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Phonological Access of the Lexicon: Evidence From Associative Priming With Pseudohomophones

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Pseudohomophones were used in a primed naming task. In Experiments 1 and 2, target pseudowords that sounded like real words (e.g., CHARE) were preceded either by context words that related associatively to the word with which the target was homophonic (TABLE–CHARE) or by context words that were not associatively related (NOVEL–CHARE). Control pairs were TABLE–THARE and NOVEL–THARE (Experiment 1) and TABLE–CHARK and NOVEL–CHARK (Experiment 2). In relation to NOVEL, TABLE benefited the naming of CHARE but not the naming of THARE or CHARK. TAYBLE–CHAIR pairs were used in Experiment 3. If the prime TAYBLE activated /table/, then /chair/ would be activated associatively and the target CHAIR would be named faster than if TARBLE was the prime. Experiment 4 extended the design of Experiment 3 to include TABLE–CHAIR pairs and a comparison of a short (280 ms) and a long (500 ms) delay between context and target onsets. The priming due to associated pseudohomophones was unaffected by onset asynchrony and equal in magnitude to that due to associated words. Results suggest that lexical representations are coded and accessed phonologically.

Most research on recognizing and pronouncing words has been motivated by the *dual-process theory* (Coltheart, 1978). According to this theory, two independent processes—a direct, visual process and a mediated, phonological process—govern the accessing of the internal lexicon, a mental dictionary that contains permanent information about the identity of individual words. The two independent processes are not used equally. The direct process, which entails a mapping between orthographic features of individual printed or written words and lexical representations, is the primary access route. The secondary access route is provided by the mediated process, which involves a set of grapheme–phoneme correspondence rules that turn spellings into phonological representations and a subsequent mapping from these phonological representations onto lexical entries. According to the theory, whereas the mediated route might dominate word identification in early stages of reading, the direct route 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.

A recent major review of the literature concluded that the dual-process theory is essentially wrong (Humphreys & Evett, 1985). The heart of the criticism was that the appeal to a rule-governed phonological process to access the lexicon is superfluous. Lexical access is achieved for all word forms in a word-specific manner, by the direct visual route. Evidence from studies with Serbo-Croatian language materials and new evidence from studies with English language materials, however, suggest a different criticism of the dual-process theory: The primary constraint on lexical access is phonological, not visual, and this constraint arises not through explicit rules but through continuous statistical regularity (Van Orden, Pennington, & Stone, 1990).

Until recently, empirical support for phonological mediation was sparse. The early demonstration by Rubinstein, Lewis, and Rubenstein (1971) that lexical decisions are slower for homophones (e.g., YOLK) and pseudohomophones, that is, nonwords homophonous with real words (e.g., TRATE), was originally taken as evidence for speech-related processes in word identification. Subsequent research, however, found that the homophony effect on *yes* responses could be eliminated by including many pseudohomophones as foils (Davelaar, Coltheart, Besner, & Jonasson, 1978), which suggests that the phonological route is optional and probably used only for the processing of nonwords. The prelexical phonological processing of a nonword such as TRATE produces a representation that activates the lexical entry for the word TRAIT, making the rejection of TRATE difficult. Unfortunately, because this evidence for prelexical phonology is provided by the slower rejection latencies, it gives rise to doubts about phonology's role in actual word identification. Various investigators have argued that even if phonological coding does occur, it occurs too slowly to be of use in lexical access (e.g., Henderson, 1982; McCusker, Hillinger, & Bias, 1981). As Coltheart, Davelaar, Jonasson, and Besner (1977, p. 551) remarked: "Unequivocal evidence for this view would be obtained by demonstrating that the phonological code for a word is sometimes used in making the 'yes' response to that

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word in a lexical decision or categorization task; such a demonstration remains to be achieved."

Recent experiments on rapid semantic categorization have provided such a demonstration (Van Orden, 1987; Van Orden, Johnston, & Hale, 1988). The basic observation is that subjects produce larger false positive error rates when they respond to foils that are homophonic to category exemplars (e.g., ROWS for the category A FLOWER) than when they respond to spelling control foils (e.g., ROBS). Furthermore, false positive errors to nonword homophone foils (e.g., SUTE for AN ARTICLE OF CLOTHING) exceed false positive errors to nonhomophonic nonword spelling controls; the phonological characteristics of the nonword foils are critical. Many other demonstrations of phonological influences on positive responses are to be found in lexical-decision and naming experiments with Serbo-Croatian materials.

Because of the use of two partially overlapping alphabets, and because of the one-letter–one-phoneme principle for both alphabets, it is possible to construct letter strings in Serbo-Croatian that can be read legally in more than one way. Take BETAP as an example. Read strictly through the letter-to-sound correspondences of the Cyrillic alphabet, this letter string is pronounced /vetar/ and is a high frequency word meaning "wind." Read strictly through the letter-to-sound correspondences of the Roman alphabet, BETAP is pronounced /betap/, a nonword. Reading with a mixture of the two sets of correspondences, Cyrillic and Roman, leads to the pronunciations /vetap/ and /betar/, which are also nonwords. The word meaning "wind" is transcribed in the Roman alphabet as VETAR. This letter string supports only a single reading, /vetar/. No other readings are possible. VETAR, unlike its Cyrillic mate BETAP, is phonologically unambiguous. In the lexical-decision and naming tasks, the latencies for BETAP and for letter strings like it are considerably longer than the latencies for VETAR and for letter strings like it, even though the two letter strings are equal in frequency, syllabic structure, number of letters, and meaning. This contrast has been called the phonological ambiguity effect.

The effect of phonological ambiguity on *yes* responses in lexical-decision and naming tasks implies that phonology mediates word identification. The same conclusion holds for nonwords. Rejection latencies are slowed for the phonologically ambiguous nonword BEMAP in relation to its phonologically unambiguous nonword mate VEMAR. (Arguably, BEMAP is coded into more phonological forms than VEMAR, and because of this, BEMAP's rejection latencies are slowed in relation to those for VEMAR.) The fact that the phonological ambiguity effect occurs for both words and nonwords suggests that phonological mediation must be routine. Significantly, the phonological ambiguity effect is generally larger for words than for nonwords (e.g., Feldman & Turvey, 1983; Lukatela, Feldman, Turvey, Carello, & Katz, 1989; Lukatela, Popadic, Ognjenovic, & Turvey, 1980). As noted previously, experiments showing that homophony influences nonword processing more so than word processing have been interpreted to mean that phonological coding must be rare in ordinary word recognition (Coltheart et al., 1977; Henderson, 1982; McCusker et al., 1981). If we apply this logic to the Serbo-Croatian results, phonological coding must be routine in ordinary word recognition because phonological ambiguity influences the processing of words more than the processing of nonwords.

It has often been suggested that phonological mediation ought to reveal effects dependent on the number of letters or syllables in a word (Forster & Chambers, 1973; Frederiksen & Kroll, 1976; Green & Shallice, 1976). Letter-length effects have been observed regularly in naming but hardly ever in lexical-decision experiments that use English language materials (Henderson, 1982). The lack of such effects in lexical decision is used to argue that contrary to dual-process theory, there is no phonological route to the lexicon. Results from research with Serbo-Croatian materials demonstrate number-of-constituents effects and thereby lead to the contrary conclusion. KOTBA has one ambiguous letter (B), BETAP has two ambiguous letters (B and P), and CABAHA has three ambiguous letters (C, B, and H). In each example, the remaining unambiguous letters are shared letters. In the lexical-decision task with such stimuli, the greater the number of ambiguous letters, the larger the phonological ambiguity effect (Feldman, Kostic, Lukatela, & Turvey, 1983; Feldman & Turvey, 1983). The implication is that there is a prelexical process that is phonologically analytic (Turvey, Feldman, & Lukatela, 1984).

Other evidence points in the same direction. We expect a phonological route to the lexicon to be largely indifferent to variables related to words, such as grammatical role and familiarity. The inflected nouns of the Serbo-Croatian language are most frequent and most prominent grammatically in the nominative singular form. A common finding is that nominative singulars are responded to faster than oblique forms (e.g., Lukatela, Carello, & Turvey, 1987). For example, VENA ("vein" in nominative singular) is responded to much faster than VENI (same word in dative or locative singular); however, if VENA and VENI are written in Cyrillic, that is, BEHA and BEHИ, respectively, then the less frequent and less grammatically prominent dative–locative form BEHИ is responded to faster. The latency difference between BEHA and VENA is large (the phonological ambiguity effect); in contrast, the latencies to BEHИ and VENI do not differ (Feldman et al., 1983). The process underlying the phonological ambiguity effect is not affected by the grammatical significance of word stimuli. Furthermore, the effect has been shown to be indifferent to frequency; it is of the same magnitude for both frequent and infrequent words (Lukatela & Turvey, 1987).

