN, KROWN, CREWN, WEERT, CROWN
27. FRAB, KRAB, CRYB, FLOM, CRAB
28. YART, KART, CAYT, YEYS, CART
29. DRACK, KRACK, CRYCK, DEYST, CRACK
30. FLUMP, KLUMP, CLIMP, FRINE, CLUMP
31. PRASH, KRASH, CRISH, PLICE, CRASH
32. SLIFF, KLIFF, CLOFF, SPOMP, CLIFF
33. PLIP, KLIP, CLEP, PREM, CLIP
34. YULT, KULT, CUET, YOEM, CULT
35. TREED, KREED, CROED, THOOB, CREED
36. WROP, KROP, CREP, WOEM, CROP
37. YOPS, KOPS, COYS, YEYE, COPS
38. ZAMP, KAMP, CAUP, ZOUN, CAMP
39. NORN, KORN, COWN, NAWP, CORN
40. NOURT, KOURT, COERT, NEEPS, COURT
41. YATS, KATS, CALS, YOLB, CATS
42. FLUB, KLUB, CLEB, FREG, CLUB
43. BLAY, KLAY, CLOY, BELD, CLAY
44. VUTS, KUTS, CUIS, VERN, CUTS
45. NUPS, KUPS, CURS, NORF, CUPS
46. FRIB, KRIB, CROB, FLOY, CRIB
47. YAST, KAST, CAWT, YOWM, CAST
48. FREST, KREST, CROST, FLONT, CREST

## APPENDIX B

Mean item RTs for Experiment 1. The first column identifies the target words. The other three pairs of columns identify the mean item RTs to the pseudohomophone test prime and to the orthographic control prime for three different SOAs of 43, 57, and 72 ms, respectively.

| | | | | | | |
|---|---|---|---|---|---|---|
| 1. CORK | 637 | 623 | 641 | 670 | 565 | 639 |
| 2. CORD | 574 | 653 | 596 | 638 | 560 | 608 |
| 3. COINS | 589 | 595 | 575 | 595 | 505 | 587 |
| 4. CRISP | 602 | 614 | 604 | 578 | 533 | 552 |
| 5. CLERK | 626 | 614 | 597 | 630 | 518 | 575 |
| 6. CLOCK | 592 | 568 | 517 | 585 | 552 | 565 |
| 7. CREEK | 585 | 623 | 669 | 649 | 576 | 562 |
| 8. CATCH | 596 | 577 | 604 | 562 | 546 | 595 |
| 9. CARD | 537 | 571 | 576 | 498 | 541 | 577 |
| 10. CAPS | 630 | 619 | 576 | 644 | 535 | 627 |
| 11. CLUE | 540 | 611 | 551 | 567 | 484 | 530 |
| 12. CLING | 696 | 668 | 653 | 679 | 600 | 617 |
| 13. CLAM | 611 | 583 | 585 | 830 | 502 | 596 |
| 14. CANS | 660 | 666 | 679 | 601 | 553 | 586 |
| 15. CREW | 616 | 572 | 528 | 569 | 487 | 498 |
| 16. CASE | 599 | 590 | 641 | 602 | 498 | 574 |
| 17. COST | 633 | 585 | 634 | 677 | 505 | 541 |
| 18. CROSS | 544 | 519 | 619 | 588 | 532 | 543 |
| 19. CAGE | 600 | 640 | 710 | 572 | 589 | 593 |
| 20. COACH | 553 | 543 | 602 | 713 | 598 | 575 |
| 21. CRUDE | 577 | 664 | 725 | 604 | 628 | 621 |
| 22. CARS | 541 | 543 | 567 | 545 | 498 | 485 |
| 23. CRAFT | 566 | 561 | 616 | 522 | 484 | 532 |
| 24. CLOUD | 588 | 542 | 621 | 618 | 519 | 556 |
| 25. COLD | 626 | 562 | 521 | 577 | 554 | 509 |
| 26. CROWN | 580 | 633 | 609 | 603 | 540 | 529 |
| 27. CRAB | 617 | 571 | 574 | 611 | 521 | 530 |
| 28. CART | 634 | 671 | 553 | 655 | 548 | 545 |
| 29. CRACK | 547 | 530 | 562 | 581 | 515 | 620 |
| 30. CLUMP | 675 | 665 | 621 | 716 | 668 | 677 |
| 31. CRASH | 545 | 560 | 535 | 580 | 504 | 518 |
| 32. CLIFF | 611 | 633 | 572 | 663 | 567 | 581 |
| 33. CLIP | 614 | 624 | 576 | 546 | 573 | 591 |
| 34. CULT | 658 | 646 | 681 | 757 | 592 | 575 |
| 35. CREED | 603 | 584 | 667 | 710 | 646 | 530 |
| 36. CROP | 632 | 640 | 594 | 738 | 530 | 624 |
| 37. COPS | 556 | 547 | 575 | 621 | 569 | 584 |
| 38. CAMP | 644 | 622 | 643 | 706 | 560 | 614 |
| 39. CORN | 550 | 603 | 520 | 605 | 535 | 567 |
| 40. COURT | 544 | 599 | 539 | 551 | 525 | 540 |
| 41. CATS | 544 | 567 | 516 | 555 | 531 | 527 |
| 42. CLUB | 577 | 552 | 565 | 657 | 574 | 529 |
| 43. CLAY | 585 | 622 | 613 | 672 | 545 | 574 |
| 44. CUTS | 598 | 600 | 553 | 620 | 579 | 528 |
| 45. CUPS | 563 | 609 | 602 | 625 | 526 | 560 |
| 46. CRIB | 602 | 646 | 663 | 654 | 551 | 593 |
| 47. CAST | 614 | 587 | 697 | 613 | 562 | 521 |
| 48. CREST | 608 | 560 | 550 | 589 | 601 | 502 |

