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Pseudohomophone Effects and Models of Word Recognition

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Two experiments examined factors that influence the processing of pseudohomophones (nonwords such as *brane* or *joak*, which sound like words) and nonpseudohomophones (such as *brone* and *joap*, which do not sound like words). In Experiment 1, pseudohomophones yielded faster naming latencies and slower lexical-decision latencies than did nonpseudohomophones, replicating results of R. S. McCann and D. Besner (1987) and R. S. McCann, D. Besner, and E. Davelaar (1988). The magnitude of the effect was related to subjects' speed in lexical decision but not naming. In Experiment 2, both immediate and delayed naming conditions were used. There was again a significant pseudohomophone effect that did not change in magnitude across conditions. These results indicate that pseudohomophone effects in the lexical-decision and naming tasks have different bases. In lexical decision, they reflect the pseudohomophone's activation of phonological and semantic information associated with words. In naming, they reflect differences in ease of articulating familiar versus unfamiliar pronunciations. Implications of these results concerning models of word recognition are discussed, focusing on how pseudohomophone effects can arise within models that do not incorporate word-specific representations, such as the M. S. Seidenberg and J. L. McClelland (1989) model.

One goal of research on visual word recognition is to identify the aspects of lexical structure that influence processing. Numerous studies have examined the effects of properties such as frequency (e.g., Forster & Chambers, 1973), familiarity (e.g., Gernsbacher, 1984), age of acquisition (e.g., Morrison & Ellis, 1995), bigram and trigram frequency (e.g., Massaro, Venezky, & Taylor, 1979), positional letter frequency (e.g., Mason, 1975), and imageability (e.g., Strain, Patterson, & Seidenberg, 1995). The basic research strategy in such studies involves identifying a structural variable (such as word frequency), deriving an operational measure of it (e.g., identifying "word frequency" with "frequency in the Kučera & Francis, 1967, corpus"), developing stimuli that vary with respect to the variable in question but are equated in terms of other factors not under investigation, and determining the effects of the variable on the performance of tasks such as naming or lexical decision.

The extent to which the effects of a given factor can be assessed depends on how well other potentially confounding factors are controlled. Words make it difficult to enforce this ceteris paribus requirement because many aspects of lexical structure are correlated with one another. For example, frequency is correlated with length in letters (Zipf, 1935) and with subjective estimates of familiarity and age of acquisition (Gilhooly & Logie, 1980), among other factors. The partial correlations among many aspects of lexical structure make it difficult to isolate the unique contributions of individual factors. Moreover, it is not known in advance exactly which factors are relevant and need to be controlled, and it is not always practical to generate a sufficient number of stimuli that are equated along multiple dimensions simultaneously. Finally, although some structural factors (such as length in letters) can be objectively controlled, many others (such as word or bigram frequency) are statistical in nature and must be estimated (e.g., using the Kučera & Francis, 1967, corpus), introducing additional error (Gernsbacher, 1984). These circumstances suggest that the results of individual studies need to be interpreted cautiously and that replication using additional materials is essential.[1]

The same concerns arise in studies involving pronounceable nonwords, which are stimuli that are wordlike but not actual words. Many studies have examined what are called pseudohomophone effects. Pseudohomophones are nonwords that sound like words (e.g., *brane* and *fownd*). They are typically compared to nonpseudohomophones, which do not sound like words (e.g., *frane* and *yownd*). The comparison between these stimuli is interesting because it potentially provides a way to diagnose the activation of phonological information in reading. Pseudohomophone stimuli would be expected to yield different results from nonpseudohomophone stimuli only if subjects

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[1] Considerable interest has developed in determining whether effects that have been attributed to word frequency are actually due to the correlated age of acquisition factor (e.g., Morrison & Ellis, 1994). Although this issue is important, it is not directly relevant to the questions addressed in this article. In the text, we refer to "frequency effects," but this could be interpreted as "frequency and/or age of acquisition effects" without affecting any major conclusions.