There are two kinds of error patterns that enforce the notion of phonological mediation. Rejecting a BETAP-type word as a word occurs on a high proportion of the times such a word is presented, for example, 20% (Lukatela, Savic, Gligorijevic, Ognjenovic, & Turvey, 1978, Experiment 1), 19% (Lukatela et al., 1978, Experiment 2), 26% (Lukatela et al., 1980), 22% (Lukatela, Feldman, et al., 1989, Experiment 1), and 21% (Lukatela, Feldman, et al., 1989, Experiment 2). In these examples, average false negatives on phonologically unambiguous words were in the range of 1%–4%. False negatives of the order of 20%–25% suggest a process in which the representation activating the lexicon frequently does not correspond to a word. This is understandable if BETAP can give rise to a number of phonological representations that do not correspond to a word and the lexicon is accessed through phonological representations. The same conclusion follows from a consideration of false positive responses.

There are two significant types of phonologically ambiguous nonwords in Serbo-Croatian. One type consists of letter strings that are (a) composed of shared letters, one or more of which are ambiguous, (b) unreadable as a word in either Roman or Cyrillic, and (c) unreadable as a word in a mixture of both alphabets. The other type satisfies (a) and (b) but not (c). Consider the nonword HAPEB as an example of the second type. If the letter–phoneme correspondences of both alphabets are applied to HAPEB, then one of the resulting six phonological descriptions corresponds to a word, namely, /napev/, meaning "tune." It comes about by assigning the phoneme /n/ to H by the Cyrillic alphabet, assigning the phoneme /p/ to P by the Roman alphabet, and assigning the phoneme /v/ to B by the Cyrillic alphabet. Compare HAPEB to a nonword of the first type, such as BEMAP. BEMAP has all but one letter in common with a real word (BETAP) and all but one phoneme in common with this real word. HAPEB similarly has all but one letter in common with a real word (НАПЕВ). HAPEB, however, has all phonemes in common with a real word if both alphabets apply. If lexical access is visual, then false positives to BEMAP and HAPEB ought to be few and equal. In contrast, if lexical access is based on phonemic descriptions computed prelexically and if the computation is analytic, assigning as many phonemes per letter as permitted, then false positives ought to be greater for HAPEB. Experimentation shows that BEMAP and its unambiguous nonword control VEMAR generate the same small number of false positives (about 2%–3%). When preceded by a neutral-context word, HAPEB generated 31% false positives; when preceded by an associate of /napev/, namely, MELODIJA ("melody"), HAPEB generated 55% false positives (Lukatela, Turvey, Feldman, Carello, & Katz, 1989). The latencies of the false positives in the neutral and associative contexts were 890 ms and 779 ms, respectively. Furthermore, the false positive *yes* response times to HAPEB-type nonwords and correct *yes* response times to their corresponding control words (e.g., NAPEV) were closely similar, 824 ms to 795 ms. The same pattern of results with respect to BETAP and VEPAR, and HAPEB and NAPEV, held for naming (Lukatela, Feldman, et al., 1989; Lukatela, Turvey, et al., 1989). These results are understandable if (a) a phonologically ambiguous nonword can give rise automatically to all of the phonological representations that its letter structure permits, (b) for some phonologically ambiguous nonwords one of the automatically generated phonological representations corresponds to a word, and (c) the lexicon is accessed through phonological representations.

The conclusion to be drawn from the aforementioned English and Serbo-Croatian data is that phonological mediation plays a significant role in lexical access. The supportive data from English language studies remains limited; however, the majority of the evidence provided was from Serbo-Croatian studies, and most of it was obtained with tasks that exploited the peculiarities of the Serbo-Croatian orthography. Our goal in the present article is to provide a further line of support within the English language for this core hypothesis of the dual-process theory. The experiments reported constitute a return to the pseudohomophony manipulation introduced by Rubenstein et al. (1971); they exploit, therefore, a feature of the English orthography that has no counterpart in the phonetically precise Serbo-Croatian orthography. We place the pseudohomophony manipulation in the context of the associative priming phenomenon, and we use naming rather than lexical decision as the response measure. Associative priming is the improvement in word identification that follows from preceding the target word by an associate, for example, TABLE–CHAIR, in which the control is provided by the same target word following a nonassociative, for example, NOVEL–CHAIR. This effect is said to arise from the connections within the internal lexicon. From the perspective of evaluating the nature of lexical access, naming has the advantage in that unlike lexical decision, it does not necessitate postlexical processes. In signal-detection terminology, whereas lexical decision involves sensitivity and bias, naming involves only sensitivity; it does not entail a decision that requires a criterion (Seidenberg, Waters, Sanders, & Langer, 1984).

Consider the task of naming the pseudohomophone CHARE when it follows the "associate" TABLE. If TABLE's phonology is computed prelexically, and this representation is used to access the lexicon, then TABLE would fully activate its lexical representation /table/ and partially activate (through lexical interconnections) the associated representation /chair/. The preactivation of /chair/ could benefit the naming of CHARE in two ways. The first way is based on the reasonable assumption that the prelexically computed phonology is incomplete; for example, it would not specify stress. Consequently, to name a word, the full phonology must be retrieved from the lexicon. If CHARE is coded phonologically prior to lexical access, then it will contact /chair/ in the lexicon, and because of the associative priming of /chair/, it will retrieve the full phonology faster when it follows TABLE than when it follows a nonassociate. The second way CHARE could benefit from the priming of /chair/ is based on the assumption that the prelexical computation of phonology and the accessing of lexical phonology ordinarily interact in the determination of a letter string's name. If so, then CHARE will benefit from the prior presentation of TABLE through the feedback from the preactivated lexical item /chair/ to the process by which CHARE's phonology is assembled. (The notions of assembled phonology and lexical phonology are not mutually exclusive, and in interpretations of Serbo-Croatian word naming the need for both sources of phonological information has been repeatedly underscored [Carello, Lukatela, & Turvey, 1988; Lukatela & Turvey, 1987; Lukatela & Turvey, 1990b; Lukatela, Turvey, et al., 1989]. An analogous though weaker version of the same idea has been advanced for English by McCann and Besner, 1987.) Similar arguments apply to the even more interesting case in which the pseudohomophone is in the role of the prime, for example, TAYBLE–CHAIR. According to the phonological mediation hypothesis, the context stimulus TAYBLE will activate the lexical entry /table/ and, by lexical interconnections, the associate /chair/. As a result, naming CHAIR will benefit from the prior processing of TAYBLE.

The phonological mediation hypothesis of dual-process theory makes the following predictions.

1. A target pseudohomophone will be named faster in the context of an associate of the pseudohomophone's source word than in an unrelated context.
2. A target word will be named faster in the context of a pseudohomophone whose source word is an associate of the target word than in the context of the pseudohomophone whose source word is unrelated to the target word.

Experiments 1 and 2 test Prediction 1, and Experiments 3 and 4 test Prediction 2.

Experiment 1

This experiment uses stimuli constructed similarly to McCann and Besner's (1987) demonstration that pseudohomophones are named faster than ordinary nonwords. The nonpseudohomophone controls (e.g., THARE) were distinguished from the pseudohomophones (e.g., CHARE) by a single initial letter. The experiment compared target-naming latencies for TABLE–CHARE, NOVEL–CHARE, TABLE–THARE, and NOVEL–THARE pairs.

Method

Subjects. The participants in the experiment were 24 students from the Department of Psychology at the University of Connecticut. A subject was assigned to one of four groups, giving 6 subjects per group.

Materials. A set of 60 semantically related word pairs (e.g., TABLE–CHAIR) was generated on the basis of a high associativity rating by Palermo and Jenkins (1964) and in a tabulation of associative norms collected at the University of Connecticut. In each context–target pair the target word was replaced by its pseudohomophone to produce a set of 60 word–pseudohomophone pairs (TABLE–CHARE). With the same pseudohomophone targets, another set of 60 associatively unrelated pairs (NOVEL–CHARE) was also generated.

A third set of 60 word–nonword pairs (e.g., TABLE–THARE) was generated by replacing the first (or in some cases the second) grapheme of each pseudohomophone (CHARE) with another legal grapheme (THARE). A fourth set of 60 word–nonword pairs was assembled by combining the associatively unrelated context word (GULF) with the nonpseudohomophone target (THARE). The complete set of experimental materials is presented in Appendix A. In addition, a foil set of 48 word–word pairs was selected from a different word list. In one half of the foil pairs, the context word and target word were associatively related, and in the other half they were unrelated.

Four counterbalanced lists of stimuli pairs were prepared. In each group, each subject saw 15 instances of each stimulus pair. For example, in one group the subjects saw 15 FOOT–HANNED (associated pseudohomophone derived from HAND) pairs, 15 HAMMER–LALE (associated nonpseudohomophone derived from NAIL pairs, 15 FACT–KWEEN (nonassociated pseudohomophone derived from QUEEN) pairs, and 15 DRESS–SUDDER (nonassociated nonpseudohomophone derived from BUTTER) pairs. In addition, each subject saw 24 related word–word pairs (GOLF–BALL) and 24 unrelated word–word pairs (FOOL–BALL).

Design. The major constraint on the design was that a given subject never encountered a given target more than once. There were four (2 × 2) stimulus types (Associative Relation × Target Homophony). Each subject was presented with 15 experimental stimulus pairs from each of the four types and 48 foils, giving 108 stimulus pairs. The experimental sequence was divided into quarters, with a brief rest after each quarter. Stimulus types were ordered pseudorandomly within each quarter. Experimental sequence was preceded by a practice sequence of 32 stimulus pairs.