## APPENDIX C

Mean item RTs for Experiment 2. The first column identifies the target words. The second and third columns identify the mean item RTs to the same onset/different body prime and to the different onset/same body prime, respectively.

| | | |
|---|---|---|
| 1. CORK | 641 | 644 |
| 2. CORD | 628 | 626 |
| 3. COINS | 542 | 617 |
| 4. CRISP | 668 | 608 |
| 5. CLERK | 582 | 619 |
| 6. CLOCK | 591 | 576 |
| 7. CREEK | 654 | 533 |
| 8. CATCH | 574 | 609 |
| 9. CARD | 605 | 609 |
| 10. CAPS | 607 | 676 |
| 11. CLUE | 554 | 575 |
| 12. CLING | 635 | 656 |
| 13. CLAM | 668 | 625 |
| 14. CANS | 648 | 626 |
| 15. REW | 605 | 617 |
| 16. CASE | 633 | 631 |
| 17. COST | 623 | 637 |
| 18. CROSS | 659 | 583 |
| 19. CAGE | 577 | 608 |
| 20. COACH | 605 | 624 |
| 21. CRUDE | 677 | 684 |
| 22. CARS | 571 | 611 |
| 23. CRAFT | 612 | 551 |
| 24. CLOUD | 571 | 564 |
| 25. COLD | 616 | 591 |
| 26. CROWN | 583 | 611 |
| 27. CRAB | 537 | 578 |
| 28. CART | 630 | 620 |
| 29. CRACK | 606 | 518 |
| 30. CLUMP | 664 | 640 |
| 31. CRASH | 608 | 538 |
| 32. CLIFF | 700 | 629 |
| 33. CLIP | 687 | 592 |
| 34. CULT | 685 | 567 |
| 35. CREED | 626 | 675 |
| 36. CROP | 718 | 656 |
| 37. COPS | 609 | 534 |
| 38. CAMP | 652 | 598 |
| 39. CORN | 615 | 569 |
| 40. COURT | 596 | 616 |
| 41. CATS | 563 | 540 |
| 42. CLUB | 659 | 598 |
| 43. CLAY | 563 | 576 |
| 44. CUTS | 577 | 574 |
| 45. CUPS | 601 | 542 |
| 46. CRIB | 579 | 637 |
| 47. CAST | 607 | 569 |
| 48. CREST | 653 | 633 |