accessed phonological information in performing the experimental task (e.g., lexical or semantic decision). Such an effect might at the same time provide evidence about the use of phonology in reading actual words. This was the logic behind the original Rubenstein, Lewis, and Rubenstein (1971) study using such stimuli and many subsequent experiments (e.g., Barron, 1979; Coltheart, Davelaar, Jonasson, & Besner, 1977). Studies of pseudohomophone effects using the lexical-decision task have yielded mixed results over the years and some controversy concerning both the reliability of the effects (they were among the findings called into question in Clark's famous 1973 article) and their relevance to issues concerning normal word processing (see, e.g., Coltheart et al., 1977; Henderson, 1982). More recently, studies of pseudohomophone effects using semantic-decision tasks have yielded more robust effects (e.g., Jared & Seidenberg, 1991; Van Orden, Johnston, & Hale, 1988) and played a central role in theorizing, and these stimuli continue to be widely used in word recognition research.

A pair of articles by McCann and Besner (1987) and McCann, Besner, and Davelaar (1988) provided a wealth of data concerning the effects of the pseudohomophony factor on subjects' performance in the lexical-decision and naming tasks. McCann and Besner observed significantly faster naming latencies for pseudohomophones compared to nonpseudohomophones. This pattern suggested that pronunciation of a pseudohomophone involves accessing the base word from which it is derived. Thus, accessing *found* facilitates the pronunciation of *fownd*, whereas *yownd* does not benefit in this way. Of particular importance, latencies for the pseudohomophones were not correlated with the Kučera and Francis (1967) frequencies of their base words. The interpretation of this result was that access to the base word in reading the pseudohomophone is not governed by lexical frequency.

McCann et al. (1988) performed replication studies using the lexical decision task. They found that pseudohomophones yielded *longer* latencies than nonpseudohomophones, in contrast to the *shorter* latencies that were found in the naming study. The results were taken as further support for the claim that processing a pseudohomophone involves accessing its base word in lexical memory. Whereas this facilitates generating a pronunciation, it interferes with deciding that the target is not a word. Latencies in the pseudohomophone condition were again unrelated to the frequencies of the base words from which they were derived. Fera and Besner (1992) then used these stimuli in additional studies examining strategy effects in lexical decision.

The results of these studies may provide important constraints on theories of lexical representation and processing. First, they suggest that the mental lexicon must include representations of individual words, because otherwise there would appear to be no way for the base words from which the pseudohomophones are derived to influence processing (Besner, Twilley, McCann, & Seergobin, 1990). This constraint might be difficult to accommodate in models of the lexicon employing distributed representations (e.g., Hinton & Shallice, 1991; Plaut, McClelland, Seidenberg, & Patterson, in press; Plaut & Shallice, 1993; Seidenberg & McClelland, 1989). In a model such as Seidenberg and McClelland's, for example, it is hard to see how the word *brain* could influence the processing of the pseudohomophone *brane* because *brain* does not have its own representation in the lexical network. Hence, Besner et al. (1990) took these results as strong evidence against the model. Second, McCann et al. (1988) suggested that the results call into question the assumption that frequency influences lexical access. It is hard to see how this constraint can be reconciled with any existing model of word recognition, given the universality of this assumption. McCann and Besner (1987) and McCann et al. therefore proposed an alternative model of word recognition endowed with the properties demanded by their empirical results.

Note, however, that these conclusions rest on the ceteris paribus assumption that the pseudohomophone and nonpseudohomophone stimuli differ by virtue of the fact that only the pseudohomophone items sound like words, but not with respect to other factors that influence processing. Whether this assumption is valid for these materials needs to be assessed carefully because there is a simple alternative interpretation of the results (Seidenberg, 1992). Assume for the moment that the pseudohomophone stimuli differ from the nonpseudohomophone stimuli not because they sound like actual words but because they resemble words more closely in other respects. According to this view, creating nonwords that do not sound like words tends to require using relatively uncommon spelling patterns and combinations of phonemes; creating nonwords that sound like words tends to require using components that occur more often in actual words. The *fownd–yownd* pair illustrates this possibility. There are more words that begin with *f* than *y*, more that begin with *fo* than *yo*, and more that begin with "fow" (as in *foul*) than "yow" (as in *yowl*). Creating a nonword out of the pattern *_ownd* requires using a relatively low frequency onset such as *y_* because more common onsets would create pseudohomophones (*b, s, w, h, m, r,* etc.). If this characteristic were true of the stimuli in general, it could explain all of the main findings in McCann and Besner (1987) and McCann et al. (1988). Nonwords that are more similar to actual words will be easier to pronounce than less wordlike nonwords, as in the Seidenberg and McClelland (1989) model, and they will be harder to discriminate from words in the lexical-decision task. Latencies are uncorrelated with base word frequency because processing the pseudohomophone stimuli does not involve accessing the base words at all. This account does not demand the introduction of word-specific representations, and it does not require abandoning core assumptions such as the frequency–dependency of lexical processing.