Procedure. Subjects (run 1 at a time) sat in front of an Apple IIe computer in a dimly lit room. A fixation point was centered on the screen. On each trial, there was a brief auditory warning signal after which a letter string appeared for 500 ms above the fixation point. After a 100-ms interstimulus interval, another letter string appeared below the fixation point for 500 ms. Subjects were told that they would be viewing word–word and word–nonword pairs and that some of the nonwords, when pronounced, would sound like English words. Subjects were required to pronounce each target letter string as quickly and as distinctly 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 pronunciation included a phoneme not specified by allowable grapheme-to-phoneme correspondences in English, the pronunciation was not smooth (i.e., subjects hesitated after beginning to name), or the response was not loud enough to trigger the voice key. To ensure that subjects were reading the contexts, subjects were asked occasionally (on fewer than 5% of the trials) by a computer message to report orally both words (only some of the foil word–word pairs were controlled) after the target word was named. 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 correctly stored in the computer memory.

Results and Discussion

For each subject, naming latencies more than 2 *SD*s above or below the subject's mean in all conditions were considered errors. (This procedure was followed for all of the reported experiments.) The mean latencies of each group of subjects, standard deviations, and errors for related and unrelated contexts are presented in Table 1.

A 2 × 2 analysis of variance (ANOVA) was conducted on the latency data with variables of associativeness and homophony (pseudohomophones vs. nonpseudohomophones). Homophony was significant (pseudohomophones = 610 ms vs. nonpseudohomophones = 653 ms) for subjects, $F(1, 23) = 35.53$, $p < .001$, and for stimuli, $F(1, 59) = 34.04$, $p < .001$. Associativeness was not significant as a main effect (related = 630 ms vs. unrelated = 633 ms), but it interacted with homophony (associative effect for pseudohomophones = 21 ms vs. associative effect for nonpseudohomophones = −15 ms) significantly for subjects, $F(1, 23) = 14.83$, $p < .001$, and for stimuli, $F(1, 59) = 4.33$, $p < .05$.

Because of the Associativeness × Pseudohomophony interaction, we performed separate analyses on the pseudohomophone data and the nonpseudohomophone data. Thus, associativeness for the pseudohomophone latencies (related = 600 ms vs. unrelated = 621 ms) proved to be significant for subjects, $F(1, 23) = 17.38$, $p < .001$, and for stimuli, $F(1, 59) = 3.88$, $p < .05$.

A 2 × 2 error analysis showed no significant main effects. There was, however, a significant Associativeness × Homophony interaction (associative effect for pseudohomophone errors = 6.11% vs. associative effect for nonpseudohomophone errors = −1.94%) for subjects, $F(1, 23) = 8.23$, $p < .01$, and for stimuli, $F(1, 59) = 7.19$, $p < .01$. A separate analysis for pseudohomophone error data showed that associativeness (related = 5.83% vs. unrelated = 11.94%) was significant for both subjects and stimuli, $F(1, 23) = 6.84$, $p < .01$, and $F(1, 59) = 5.07$, $p < .05$, respectively. For the nonpseudohomophone data, the main effect of associativeness (related = 661 ms vs. unrelated = 646 ms) was not significant in the latency data for subjects, $F(1, 23) = 3.74$, $p > .05$, and for stimuli, $F(1, 59) = 1.42$, $p > .05$. Associativeness (related = 7.22% vs. unrelated = 5.28%) was also not significant in the nonpseudohomophone error data for subjects, $F(1, 23) = 1.62$, $p > .05$, and for stimuli, $F < 1$.

In summary, CHARE was named faster and with fewer errors (as defined earlier) when the context was TABLE than when the context was NOVEL. In contrast, the naming of THARE showed statistically no differential sensitivity to TABLE and NOVEL.

Experiment 2

Although the outcome of Experiment 1 was straightforward, questions might be raised about the high error rates for nonrelated pseudohomophone targets and the manner in which the control nonwords were created. With respect to the high error rates, note that some of the pseudohomophones (e.g., KLOWD, HAHT, SMUTHE, . . . , standing for CLOUD, HOT, SMOOTH, . . . , respectively) in Experiment 1 (see Appendix A) did not constrain the reader to the expected homophonic pronunciation and evidently left room for various phonological interpretations. With respect to the control nonwords, one may object that the graphemic structure of nonpseudohomophones (e.g., THARE) was less like the source word CHAIR than was the graphemic structure of pseudohomophones (e.g., CHARE). Consequently, the differences obtained in Experiment 1 could be attributed wholly or in part to the graphemic advantage of the pseudohomophones over their controls. In Experiment 2 we addressed this potential criticism. If CHARE were the pseudohomophone, then the new control would be CHARK, that is, a letter string that has the same letter overlap with the source word CHAIR as does the corresponding pseudohomophone. More precisely, each "pseudohomograph" control and the corresponding pseudohomophone would share the same number of letters with the source word in terms of both exact letter positions and total number of letters. Because this manipulation required an almost new basic set of 64 source pairs (different from that in Experiment 1), Experiment 2 also tests the generality of the preceding results. Finally, in this experiment one set of words served as both associated and nonassociated contexts, in contrast to Experiment 1, in which different sets of words functioned in these roles. This additional manipulation guarded against uncontrolled effects due to differences in average familiarity of the context stimuli.

Table 1
Mean Naming Latencies (in Milliseconds) and Error Rates (in %) With the Corresponding Standard Deviations for Subjects and Items in Experiment 1

Target	Context–target relation			
	Related		Unrelated	
	Latency	Error rate	Latency	Error rate
Pseudohomophone				
M	600	5.83	621	11.94
Subject *SD*	81	6.61	82	9.63
Item *SD*	68	12.21	80	17.92
Nonpseudohomophone				
M	661	7.22	646	5.28
Subject *SD*	94	5.17	109	7.35
Item *SD*	78	10.79	90	9.45

Method

Subjects. The participants in the experiment were 24 students from the Department of Psychology at the University of Connecticut. A subject was assigned to one of four groups, giving 6 subjects per group. The subjects did not participate in Experiment 1.

Materials. The stimuli (see Appendix B) were generated from a set of 64 associatively related word pairs selected on the basis of a high associativity rating in Palermo and Jenkins (1964) and in a tabulation of associative norms collected at the University of Connecticut. In addition, a list of different words that could be conveniently transcribed as pseudohomophones was compiled in part from the source words used by Perfetti, Bell, and Delaney (1988), and in part from our own work. The list was presented to a pool of 60 undergraduate psychology students at the University of Connecticut. Each student in the pool was asked to read through the list on a word-by-word basis and after each word to write down on a prepared form the first three words that may have come to his or her mind. The appropriate associates were picked up to create new associatively related word–word pairs that were paired to make 32 related word quadruples (e.g., BITE–TEETH, CIDER–JUICE). Within each related quadruple the mutual substitution of context words produced a new unrelated word quadruple of two associatively unrelated pairs (e.g., CIDER–TEETH, BITE–JUICE). In each context–target pair the target word was replaced by its pseudohomophone to produce a set of 64 associatively related word–pseudohomophone pairs or 32 related pseudohomophone quadruples (BITE–TEATH, CIDER–JOOCE). With the same pseudohomophone targets, a second set of 32 associatively unrelated pseudohomophone quadruples (e.g., CIDER–TEATH, BITE–JOOCE) was also generated.

A third set of 64 associated word–pseudohomograph pairs or 32 related pseudohomograph quadruples (e.g., BITE–TERTH, CIDER–JORCE) was generated; thus each pseudohomograph target shared the same letters as the pseudohomophone target, in position and out of position, with the source word (e.g., TEETH, JUICE, respectively). A fourth set of 32 unrelated pseudohomograph quadruples was assembled by mutually substituting the two context words in each quadruple (e.g., CIDER–TERTH, BITE–JORCE). With regard to all pseudohomophones and pseudohomographs used in Experiments 2 and 3, a word of caution might be necessary: They met an arbitrary criterion of lexicality for a letter sequence. Namely, the pseudohomophones and pseudohomographs ought to have no entry in the work by Carroll, Davies, and Richman (1971), which is based on a corpus of approximately 5,000,000 words (tokens).

To prevent any special response strategy in rapid naming, a foil set of 32 associated word–word pairs (e.g., SOFT–HARD) and a corresponding (i.e., having the same target words) foil set of 32 unrelated word–word pairs (e.g., CHESS–HARD) were selected from a different word list. In addition, a third foil set of 32 word–nonword pairs was also created. The nonword targets were easily pronounceable, legal English letter strings.

As before, four counterbalanced lists of stimuli pairs were prepared. In each group, each subject saw eight quadruples with 16 instances of each stimulus pair. For example, in one group the subject would see 16 BITE–TEATH (associated pseudohomophone derived from TEETH) pairs, 16 DEAF–MERT (associated pseudohomograph derived from MUTE) pairs, 16 MOAN–FYVE (unrelated pseudohomophone derived from FIVE) pairs, and 16 WEAR–BUSHER (unreleted pseudohomograph derived from BUTTER) pairs. In addition, each subject saw 16 related word–word pairs (SOFT–HARD), 16 unrelated work–word pairs (OLIVE–STRICT), and 32 word–nonword pairs (ROSE–SHAIG). An experimental list consisted of 128 stimulus pairs.