## APPENDIX D

Mean item RTs for Experiment 3. The first column identifies the target words. The second, third, and fourth columns identify the mean item RTs to the pseudohomophone prime, to the different onset/same body prime, and to the same onset/different body prime, respectively.

| | | | |
|---|---|---|---|
| 1. CORK | 575 | 574 | 621 |
| 2. CLAY | 522 | 534 | 543 |
| 3. COINS | 558 | 500 | 555 |
| 4. CRISP | 503 | 534 | 579 |
| 5. CLERK | 530 | 528 | 581 |
| 6. CLOCK | 474 | 552 | 556 |
| 7. CREEK | 537 | 537 | 557 |
| 8. CATCH | 534 | 525 | 553 |
| 9. CLIP | 548 | 542 | 583 |
| 10. CULT | 590 | 570 | 685 |
| 11. CLUE | 526 | 585 | 534 |
| 12. CLING | 572 | 600 | 674 |
| 13. CLAM | 572 | 583 | 571 |
| 14. CANS | 583 | 554 | 528 |
| 15. CREW | 489 | 502 | 523 |
| 16. CASE | 521 | 573 | 596 |
| 17. COST | 535 | 573 | 567 |
| 18. CROSS | 530 | 498 | 523 |
| 19. CAGE | 549 | 549 | 573 |
| 20. COACH | 580 | 594 | 539 |
| 21. CRUDE | 554 | 617 | 588 |
| 22. CARS | 463 | 562 | 532 |
| 23. CRAFT | 502 | 573 | 580 |
| 24. CLOUD | 548 | 485 | 546 |
| 25. COLD | 543 | 522 | 524 |
| 26. CROWN | 501 | 550 | 509 |
| 27. CRAB | 546 | 548 | 537 |
| 28. CART | 502 | 551 | 597 |
| 29. CRACK | 477 | 525 | 577 |
| 30. CLUMP | 577 | 567 | 631 |
| 31. CRASH | 494 | 557 | 507 |
| 32. CLIFF | 559 | 565 | 503 |
| 33. CARD | 495 | 534 | 571 |
| 34. CAPS | 583 | 543 | 597 |
| 35. CREED | 530 | 545 | 583 |
| 36. CROP | 526 | 580 | 555 |
| 37. COPS | 532 | 535 | 539 |
| 38. CAMP | 541 | 536 | 511 |
| 39. CORN | 510 | 546 | 521 |
| 40. COURT | 546 | 533 | 524 |
| 41. CATS | 546 | 477 | 523 |
| 42. CLUB | 507 | 535 | 563 |
| 43. CORD | 547 | 528 | 642 |
| 44. CUTS | 538 | 498 | 548 |
| 45. CUPS | 467 | 550 | 565 |
| 46. CRIB | 511 | 624 | 666 |
| 47. CAST | 508 | 563 | 530 |
| 48. CREST | 566 | 529 | 511 |

## APPENDIX E

Mean item RTs in Experiment 4. The first column identifies the target words. The second and third columns identiify the mean item RTs to the same onset/different body prime and to the different onset/different body prime, respectively.