There is some prima facie evidence that McCann and colleagues' materials did exhibit this general tendency. Figure 1 summarizes the distribution of onsets in McCann and Besner's (1987) materials. The onsets are ordered from left to right along the abscissa in increasing frequency of occurrence. This ordering was derived from the number of words containing each onset in the Kučera and Francis (1967) corpus. Very similar orderings result from using token frequencies or restricting the count to monosyllabic words. The medians of the distributions fall at *n_* for the nonpseudohomophones and *f_* for the pseudohomophones. Clearly, the nonpseudo-

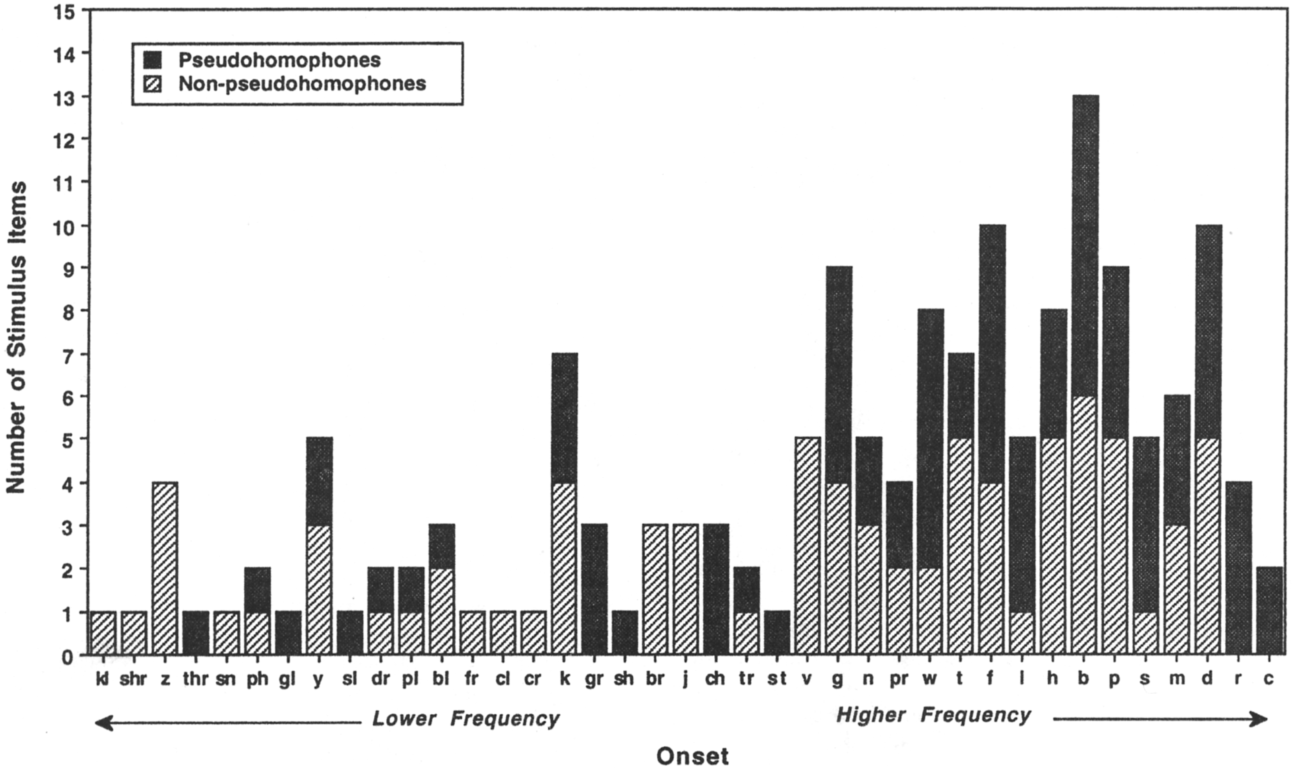

Figure 1. Distribution of onsets in McCann and Besner's (1987) materials.

homophone stimuli contain more of the lower frequency onsets such as *z*__, *v*__, and *y*__.