Design and procedure. These were the same as in Experiment 1 except that the context and target presentation time were both reduced to 400 ms each, leaving the interstimulus interval unchanged (100 ms).

Results and Discussion

The mean latencies, standard deviations, and errors for pseudohomophones and pseudohomographs in associatively related and unrelated contexts are presented in Table 2.

We conducted a 2 × 2 ANOVA on the latency data with variables of associativeness and homophony (pseudohomophones vs. pseudohomographs). Homophony was significant (pseudohomophones = 567 ms vs. pseudohomographs = 578 ms) for subjects, $F(1, 23) = 7.31$, $p < .01$, but not for stimuli, $F(1, 63) = 3.57$, $p > .05$. Associativeness was not significant as a main effect (related = 569 ms vs. unrelated = 575 ms), but it interacted with homophony (associative effect for pseudohomophones = 20 ms vs. associative effect for pseudohomographs = −5 ms) significantly for subjects, $F(1, 23) = 19.72$, $p < .001$, and stimuli, $F(1, 63) = 5.15$, $p < .05$.

Table 2
Mean Naming Latencies (in Milliseconds) and Error Rates (in %) With the Corresponding Standard Deviations for Subjects and Items in Experiment 2

	Context–target relation			
	Related		Unrelated	
Target	Latency	Error rate	Latency	Error rate
Pseudohomophone				
M	557	3.39	578	3.91
Subject *SD*	70	4.51	79	4.44
Item *SD*	59	8.84	54	8.56
Pseudohomograph				
M	582	2.86	574	3.91
Subject *SD*	78	4.87	78	4.44
Item *SD*	48	7.08	50	10.80

Because of the Associativeness × Homophony interaction, we performed separate analyses on the pseudohomophone data and the pseudohomograph data. Thus, associativeness for the pseudohomophone latencies (related = 557 ms vs. unrelated = 578 ms) proved to be significant for subjects, $F(1, 23) = 10.91$, $p < .01$, and stimuli, $F(1, 63) = 5.26$, $p < .05$. A 2 × 2 error analysis showed no significant effects and no interaction.

If we consider the pseudohomograph data, the main effect of associativeness was not significant for latencies (related = 582 ms vs. unrelated = 574 ms)—for subjects, $F(1, 23) = 2.06$, $p > .1$; for stimuli, $F(1, 63) = 0.2$, $p > .1$—nor was it significant for errors (all Fs < 1). The mean naming latency for associatively related pseudohomophones (557 ms) was reliably faster than for associatively related pseudohomographs (582 ms) both for subjects, $F(1, 23) = 18.17$, $p < .001$, and for stimuli, $F(1, 63) = 7.18$, $p < .01$.

The results suggest an associative priming of pseudohomophones and no contextual effect for the pseudohomographic controls. The magnitude of the obtained contextual effect (21 ms) compared favorably with the magnitude obtained on the foil set of 32 word–word stimulus pairs (HARD–SOFT = 525 ms vs. CHESS–SOFT = 540 ms).

Experiment 3

Although the results of Experiments 1 and 2 can be discussed in terms of the automatic priming of /chair/ and in terms of the prelexical phonological processes by which CHARE's name is assembled, other interpretations are possible. In particular, given the challenge of naming nonwords rapidly, a subject might have adopted a conscious strategy of generating on each trial a word associated with the context to help in the pronunciation of the nonword target. The fact that 25% of the pairs were of the GOLF–BALL type and 16% were of the TABLE–CHARE type might have encouraged such a strategy.

Experiment 3 examined the efficacy of a pseudohomophone as an associated prime. Specifically, the experiment compared naming latencies to CHAIR when presented after TAYBLE and TARBLE in an experimental setting in which TARBLE–CHAIR pairs accounted for only about 8% of all pairs. In this experiment we therefore militate against the conscious association–pronunciation strategy identified earlier and provide thereby a purer test of the phonological mediation hypothesis than the preceding two experiments. According to the phonological mediation hypothesis, TAYBLE will activate the lexical entry /table/, resulting in the priming of that entry's associate, /chair/. The context TARBLE, although visually similar to TAYBLE, will not activate the lexical item /table/, and therefore not prime /chair/. Consequently, naming CHAIR ought to be faster in the context TAYBLE than in the context TARBLE.

The design of this experiment is significant in an additional way. If TAYBLE–CHAIR is faster than TARBLE–CHAIR, then it would emphasize the prelexical–lexical nature of pseudoassociative priming. An effect arising from the combination of naming as the dependent measure and pseudohomophones as primes will pose difficulties for any postlexical account.

The consensus is that naming involves few if any postlexical checks and that associative priming is purely lexical (Balota & Chumbley, 1985; Carello et al., 1988; Seidenberg et al., 1984).

Method

Subjects. The participants in the experiment were 24 students from the Department of Psychology at the University of Connecticut. A subject was assigned to one of four groups, giving 6 subjects per group. None of the subjects had participated in the previous experiments.

Materials. The stimuli (see Appendix C) were generated from the same general list that was used in Experiment 2, though not all of the word–word pairs in this experiment were necessarily identical to those in Experiment 2. A basic set of 64 associatively related word pairs were paired to make 32 related word quadruples (e.g., BITE–TEETH, HATE–LOVE). Within each related quadruple, the mutual substitution of context words produced a new unrelated word quadruple of two associatively unrelated pairs (e.g., HATE–TEETH, BITE–LOVE). In each context–target pair the context word was replaced by its pseudohomophone to produce a set of 64 associatively related pseudohomophone–word pairs or 32 related pseudohomophone quadruples (BIGHT–TEETH, HAIT–LOVE). With the same word targets, a second set of stimuli that consisted of 32 associatively unrelated pseudohomophone quadruples (e.g., HAIT–TEETH, BIGHT–LOVE) was also generated.

A third set of 64 associated pseudohomograph–word pairs that consisted of 32 related pseudohomograph quadruples (e.g., BIRET–TEETH, HANT–LOVE) was generated; thus each pseudohomograph context shared the same letters as the pseudohomophone context, in position and out of position, with its source word (e.g., BITE, HATE, respectively). A fourth set of 32 unrelated pseudohomograph quadruples was assembled by mutually substituting the two context words in each quadruple (e.g., HANT–TEETH, BIRET–LOVE). A summed bigram frequency (Mayzner & Tresselt, 1965) was computed for each pseudohomophone and pseudohomograph; in the majority of pseudohomographs (i.e., 49 of 64), the summed bigram frequency was higher than in the corresponding pseudohomophones. In addition, a comparison set of 32 associated word–word pairs (e.g., BOY–GIRL) and another set having the same target words but unrelated context words (e.g., GULF–GIRL) were selected from a different word list. The target words in the comparison set were selected to have approximately the same average frequency of occurrence as the target words in the four experimental sets. To prevent any special response strategy in rapid naming, a foil set of 64 nonword–nonword pairs was assembled. In the same vein, to discourage further a subject's guessing strategy, a foil set of 32 pseudohomophone–nonword pairs was also created. All nonwords were easily pronounceable, legal English letter strings.

As in the preceding experiments, four counterbalanced lists of stimuli pairs were prepared. In each group, each subject saw eight quadruples with 16 instances of each stimulus pair. For example, in one group the subject saw 16 BIGHT–TEETH (associated pseudohomophone context derived from BITE) pairs, 16 DELF–MUTE (associated pseudohomograph context derived from DEAF) pairs, 16 MONE–FIVE (unrelated pseudohomophone context derived from MOAN) pairs, and 16 WAUR–BUTTER (unrelated pseudohomograph context derived from WEAR) pairs. In addition, each subject saw 16 related word–word pairs (e.g., BOY–GIRL), 16 unrelated work–word pairs (e.g., SKULL–LAW), 32 pseudohomophone–nonword pairs (e.g., LOGIK–SHAIG), and 64 nonword–nonword pairs (e.g., TINFER–PROLIT). The foil sets were used to counter the development of biases, such as (a) always looking for an associative relation, (b) making predictions about targets based on the sound of the context, and (c) trying to make contexts sound like words. An experimental list consisted of 192 stimulus pairs.

Design. The design was similar to that in Experiments 1 and 2, except for an increase in the number of foil stimuli pairs. This increase produced a low ratio (1:3) in the presentation of associatively related in relation to associatively unrelated stimulus pairs within each quarter. The experimental sequence was preceded by a practice sequence of 32 stimulus pairs.

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

Results and Discussion

The mean latencies, standard deviations, and errors for pseudohomophones and pseudohomographs in associatively related and unrelated contexts are presented in Table 3. We conducted a 2 × 2 ANOVA on the latency data with variables of associativeness and the homophony of the context (pseudohomophone context vs. pseudohomograph context). Associativeness as a main effect (related = 530 ms vs. unrelated = 538 ms) was significant for subjects, $F(1, 23) = 4.33$, $p < .05$, but not for stimuli, $F(1, 63) = 1.66$, $p > .1$. The main effect of context homophony was not significant for subjects, $F(1, 23) = 1.43$, $p > .1$, or for stimuli, $F(1, 73) = 0.96$, $p > .1$, respectively. Context homophony, however, interacted with associativeness (associative effect for pseudohomophone context = 20 ms vs. associative effect for pseudohomograph context = 4 ms). The interaction was significant both for subjects, $F(1, 23) = 17.84$, $p < .001$, and for stimuli, $F(1, 63) = 4.35$, $p < .05$.