| | | |
|---|---|---|
| 1. CORK | 572 | 609 |
| 2. CORD | 609 | 602 |
| 3. COINS | 555 | 547 |
| 4. CRISP | 562 | 603 |
| 5. CLERK | 539 | 552 |
| 6. CLOCK | 500 | 522 |
| 7. CREEK | 571 | 579 |
| 8. CATCH | 539 | 553 |
| 9. CARD | 605 | 570 |
| 10. CAPS | 592 | 601 |
| 11. CLUE | 502 | 515 |
| 12. CLING | 580 | 599 |
| 13. CLAM | 537 | 544 |
| 14. CANS | 524 | 582 |
| 15. CREW | 515 | 574 |
| 16. CASE | 524 | 550 |
| 17. COST | 623 | 583 |
| 18. CROSS | 511 | 536 |
| 19. CAGE | 561 | 622 |
| 20. COACH | 566 | 559 |
| 21. CRUDE | 577 | 603 |
| 22. CARS | 528 | 583 |
| 23. CRAFT | 488 | 592 |
| 24. CLOUD | 501 | 568 |
| 25. COLD | 495 | 525 |
| 26. CROWN | 549 | 480 |
| 27. CRAB | 598 | 524 |
| 28. CART | 591 | 581 |
| 29. CRACK | 527 | 539 |
| 30. CLUMP | 605 | 638 |
| 31. CRASH | 514 | 520 |
| 32. CLIFF | 553 | 614 |
| 33. CLIP | 648 | 568 |
| 34. CULT | 690 | 673 |
| 35. CREED | 566 | 655 |
| 36. CROP | 548 | 588 |
| 37. COPS | 503 | 526 |
| 38. CAMP | 572 | 576 |
| 39. CORN | 583 | 553 |
| 40. COURT | 528 | 566 |
| 41. CATS | 505 | 541 |
| 42. CLUB | 537 | 569 |
| 43. CLAY | 560 | 540 |
| 44. CUTS | 600 | 539 |
| 45. CUPS | 621 | 563 |
| 46. CRIB | 623 | 574 |
| 47. CAST | 574 | 536 |
| 48. CREST | 562 | 580 |

## APPENDIX F

Mean item RTs for Experiment 5. The first column identifies the target words. The second and third columns identify the mean item RTs to the pseudohomophone test prime and to the orthographic control prime, respectively.

| | | |
|---|---|---|
| 1. CORK | 604 | 610 |
| 2. CORD | 612 | 520 |
| 3. COINS | 521 | 558 |
| 4. CRISP | 661 | 525 |
| 5. CLERK | 576 | 575 |
| 6. CLOCK | 547 | 538 |
| 7. CREEK | 557 | 548 |
| 8. CATCH | 546 | 507 |
| 9. CARD | 601 | 507 |
| 10. CAPS | 544 | 497 |
| 11. CLUE | 551 | 560 |
| 12. CLING | 591 | 647 |
| 13. CLAM | 553 | 537 |
| 14. CANS | 593 | 534 |
| 15. CREW | 516 | 514 |
| 16. CASE | 535 | 486 |
| 17. COST | 544 | 582 |
| 18. CROSS | 535 | 552 |
| 19. CAGE | 583 | 512 |
| 20. COACH | 553 | 535 |
| 21. CRUDE | 700 | 583 |
| 22. CARS | 553 | 501 |
| 23. CRAFT | 595 | 614 |
| 24. CLOUD | 578 | 524 |
| 25. COLD | 455 | 554 |
| 26. CROWN | 499 | 585 |
| 27. CRAB | 510 | 567 |
| 28. CART | 486 | 624 |
| 29. CRACK | 569 | 565 |
| 30. CLUMP | 598 | 659 |
| 31. CRASH | 497 | 559 |
| 32. CLIFF | 577 | 598 |
| 33. CLIP | 496 | 534 |
| 34. CULT | 526 | 620 |
| 35. CREED | 564 | 633 |
| 36. CROP | 527 | 554 |
| 37. COPS | 548 | 565 |
| 38. CAMP | 494 | 559 |
| 39. CORN | 523 | 560 |
| 40. COURT | 542 | 522 |
| 41. CATS | 477 | 539 |
| 42. CLUB | 488 | 512 |
| 43. CLAY | 503 | 596 |
| 44. CUTS | 487 | 552 |
| 45. CUPS | 521 | 505 |
| 46. CRIB | 561 | 689 |
| 47. CAST | 548 | 630 |
| 48. CREST | 514 | 569 |

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