McCann and Besner (1987) and McCann et al. (1988) were aware of the need to closely equate the pseudohomophone and nonpseudohomophone stimuli in terms of other factors, and they took several steps to rule out artifactual bases for their effects. For example, they assessed whether differences in the bigram or Coltheart N (Coltheart et al., 1977) frequencies of the stimuli would account for the results, included a delayed naming condition in order to rule out differences in ease of articulation, and conducted a replication study using new stimuli containing the same onsets but different rimes in order to show that the effects were not due to the onsets alone. These were reasonable procedures based on established precedents, but each of them introduces new questions. Appendix A summarizes McCann and Besner's (1987) procedures and provides additional analyses bearing on them. These analyses do not definitively establish that McCann and Besner's conclusions were incorrect, but they are consistent with the alternative interpretation discussed above and suggest the need for replication studies using new materials.

In light of these observations and the theoretical importance that has been attached to pseudohomophone effects, we conducted two experiments modeled on the McCann and Besner studies but using new stimuli. The stimuli consisted of quadruples such as *hoap hoak joap joak.* Two of these items are pseudohomophones (*hoap* and *joak*) and two are not (*hoak* and *joap*). The main feature of the stimuli is that exactly the same onsets and rimes occur in both pseudohomophone and nonpseudohomophone stimuli; thus, the lists are identical in terms of onset frequencies, bigram frequencies, and Coltheart N values and provide closer control over potentially confounding variables than in the previous studies.

Experiment 1

The first experiment was an attempt to replicate the basic pseudohomophone effects in naming and lexical decision using new stimuli.

Method

Subjects. Forty-eight students from the University of Southern California community participated in the experiment, half in the lexical-decision portion of the experiment and the other half in the naming task. All participants were native speakers of English. Subjects either were paid or received course credit for participating.

Stimuli. Thirty-two sets of monosyllabic nonword stimuli were constructed. Each set contained four nonwords, formed by crossing two onsets (e.g., *j*__ and *h*__) and two rimes (e.g., __ *oak* and __ *oap*) to form two pseudohomophones (*hoap* and *joak*) and two nonpseudohomophones (*hoak* and *joap*). The stimuli were divided into two counterbalanced lists with an equal number of pseudohomophones and nonpseudomophones in each list. For half of the quadruples, the *hoap* and *joak* pair appeared in List A and the *hoak* and *joap* pair in List B. The assignment of pairs to lists was reversed for the other half. This method of assigning items to lists avoided repetitions of either rime or onset-nucleus patterns within subjects. Thus, no one saw both *hoap* and *joap* or both *hoak* and *hoap;* rather, *hoap* occurred with *joak* and *hoak* with *joap.* The stimuli are listed in Appendix B.

Sixty-four monosyllabic words were used as filler items for the lexical-decision task. Words that are homophones of the nonword items were excluded. The average Kučera and Francis (1967) frequency of the words was 24.2 ($SD = 17.3$; range = 7–72).

Procedure. In both the naming and lexical-decision tasks, stimuli were presented individually in the center of the screen of an IBM Model 70 PC. Subjects were seated in front of the computer at a comfortable distance in a dimly lit, quiet room. For the naming task, subjects were instructed to quickly and accurately name each letter string that appeared on the screen. Subjects spoke into a table microphone connected to the computer by means of a button box containing a voice-activated relay. For the lexical-decision task, subjects were instructed to use keyboard keys that were labeled *Y* and *N* to indicate whether or not the letter string was an English word.