The Associativeness × Context Homophony interaction motivated separate analyses on the pseudohomophone context pairs and the pseudohomograph context pairs. Thus, the effect on naming latency of associativeness when contexts were pseudohomophones (related = 522 ms vs. unrelated = 542 ms) proved to be significant for subjects, $F(1, 23) = 19.07$, $p < .001$, and for stimuli, $F(1, 63) = 6.76$, $p < .01$.

A 2 × 2 error analysis displayed a significant main effect of associativeness (related = 2.47% vs. unrelated = 0.91%), $F(1, 23) = 5.75$, $p < .05$, and $F(1, 63) = 7.28$, $p < .01$. The main effect of context homophony was not significant, $F(1, 23) = 1.68$, $p > .1$, and $F(1, 63) = 1.54$, $p > .1$; neither was the

Table 3
Mean Naming Latencies (in Milliseconds) and Error Rates (in %) With the Corresponding Standard Deviations for Subjects and Items in Experiment 3

	Context–target relation			
	Related		Unrelated	
Context	Latency	Error rate	Latency	Error rate
Pseudohomophone				
M	522	1.82	542	0.78
Subject *SD*	45	2.90	47	2.11
Item *SD*	41	5.24	46	3.73
Pseudohomograph				
M	538	3.13	534	1.04
Subject *SD*	53	4.12	49	2.38
Item *SD*	51	7.63	41	3.60

Context Homophony × Associativeness interaction ($F < 1$). A similar analysis on the context pseudohomograph data revealed that the main effect of associativeness was not significant for latencies (related = 538 ms vs. unrelated = 534 ms) either for subjects or for stimuli ($F < 1$ in both cases).

A further observation was that the mean naming latency for word targets preceded by associatively related pseudohomophones (557 ms) was reliably faster than the mean naming latency for word targets preceded by associatively related pseudohomographs (582 ms), both for subjects, $F(1, 23) = 18.17$, $p < .001$, and for stimuli, $F(1, 63) = 7.18$, $p < .01$.

How efficient are pseudohomophones as associative primes compared with real-word contexts? An approximate evaluation is provided by an ANOVA (with variables of associativeness and context lexicality) conducted on the target latencies of the experimental set of 32 pseudohomophone–word pairs (e.g., TAYBLE–CHAIR) and the set of 32 word–word pairs (BOY–GIRL). The analysis was within subjects and between items. The evaluation is only approximate because of the different target items and different associative strengths in the comparison pairs. The main effect of associativeness (related = 521 ms vs. unrelated = 540 ms) was significant for subjects, $F(1, 23) = 38.87$, $p < .001$, and for stimuli, $F(1, 62) = 10.24$, $p < .01$, respectively. The important effects of context lexicality (pseudohomophones = 532 ms vs. words = 529 ms) and the Associativeness × Context Lexicality interaction (Associativeness × Pseudohomophone Context = 20 ms vs. Associativeness × Word Context = 19 ms) were not significant ($F < 1$ in both cases).

Finally, we note that given the design of the experiment, a strategy of looking for associations was not encouraged (only ⅙ of all stimulus pairs were associated words), and neither was the assembling of a name for the prime (only targets had to be named). Despite these discouraging features of the experimental design, TAYBLE primed CHAIR, which suggests that neither the effect of association nor the effect of phonology was optional.

Experiment 4

In Experiment 3, the stimulus onset asynchrony (SOA) between context and target was 500 ms. With respect to the trials with nonword contexts, the delay from context to target may have allowed subjects the opportunity to construct the context's phonology and then to determine consciously whether there was a word with which it was homophonic. That is, the source of TAYBLE's advantage over TARBLE in the priming of CHAIR may have resided in strategic postlexical processes rather than automatic prelexical and lexical processes. The inclusion in Experiment 3 of a relatively small proportion of TAYBLE–CHAIR pairs (8.3% of the total number of pairs) was to minimize conscious guessing strategies of the preceding kind, but the possibility remains that this protective measure was not sufficient. In Experiment 4, the conditions of priming by a nonword homophonic with an associate of the target were repeated with SOAs of 280 ms and 500 ms. A much-reduced delay of target in relation to the context ought to restrain the use of conscious strategies or at least render them less effective. Consequently, if the priming effect of TAYBLE is strategic, then there ought to be an interaction between onset asynchrony and the associative relation between context and target; that is, in relation to TARBLE, TAYBLE ought to prime CHAIR less with an SOA of 280 ms than with an SOA of 500 ms.

In addition to examining the effect of SOA, Experiment 4 was designed to provide an assessment of the degree to which priming a target word by a nonword homophonic with an associate of the target is comparable to priming a target word by an associated word. In Experiment 3, the relative efficacy of pseudohomophonic priming had been evaluated statistically by comparing pairs such as TAYBLE–CHAIR with pairs such as BOY–GIRL. Neither the lexical status of the context nor the Associativeness × Context Lexicality interaction was significant. In Experiment 4, the comparison is made across pairs that have the same target and the same associative strength, for example, TAYBLE–CHAIR versus TABLE–CHAIR. We looked for evidence that pseudohomophonic nonwords prime as well as words in the latency differences between (a) CHAIR preceded by TAYBLE and BLOO and (b) CHAIR preceded by TABLE and BLUE. If pseudohomophones prime equally as well, then the advantage of TAYBLE over BLOO in (a) ought to be of the same magnitude as the advantage of TABLE over BLUE in (b), and if the pseudohomophonic priming effect witnessed in the preceding experiments is due to nonstrategic processes, then this equation ought to hold equally over both the short (280 ms) and long (500 ms) SOAs.

Method

Subjects. The participants in the experiment were 60 students at the University of Connecticut. For participating, subjects received either credit for an introductory psychology course or were paid $5. A subject was assigned to one of two main groups (distinguished by SOA) and within a group to one of six subgroups, giving 5 subjects per subgroup. None of the subjects had participated in the previous experiments.

Materials. There were six word sets (see Appendix C). The first set (also the base set) consisted of 96 associatively related word pairs that were paired to make 48 related word quadruples (e.g., BITE–TEETH, HATE–LOVE). From this first set, five other sets of 96 pairs were generated in the manner described in Experiment 3: Set 2 (unrelated word) was represented by BITE–LOVE, Set 3 (related pseudohomophone) was represented by HAIT–LOVE, Set 4 (unrelated pseudohomophone), was represented by BIGHT–LOVE, Set 5 (related pseudohomograph) was represented by HANT–LOVE, and Set 6 (unrelated pseudohomograph) was represented by BIRET–LOVE.

Six counterbalanced lists of stimuli pairs were prepared. In each subgroup, each subject saw 16 pairs from of each stimulus set (for a total of 96), plus a foil set of 64 nonword–nonword pairs, a foil set of 32 pseudohomophone–nonword pairs (all nonwords were easily pronounceable, legal English letter strings), and a small set of eight nonrelated word–word pairs used for probing awareness of the context. As in Experiment 3, the foil sets were used to counter the development of biases such as (a) always looking for an associative relation, (b) making predictions about targets on the basis of the sound of the context, and (c) trying to make contexts sound like words. An experimental list consisted of 200 stimulus pairs.

Procedure. The stimuli were presented differently from the previous experiments. Contexts and targets were fixed at 200 ms nominal duration. The interstimulus interval was either 300 ms or 80 ms to produce nominal SOAs of 500 ms and 280 ms, respectively. In further contrast to the preceding experiments, the context and target were presented at the same place (at the fixation point). The latter change in the presentation of stimuli was demanded because for an SOA of 280 ms, the time to shift fixation within the procedure used in Experiment 1–3 would be detrimental to performing the main task (e.g., the subject would learn to fixate on the area below the fixation point in which the target appeared consistently). A major consequence of this change in displaying the paired stimuli was the possibility for forward and backward masking, especially at an SOA of 280 ms. In this regard, note that pilot work revealed that for the nominal stimulus exposure times of 200 ms, nominal SOAs briefer than 280 ms (e.g., 230 ms) produced an unacceptable level of error in reporting the context of the probed pairs.

Table 4
Mean Naming Latencies (in Milliseconds) and Error Rates (in %) With the Corresponding Standard Deviations for Subjects and Items in Experiment 4

	Context–target relation			
	Related		Unrelated	
Context	Latency	Error rate	Latency	Error rate
Stimulus onset asynchrony = 500 ms				
Word				
M	527	2.29	545	1.25
Subject *SD*	53	3.84	54	2.54
Item *SD*	47	7.61	45	4.87
Pseudohomophone				
M	537	0.21	552	1.04
Subject *SD*	47	1.14	47	2.37
Item *SD*	44	2.04	43	4.47
Pseudohomograph				
M	549	1.25	544	0.83
Subject *SD*	50	3.03	54	2.16
Item *SD*	46	5.67	43	4.02
Stimulus onset asynchrony = 280 ms				
Word				
M	543	0.83	556	1.46
Subject *SD*	60	2.16	61	3.55
Item *SD*	50	4.02	48	5.23
Pseudohomophone				
M	555	1.46	573	1.67
Subject *SD*	54	3.91	59	3.26
Item *SD*	43	5.23	50	6.27
Pseudohomograph				
M	572	0.42	571	0.83
Subject *SD*	57	1.59	59	2.16
Item *SD*	49	2.87	47	4.02

Results and Discussion

The mean latencies, mean errors, and standard deviations for words, pseudohomophones, and pseudohomographs in associatively related and unrelated contexts at both SOAs are presented in Table 4. We conducted a 2 × 3 × 2 ANOVA with within-subject variables of associativeness and context and a between-subject variable of SOA. The main effect of associativeness (associated = 547 ms vs. nonassociated = 557 ms) was significant for subjects, $F(1, 58) = 33.89$, $p < .001$, and for stimuli, $F(1, 190) = 13.66$, $p < .001$. The main effect of context (word = 543 ms, pseudohomophone = 554 ms, pseudohomograph = 559 ms) was significant for subjects, $F(2, 116) = 25.37$, $p < .001$, and for stimuli, $F(2, 380) = 16.33$, $p < .001$. The main effect of SOA was not significant (long SOA = 542 ms vs. short SOA = 562 ms) for the subject analysis, $F(1, 58) = 2.01$, $p > .05$, but it was significant for the stimulus analysis, $F(1, 190) = 36.63$, $p < .001$. Of all possible interactions, only the Associativeness × Context interaction (related–unrelated difference for words = 16 ms vs. related–unrelated difference for pseudohomophones = 17 ms vs. related–unrelated difference for pseudohomographs = −3 ms) was significant: for subjects, $F(2, 116) = 17.84$, $p < .001$; for stimuli, $F(2, 380) = 5.09$, $p < .007$.

With regard to the partial interactions, both that between words and pseudohomographs and that between pseudohomophones and pseudohomographs were significant for subjects, $F(1, 58) = 22.02$, $p < .001$; for stimuli, $F(1, 190) = 7.70$, $p < .006$; and for subjects, $F(1, 58) = 28.14$, $p < .001$; for stimuli, $F(1, 190) = 7.77$, $p < .006$, respectively. The partial interaction between words and pseudohomophones was not significant ($F < 1$ in both the subject and stimulus analyses). Note that the partial interaction between words and pseudohomophones was not significant at either SOA (all Fs < 1), which suggests that the Associativeness × Context interaction was due solely to the behavior of the TARBLE–CHAIR/BLOM–CHAIR pairs in relation to the word and pseudohomophone pairs.

Experiment 4 was designed to determine whether associative priming of word targets through pseudohomophones was dependent on the magnitude of time elapsing between context and target. Experiment 3 had used an SOA of 500 ms. The present experiment used an SOA of the same magnitude and one that was considerably shorter, namely 280 ms. The analyses show that the efficacy of pseudohomophone associative priming was indifferent to the SOA difference and of the same magnitude as word associative priming. For an SOA of 500 ms, TABLE–CHAIR differed from its unrelated control by 18 ms: This planned comparison was significant for both subjects and stimuli, $F(1, 29) = 14.51$, $p < .001$, and $F(1, 95) = 8.46$, $p < .005$, respectively. In addition, TAYBLE–CHAIR differed from its unrelated control by 15 ms: This was significant for both subjects and stimuli, $F(1, 29) = 27.26$, $p < .001$, and $F(1, 95) = 5.82$, $p < .02$, respectively. Finally, TARBLE–CHAIR differed from its unrelated control by −5 ms: This was not significant for either subjects or stimuli, $F(1, 29) = 3.12$, $p > .05$, and $F < 1$, respectively. For an SOA of 280 ms, TABLE–CHAIR, TAYBLE–CHAIR, and TARBLE–CHAIR differed respectively from their unrelated controls by 13 ms—$F(1, 29) = 24.29$, $p < .001$, and $F(1, 95) = 4.22$, $p < .05$—by 18 ms—$F(1, 29) = 17.98$, $p < .001$, and $F(1, 95) = 5.23$, $p < .03$—and by −1 ms—$F < 1$ for both subjects and stimuli. The implication is that the same mechanism underlies both pseudohomophone and word associative priming and that pseudohomophone associative priming, therefore, is not due to a special (postlexical) strategy.

There was a main effect of context lexicality in the sense that naming CHAIR was faster to the same degree when it follows each of the two word contexts (TABLE and BLUE) than when it followed each of the two pseudohomophone contexts (TAYBLE and BLOO). Clearly, this faster naming after word contexts has nothing to do with the mechanism of associative priming. It might be due to a postlexical verification process in which the subject compares the assembled name with the initial representation of the stimulus prior to executing the response (see Paap, Newsome, McDonald, & Schvaneveldt, 1982). Suppose that the verification (match–mismatch) process is modulated over the short term by the kind of letter string just processed. Then, the possibility can be entertained that processing a pseudohomophone temporarily raises the criterion for verification; as a consequence, the time to name subsequent word is slowed. That pseudohomophone contexts may have exerted an inhibitory effect on word targets is suggested by the slower response to CHAIR when it followed BLOO than when it followed BLOM in the 500-ms-SOA condition. The absence of a similar inhibitory effect in the 280-ms-SOA condition suggests that the raising of the verification criterion is not instantaneous.

General Discussion

A large body of evidence which favors the idea that phonologic coding is the key process in printed-word identification is available for Serbo-Croatian (see the introduction and Lukatela & Turvey, 1990b, for a review). The results of the experiments of this article, especially Experiments 3 and 4, might be interpreted as adding to a growing body of evidence that phonological coding may be similarly dominant in printed-word identification in English (Perfetti et al., 1988; Van Orden, 1987; Van Orden et al., 1988). In Experiments 1 and 2, we showed that a word prime can facilitate the naming of a nonword target if the nonword had the same phonology as an associate of the prime. In Experiments 3 and 4, we showed that a nonword prime can facilitate naming of a word target if its phonology is the same as that of an associate of the target. The general consensus is that associative priming—whether the mechanism be spreading activation, expectancy set, or resonant matching (Stone & Van Orden, 1989)—is a lexical process. For the observed associative effects to have occurred, there must have been lexical access. And given the homophony conditions under which these effects occurred, the lexical representations accessed must have been phonological, and the access must have been through phonology. It seems unlikely that an account of the data can be given in terms of a model that does not grant a central role to phonology in lexical access. Consider analogy models (e.g., Glushko, 1979), for example. TAYBLE would be assigned a phonology by analogy with its orthographic neighbors. To enhance the naming of CHAIR, this assembled phonological representation /table/ would have to affect the lexical representation of CHAIR. The minimal implication is that /table/ must function as a lexical access code, triggering lexical processes beneficial to the eventual naming of CHAIR.

In light of the evidence presented here and elsewhere for phonological mediation, we are tempted to ask whether there is experimental support for another process separate from phonological mediation. A basic prediction of dual-process theory is that irregular–exception words can only be processed by the direct access route because they cannot be coded by grapheme–phoneme correspondence rules. Van Orden et al. (1990) have argued that the logic by which irregular words constitute a priori evidence for direct processing depends on the validity of the claim that explicit, discrete rules map spellings to sounds. If the mapping is achieved differently, by a continuous version of regularity (captured by the degree of covariation between orthographic and phonologic features across neighborhoods of similarly spelled words), for example, then the prediction is not valid. Van Orden et al. also questioned critically the arguments for an independent direct process that is based on the word-superiority effect (McCusker et al., 1981) and successful reading by the deaf (McCusker et al., 1981). As they noted, there is considerable experimental evidence contrary to both arguments; phonological variables affect both the word-superiority effect (e.g., Chastain, 1981, 1984) and word identification by deaf readers (e.g., Hanson & Fowler, 1987).

One experimental result offered in favor of a separate direct access is the demonstration that in a masking paradigm, phonologic priming fails to benefit target identification over orthographic priming (Evett & Humphreys, 1981). Thus, TILE primes FILE (phonologically similar/graphemically similar) no more than TOUCH primes COUCH (phonologically dissimilar/graphemically similar). The logic here is that if one can demonstrate orthographic priming without phonological priming, then one has evidence for an independent direct visual access. Van Orden et al. (1990) suggested that the Evett and Humphreys application of this logic is flawed in that the difference between the critical stimulus pairs was too small to produce a noticeable difference in identification. Moreover, there are other sources of data which suggest that TOUCH can affect the processing of COUCH detrimentally because of the phonological inconsistency between the items (Meyer, Schvanaveldt, & Ruddy, 1974). Although Hillinger (1980) provided evidence for strictly phonological priming in the lexical-decision task, the observation has failed to be replicated in further experiments with lexical decision (Martin & Jensen, 1988) and in experiments with naming latency (Peter, Turvey, & Lukatela, 1990). These same experiments, however, also failed to demonstrate any benefits to processing a graphemically similar preceding stimulus. This confusing state of affairs with respect to forward priming experiments with English language materials contrasts sharply with the results from similar forward priming experiments in Serbo-Croatian and backward priming experiments with English and Serbo-Croatian, which contradict an independent direct visual route.