The sequence of events on each trial was similar for both tasks. A fixation cross appeared at the center of the screen for 200 ms, followed by a 50-ms blank interval, followed by the target item in the center of the screen. The target remained on the screen until the subject's naming or lexical-decision response. For the naming task, the experimenter pushed a button on an external button box to record whether the subject's pronunciation was correct or incorrect, or whether there had been a spoiled trial (e.g., early triggering of the relay from an extraneous sound); this keypress initiated the next trial. For the lexical-decision task, there was a 2-s intertrial interval before the reappearance of the fixation cross.

Subjects were presented with short lists of practice items to familiarize them with the task. Subjects in the lexical-decision task were then presented with either List A or List B, which was merged with the list of word fillers. For both tasks, half of the subjects were presented with each list. The randomly intermixed stimuli were presented in two blocks. Stimuli occurred in a different random order for each subject. The first block began with four warmup trials. There was no break between blocks. Stimuli were presented in the same manner for the naming subjects but with the word stimuli excluded.

Results

Naming task. Overall results are summarized in Table 1. Latency analyses were based on correct responses. Analyses were performed on both trimmed and untrimmed data sets, which yielded very similar results. The trimming procedure excluded scores more than 3 *SD*s above or below a subject's mean latency as outliers. This procedure affected 18 scores (1.2%), 8 from the pseudohomophone condition and 10 from the nonpseudohomophone condition. Given that the scores were evenly distributed across conditions, they were considered to be true outliers; thus, analyses from the trimmed dataset are reported. Analyses of variance (ANOVAs) were conducted using both subject (F_1) and item (F_2) means. The variables were List (A or B), Block (first or second) and Type (pseudohomophone or nonpseudohomophone). The List and Block variables yielded no significant main effects or interactions with other variables and are not considered further. Pseudohomophones were named 15 ms faster than nonpseudohomophones, a small difference that was reliable in both subject and item analyses, $F_1(1, 22) = 12.18, MSE = 446.1, p < .005$, and $F_2(1, 63) = 5.16, MSE = 2{,}887.0, p < .05$, respectively. Subjects made essentially no errors in naming: Accuracy was greater than 99% for both types of nonwords. We examined the correlations between pseudohomophone naming latencies and two estimates of the frequencies of their base words (from the 1 million word Kučera and Francis, 1967, corpus and a corpus of 40 million words from the *Wall Street Journal,* Marcus, Santorini, & Marcinkiewicz, 1993). As in McCann and Besner's (1987) study, these correlations did not approach significance (both $0 < r < .10$).[2]

Table 1

Mean Naming and Lexical Decision Latencies (in Milliseconds)

	Task					
	Naming			Lexical decision		
Nonword type	*M*	*SE*	%	*M*	*SE*	%
Pseudohomophones	582	19.4	99.8	715	18.7	90.5
Nonpseudohomophones	597	19.8	99.7	684	14.7	94.1
Effect size	15			31		

Lexical-decision task. Latency data were based on correct responses in the nonword conditions. Analyses were again performed on both trimmed and untrimmed data sets. The 3-*SD* trimming procedure had a somewhat different effect than in the naming task, however: It affected 35 scores (2.4%) and more pseudohomophone scores (22) than nonpseudohomophone scores (12). Because the scores were not evenly distributed across conditions, the analyses based on the untrimmed data are reported. The ANOVAs involved the same variables as in the naming task. Latencies for pseudohomophones were 31 ms longer than for nonpseudohomophones, and this difference was reliable in both subject and item analyses, $F_1(1, 22) = 110.79, MSE = 2{,}168.3, p < .005$, and $F_2(1, 63) = 6.83, MSE = 11{,}182.4, p < .05$, respectively. Subjects were more accurate on nonpseudohomophones (94.1% correct) than on pseudohomophones (90.5% correct). This difference was significant by subjects, $F_1(1, 22) = 9.06, MSE = 0.0035, p < .01$, and marginally significant by items, $F_2(1, 63) = 3.42, MSE = 0.07, p < .07$. The correlations between the two estimates of base word frequencies and lexical decision latencies were again not statistically significant (both $rs = -.14$).

Analyses of subjects' speed. Additional analyses examined how the magnitudes of the pseudohomophone effects related to subjects' speed of responding. Seidenberg (1985b) found that the magnitude of effects of orthographic–phonological regularity in word naming depended on subjects' speed. It has been suggested (e.g., Seidenberg, 1985a) that phonological effects on lexical decision will be larger for lower frequency words and slower subjects. These observations led us to examine whether pseudohomophone effects would vary in similar ways.