With respect to the forward priming experiments, a large number of experiments demonstrate unequivocally that there is no orthographic priming in lexical decision or naming over phonological priming (Lukatela, Carello, & Turvey, 1990; Lukatela & Turvey, 1990b). In these experiments, the primes and targets consist of phonologically unique letter strings written either in different alphabets (e.g., prime is in Cyrillic, target is in Roman) and different cases or in the same alphabet (both are in Cyrillic) and the same case. When they are in the same case, the graphemically dissimilar/phonologically similar pairs never share more than one letter in common, and often they share none; the graphemically similar/phonologically similar pairs share all but one letter in common. In different cases and alphabets, there are no visually identical letter forms. Especially significant aspects of the results are that phonological similarity effects in both lexical decision and naming are independent of graphemic similarity; that phonological similarity expedites the naming of words and nonwords, and to the same degree; and that the phonological similarity effect occurs even when the context is a masked nonword. The latter result in particular has special bearing on the issue of an independent direct visual route.

By hypothesis, once a word unit has been activated directly on the basis of its orthographic properties, phonological information about the word is made available. Suppose that the direct access is mandatory (automatic) and that the phonological mediation way is optional (nonautomatic), as has been frequently proposed. Then, under masking conditions that minimize optional strategies, only the lexical way ought to work. On the basis of the preceding argument, Humphreys, Evett, and Taylor (1982, p. 581) hypothesized the following: "If phonological information is activated via a nonlexical route, a pseudohomophone priming effect should occur." Finding that the pseudohomophone condition (tial–TILE) in their masking experiment did not differ from its graphemic control condition (tirl–TILE), Humphreys et al. (1982) concluded that the lexical (direct visual access) way of deriving phonology is the only one of the two that is automatic and is probably the only way to activate phonological information. To the contrary, the successful demonstration of "pseudohomophone priming" under masking in Serbo-Croatian confirms the Humphreys et al. (1982) hypothesis and suggests, therefore, that the phonological access route is automatic and (continuing their logic) is the only one available.

We now consider the backward priming experiments. These entail the identification of briefly exposed target words under backward masking conditions with the following key features: The masks are nonwords, phonologically related or unrelated to the targets, that are followed by patterned stimuli to reduce their identification and guessing strategies about target–mask relationships. The figural structure of the masks and comparable intensities of the targets and masks confine the masking effects on the targets to primarily central processes (Michaels & Turvey, 1979; Turvey, 1973). Perfetti et al. (1988) argued that if phonology is computed automatically, then phonological similarity between the mask and target will reduce the interruption of central processing normally induced by the mask. They reasoned that a phonologically similar mask will reinforce the phonological information activated partially by the target. In contrast, a phonologically dissimilar mask will partially activate other phonological information. If lexical activation follows from phonological information, then a target preceding a phonologically similar mask will be identified better than a target preceding a phonologically dissimilar mask. The idea is that lexical entries partially activated by a target will be activated further by a subsequent mask with common phonological properties. The outcomes of experiments by Naish (1980) and by Perfetti et al., both with native speakers and readers of English and English language materials, were in agreement with this prediction, as were the experiments of Lukatela and Turvey (1990a), which used native speakers and readers of Serbo-Croatian and Serbo-Croatian materials. All of these experiments showed significantly higher levels of target identification for homophonous masking than for nonhomophonous masking. Put differently, none showed graphemic backward priming effects over phonological priming effects. With respect to Evett and Humphreys's (1981) logic, this outcome is contrary to that expected from an independent direct visual access.

Van Orden et al. (1990) remarked that traditionally the best evidence cited in favor of the independent direct access hypothesis comes from experiments that did not yield predicted effects of stimulus phonology—a strategy of arguing from other-than-positive effects. With respect to the semantic category task, the direct access hypothesis predicts that the effects of homophony ought to be reduced as a function of the familiarity of the homophones (direct access is the exclusive route for familiar words). Contrary to this prediction, the effect of homophone familiarity was null (Van Orden, 1987; Van Orden et al., 1988). In the spirit of the other-than-positive-effects strategy, this outcome ought to be interpreted in favor of phonological mediation and against direct visual access (Van Orden et al., 1990; Van Orden, in press).

In summary, despite the ubiquity of the claim for direct visual access, the evidence is not strong, raising the possibility that the overarching hypothesis of Coltheart's (1978) original theory of two independent processes could be false. In contrast, there is substantial and accumulating evidence, including that reported in the present article, for phonological mediation. We conclude by noting that although discussions of differences among lexical access codes have usually been expressed in terms of activation times (e.g., orthographic features are earlier sources of constraint on lexical coding than phonologic features, or vice versa), other ways of expressing the differences are possible. One interesting, contemporary idea from dynamical interpretations of lexical access is that all codes are activated in parallel, but the phonological code is initially more coherent (less noisy, closer to its "attractor") than the others and acts as a dynamic frame that constrains other linguistic encodings that are initially less coherent (Van Orden et al., 1990). It remains to be seen whether this new version of the phonological mediation hypothesis, in conjunction with the new sources of data, can deflect the criticisms levied at earlier versions (e.g., Humphreys & Evett, 1985).

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Appendix A

Target Source Words, Pseudohomophones, Nonpseudohomophones, and the Corresponding Context Words: Experiment 1

Context	Target		
	Source word	Pseudohomophone	Nonpseudohomophone
FARM	BARN	BAHRN	MAHRN
MEAT	BEEF	BEAF	GEAF
WINE	BEER	BEERE	KEERE
ATOM	BOMB	BAHM	SAHM
NOVEL	BOOK	BOOCK	POOCK
BREAD	BUTTER	BUDDER	SUDDER
TABLE	CHAIR	CHARE	THARE
SKY	CLOUD	KLOWD	SLOWD
MINER	COAL	KOEL	THOEL
PARTY	DANCE	DANSE	MANSE
LIGHT	DARK	DARCK	VARCK
WISH	DESIRE	DEZIER	NEZIER
LIVE	DIE	DIGH	KIGH
GROUND	DIRT	DURT	FURT
SLOW	FAST	PHAST	CHAST
AFRAID	FEAR	FEER	VEER
SMOKE	FIRE	FYER	NYER
FOUR	FIVE	PHIVE	THIVE
CEILING	FLOOR	FLOAR	PLOAR
POWER	FORCE	PHORCE	THORCE
LOST	FOUND	PHOUND	KOUND
BOY	GIRL	GURL	SURL
WINDOW	GLASS	GLAS	PLAS
BIBLE	GOD	GAHD	HAHD
FOOT	HAND	HANNED	DANNED
MOUNTAIN	HILL	HIL	ZIL
FOG	HORN	HOARN	DOARN
COLD	HOT	HAHT	MAHT
TRUTH	LIES	LIZE	NIZE
HIGH	LOW	LOE	KOE
MAJOR	MINOR	MIGHNER	FIGHNER
LEAST	MOST	MOAST	NOAST
HAMMER	NAIL	KNALE	LALE
ARMY	NAVY	NAYVY	LAYVY
DAY	NIGHT	NITE	GITE
EIGHT	NINE	NIGHN	BIGHN
EYES	NOSE	KNOES	KOES
PHONE	NUMBER	NUMBUR	DUMBUR
DOCTOR	NURSE	NERSE	DERSE
WAR	PEACE	PEES	DEES
KING	QUEEN	KWEEN	DWEEN
POOR	RICH	RITCH	LITCH
STREET	ROAD	WRODE	TRODE
STONE	ROCK	ROK	TOK
SQUARE	ROUND	WROUND	LOUND
HAPPY	SAD	SADD	YADD
BOAT	SAIL	SAYL	THAYL
BEACH	SAND	SANDE	MANDE
BED	SLEEP	SLEAP	CLEAP
ROUGH	SMOOTH	SMUTHE	SLUTHE
MUSIC	SONG	SAWNG	NAWNG
NORTH	SOUTH	SOUTHE	POUTHE
MOON	STAR	STAHR	SLAHR
MARKET	STORE	STOAR	SLOAR
GIVE	TAKE	TAICK	NAICK
SHORT	TALL	TAWL	NAWL
BEAUTIFUL	UGLY	UGLIE	IGLIE
STRONG	WEAK	WIEK	FIEK
SHEEP	WOOL	WULL	TULL
RIGHT	WRONG	RONG	FONG

Appendix B

Target Source Words, Pseudohomophones, Pseudohomographs, and the Corresponding Context Words: Experiment 2