For both tasks, three groups of 8 subjects each were formed on the basis of subjects' mean nonword response latencies. Figure 2 provides summary data for the naming (upper panel) and lexical-decision (lower panel) tasks. The effects of subjects' speed on the magnitude of the pseudohomophone effect

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[2] The *Wall Street Journal* (Marcus et al., 1993) corpus is about 40 million words of text taken from 3 years of this publication and distributed by The University of Pennsylvania. Word frequencies derived from this corpus correlate with those in Kučera and Francis (1967) at about the .98 level; the rank-order correlation is about .65.

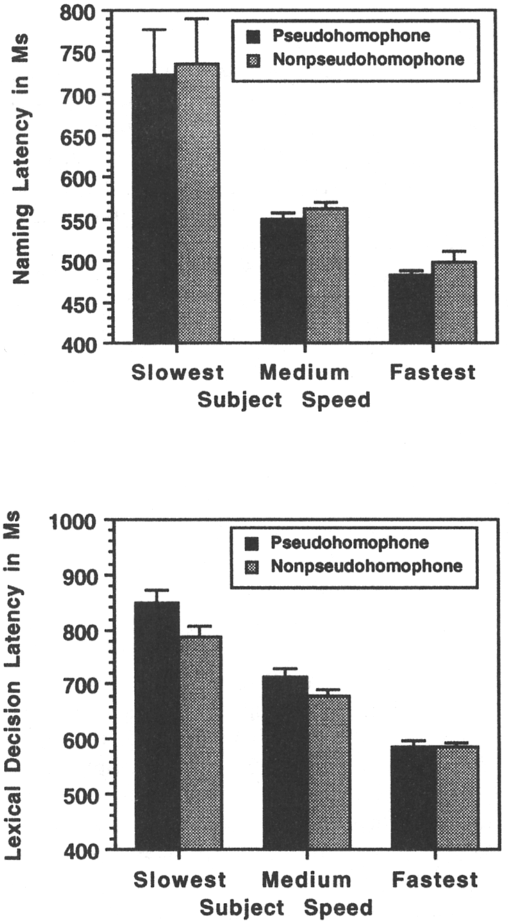

Figure 2. Mean naming and lexical-decision latencies (and standard errors) as a function of subjects' speed.

were quite different for the two tasks. In naming, the pseudohomophone effect was essentially flat across subject groups: Numerically, the effects were −15, −14, and −16 ms for the slowest, medium, and fastest subjects, respectively. This was borne out by main effects of subject group, $F_1(2, 21) = 14.88$, $MSE = 16{,}508.5$, $p < .001$, and stimulus type, $F_1(1, 21) = 11.45$, $MSE = 237.1$, $p < .005$, but there was no interaction between the variables, $F < 1$.

For the lexical-decision task, in contrast, the magnitude of the effect depended on subject speed. There were significant main effects of group, $F_1(2, 21) = 52.84$, $MSE = 4{,}194.8$, $p < .001$, and stimulus type, $F_1(1, 21) = 15.10$, $MSE = 820.8$, $p < .001$, and a significant interaction between them, $F_1(2, 21) = 4.85$, $MSE = 820.8$, $p < .02$. The effect was 63 ms for slower subjects, 35 ms for medium-speed subjects, and 1 ms for the fastest subjects. Error rates did not differ reliably across groups (94, 91, and 93% correct for the fast, medium, and slow subjects, respectively).

Discussion

Pseudohomophones were named more rapidly than nonpseudohomophones but yielded longer lexical-decision latencies, replicating the overall patterns found by McCann and Besner (1987) and McCann et al. (1988), using more closely controlled stimuli. As in their studies, pseudohomophone latencies did not reliably correlate with frequencies of the words from which they were derived. The lexical-decision results are roughly similar in magnitude to those in McCann et al.'s Experiment 1 (20 ms in McCann et al. vs. 31 ms in our experiment). Our study provides the additional information that the size of the effect decreased as a function of subject speed with this task. Moreover, there was a floor effect for the fastest subjects who showed no pseudohomophone effect at all. For the naming task, the basic pattern was the same as in McCann and Besner's study; however, the magnitude of the effect (15 ms) was closer to that in their delayed naming condition (11 ms) than in their immediate naming condition (35 ms). In this task, the size of the effect did not vary with subject speed.