Context	Target		
	Source word	Pseudohomophone	Pseudohomograph
GONE	AWAY	AWEIGH	AWELTH
ROAST	BEEF	BEAF	BELF
HAWK	BIRD	BURD	BORD
BREAD	BUTTER	BUDDER	BUSHER
BAKE	CAKE	CAIK	CAWK
TABLE	CHAIR	CHARE	CHARK
OPEN	CLOSED	CLOZED	CLOOED
WEAR	CLOTHES	CLOZE	CLOME
SNEEZE	COUGH	COPH	COCH
WEEP	CRY	CRIE	CRIT
WET	DRY	DRIE	DROE
NEAR	FAR	PHARR	PHAER
SMOKE	FIRE	FYER	FLER
FOUR	FIVE	FYVE	FOVE
FAKE	FRAUD	FRAWD	FRAID
GRAPE	FRUIT	FRUTE	FRUST
BIBLE	GOD	GAHD	GERD
MOAN	GROAN	GRONE	GRONT
ACHE	HEAD	HEDD	HEND
HOUSE	HOME	HOAM	HORM
PAIN	HURT	HERT	HORT
CIDER	JUICE	JOOCE	JORCE
BLADE	KNIFE	NYFE	NOFE
ROAD	LANE	LAIN	LARN
EARLY	LATE	LAIT	LART
MOST	LEAST	LEEST	LERST
TRUTH	LIES	LIZE	LIDE
GREEN	LIGHT	LITE	LITH
TIGHT	LOOSE	LUSE	LESE
HATE	LOVE	LUV	LIV
YOUR	MINE	MYNE	MENE
DEAF	MUTE	MEWT	MERT
HAMMER	NAIL	NALE	NARL
FLEET	NAVY	NAYVY	NARVY
EIGHT	NINE	NYNE	NUNE
FILE	PAPER	PAYPER	PARPER
WAR	PEACE	PEECE	PERCE
GROUP	PEOPLE	PEEPLE	PERPLE
PIECE	PIE	PYE	POE
STOVE	PIPE	PYPE	PUPE
CLOUD	RAIN	RANE	RAND
LION	ROAR	RORE	ROTR
DEEP	ROOTED	RUTED	RETED
OATS	RYE	RIE	REE
BOAT	SAIL	SAYL	SARL
OBEY	SERVE	SURVE	SARVE
HERD	SHEEP	SHEAP	SHEMP
SOLE	SHOE	SHOOH	SHORN
DREAM	SLEEP	SLEAP	SLEMP
SUDS	SOAP	SOPE	SORP
EAT	SOUP	SUPE	SUPL
BITE	TEETH	TEATH	TERTH
FLOOR	TILE	TIAL	TIRL
GRAVE	TOMB	TOOM	TORM
TRAIN	TRACKS	TRAX	TRAW
PINE	TREE	TREA	TREM
ONE	TWO	TWOO	TWOK
SPIDER	WEB	WHEB	WERB
TON	WEIGHT	WATE	WRAT
FLOUR	WHEAT	WHEET	WHEST
CHALK	WHITE	WHYTE	WHOTE
READ	WRITE	WRYTE	WRUTE
OLD	YOUNG	YUNG	YING
NONE	ZERO	ZEERO	ZEBRO

Appendix C

Context Source Words, Pseudohomophones, Pseudohomographs, and the Corresponding Target Words: Experiments 3 and 4

Target	Context		
	Source word	Pseudohomophone	Psuedohomograph
HEAD	ACHE	AIKE, 204	ARRE, 232
CAKE	BAKE	BAIK, 192	BAWK, 78[a]
GOD	BIBLE	BYBLE, 64	BOBLE, 83
TEETH	BITE	BIGHT, 303	BIRET, 147[a]
KNIFE	BLADE	BLAID, 129	BLARD, 199
SKY	BLUE	BLOO, 24	BLOM, 185
SAIL	BOAT	BOTE, 129	BOTS, 115[a]
COWARD	BRAVE	BRAIV, 139	BRARV, 201
BUTTER	BREAD	BREDD, 127	BREND, 191
GLASS	BREAK	BRAIK, 139	BRACK, 187
DULL[b]	BRIGHT	BRITE, 179	BRITH, 195
HOAX	CHEAT	CHEET, 364	CHENT, 367
APPLE	CIDER	SIDER, 332	MIDER, 339
SECRET	CODE	COAD, 114	COID, 128
BOX	CRATE	CRAIT, 120	CRAST, 195
FRIEND	DATE	DAIT, 166	DAST, 347
MUTE	DEAF	DEFF, 51	DELF, 170
BARGAIN[b]	DEAL	DEEL, 226	DERL, 193[a]
KNOB	DOOR	DORE, 429	DORN, 227[a]
SLEEP	DREAM	DREEM, 129	DRERM, 244
LATE	EARLY	URLY, 63	ORLY, 63
WEST	EAST	EEST, 255	ERST, 216[a]
DRINK[b]	EAT	EET, 96	ERT, 6[a]
NINE	EIGHT	AIT, 55	DIT, 77
FORTUNE[b]	FAME	FAIM, 175	FAUM, 59[a]
DESTINY[b]	FATE	FAIT, 181	FANT, 207
TILE	FLOOR	FLORE, 311	FLOTR, 141[a]
FIVE	FOUR	FOAR, 127	FOGR, 45[a]
PEAR	FRUIT	FRUTE, 102	FRUST, 129
WORLD[b]	GLOBE	GLOAB, 93	GLOOB, 121
STICK	GLUE	GLOO, 21	GLAM, 37
AWAY	GONE	GAWN, 88	GERN, 174
MILK	GOAT	GOTE, 121	GOOT, 233
JEWEL[b]	GOLD	GOALD, 236	GOOLD, 233
SCHOOL	GRADE	GRAID, 146	GRALD, 178
TOMB	GRAVE	GRAIV, 131	GRARV, 193
SORROW	GRIEF	GREEF, 151	GROEF, 114[a]
PEOPLE	GROUP	GRUPE, 57	GRUSP, 77
LOVE	HATE	HAIT, 321	HANT, 347
DISPAIR	HOPE	HOAP, 67	HORP, 177
HOME	HOUSE	HOWSE, 217	HOLSE, 234
PRISON[b]	JAIL	JALE, 92	JALL, 232
POND[b]	LAKE	LAIK, 182	LASK, 160
DARK	LIGHT	LITE, 400	LITH, 596
LETTER[b]	MAIL	MAYL, 168	MAAL, 140[a]
STREET	MAIN	MAYN, 168	MARN, 212
FOOD[b]	MEAL	MEEL, 213	MERL, 180[a]
GROAN	MOAN	MONE, 254	MOND, 271
YEAR[b]	MONTH	MUNTH, 108	MINTH, 151
LEAST	MOST	MOAST, 268	MOYST, 204[a]
MARINE[b]	NAVY	NAIVY, 53	NARVY, 75
FAR	NEAR	NEER, 298	NEBR, 37[a]
TIDY[b]	NEAT	NEET, 238	NERT, 211[a]
ZERO	NONE	NUNN, 15	NANO, 113
RYE	OATS	OTES, 46	ONTS, 177
SERVE	OBEY	OBAY, 30	OBLY, 73
TWO	ONE	WUN, 23	WEN, 34
HURT	PAIN	PAYN, 87	PARN, 131
PIE	PIECE	PEECE, 122	PRECE, 164
NUMBER[b]	PHONE	FOAN, 129	FORN, 188
MUD[b]	RAIN	RANE, 184	RAWN, 90[a]
WRITE	READ	WREED, 215	WREND, 148[a]
HIGHWAY	ROAD	ROED, 117	ROND, 243
BED[b]	ROOM	RUME, 242	REME, 245

Appendix C (*continued*)

Target	Context		
	Source word	Pseudohomophone	Psuedohomograph
SECURE[b]	SAFE	SAIF, 235	SARF, 189
OTHER[b]	SAME	SAIM, 237	SARM, 199[a]
TREE	SHADE	SHAID, 150	SHALD, 282
SEVEN[b]	SIX	SIKS, 107	SILE, 140
FIRE	SMOKE	SMOAK, 55	SMONK, 131
WINTER[b]	SNOW	SNOE, 64	SNOP, 74
BATH[b]	SOAP	SOPE, 145	SOPH, 118[a]
SHOE	SOLE	SOAL, 137	SORL, 240
SALAD[b]	SOUP	SUPE, 73	SURP, 74
POLICE[b]	STATE	STAIT, 223	STANT, 255
MEAT[b]	STEAK	STAIK, 213	STREK, 187[a]
ROCK[b]	STONE	STOAN, 216	STORN, 214
PIPE	STOVE	STOAV, 176	STORV, 208
CHAIR	TABLE	TAYBLE, 162	TARBLE, 201
GIVE[b]	TAKE	TAIK, 165	TARK, 140[a]
WILD[b]	TAME	TAIM, 167	TARM, 129[a]
MONEY	TAX	TAKS, 106	TAMS, 124
LEARN	TEACH	TEECH, 190	TERCH, 159[a]
ANNOY	TEASE	TEEZE, 58	TERLE, 133
STEAL[b]	THIEF	THEEF, 414	THREF, 391[a]
LOOSE	TIGHT	TITE, 323	TITH, 519
FROG	TOAD	TODE, 130	TORD, 225
WEIGHT	TON	TUNN, 22	TANN, 106
SOUND[b]	TONE	TOAN, 152	TOON, 233
TRACKS	TRAIN	TRANE, 160	TRANK, 167
ARMY	TROOP	TRUPE, 61	TRAPE, 105
LIES	TRUTH	TROOTH, 94	TREETH, 61[a]
PEACE	WAR	WOAR, 123	WAYR, 112[a]
WATER[b]	WADE	WAID, 256	WAAD, 105[a]
STOP[b]	WAIT	WATE, 138	WATH, 334
BLACK	WHITE	WHYTE, 237	WHOTE, 326
MINE	YOUR	YURE, 248	YURM, 38[a]

Note. Numerals denote summed bigram frequencies.

[a] The summed bigram frequency of the pseudohomograph is lower than that of the corresponding pseudohomophone.

[b] These stimuli did not appear in Experiment 3.

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