The differing effects of subjects' speed provide an important hint that the pseudohomophone effects derive from different sources in the two tasks. The lexical-decision data are consistent with earlier suggestions that there are greater phonological effects in tasks such as lexical decision for slower subjects and lower frequency words (e.g., Jared & Seidenberg, 1991; McCusker, Hillinger, & Bias, 1981; Seidenberg, 1985a). If, as in the recurrent networks described by Plaut and McClelland (1993) and Plaut et al. (in press), phonological information is activated over time, slower subjects will show larger phonological effects simply because there is more time for this information to become available. Slower subjects may also rely more on using this information in making their responses. When the stimulus is a pseudohomophone, the fact that its phonological code is that of a word interferes with making a nonword response. This could occur either because the phonological code itself is associated with a word or because it activates semantic information associated with the word (Van Orden et al., 1988).

The fastest subjects showed no interference in the pseudohomophone condition, which suggests two possibilities. One is that they were able to make their responses without using phonological information. For example, they might have used orthographic information or semantic information activated directly from orthography. A second possibility is that the fastest subjects also activated phonological information in performing the task, but it did not interfere with making the response. For example, the subjects might have activated the phonological and semantic codes associated with the pseudohomophone, as in Van Orden et al.'s (1988) studies, and rapidly performed a spelling check that allowed them to identify the stimulus as a nonword, thereby producing no difference between pseudohomophone and nonpseudohomophone conditions (Lesch & Pollatsek, 1993, develop this account). The data do not militate between these alternative interpretations, largely because there are no observable behavioral effects associated with the hypothesized spelling check: It is assumed to work equally well and take equal amounts of time for both pseudohomophone and nonpseudohomophone stimuli. Hence, there is no direct evidence as to whether it has occurred or not. The role of spelling check mechanisms in processing homophones and pseudohomophones clearly needs to be studied further. The important point relevant to the present results, however, is that both interpretations suggest that the pseudohomophone effect in the lexical-decision task derives from decoding processes that produce the activation of phonological or semantic codes by the pseudohomophones.

The naming results suggest a different locus for the pseudohomophone effect obtained with this task. Subjects varied considerably in overall naming latencies but not in the magnitude of the pseudohomophone effect. This implies that the effect was due to factors unrelated to decoding skill. One possibility is that the effect derives from processes involved in generating articulatory output. The naming process is standardly assumed to involve decoding letters, generating a phonological code, and producing articulatory motor output (Balota & Chumbley, 1985; McRae, Jared, & Seidenberg, 1990; Monsell, Doyle, & Haggard, 1989). This view is illustrated in Figure 3. Parts of the processes of identifying letters and performing orthographic-to-phonological conversion have been addressed in models such as those proposed by McClelland and Rumelhart (1981) and Seidenberg and McClelland (1989). The phonological-to-articulatory computation in the figure reflects the processes involved in converting an internal phonological code into an explicit articulatory response. This process can be envisioned in terms of a recurrent network that produces time-varying output over units representing articulatory features (see, e.g., Jordan, 1986). Differences between subjects in terms of naming speed reflect differences in their ability to decode the input and generate a phonological code. Because the pseudohomophone and nonpseudohomophone stimuli were closely matched in terms of orthographic and phonological properties, they do not differ with respect to these components of the naming process. By hypothesis, the stimuli do differ in terms of ease of articulation, however. The pronunciations of pseudohomophones are familiar, overlearned articulatory trajectories associated with common monosyllabic words such as *hope.* The pronunciations of nonpseudohomophones are novel trajectories such as /jOp/. Thus, even if the stimuli do not differ in terms of factors relevant to generating the phonological code, they may differ with respect to ease of producing articulatory output. In short, the process of generating articulatory output is primarily affected by whether the phonological pattern to be produced is familiar or not, not by whether the orthographic stimulus that generated this pattern is a word, pseudohomophone, or nonpseudohomophone stimulus.

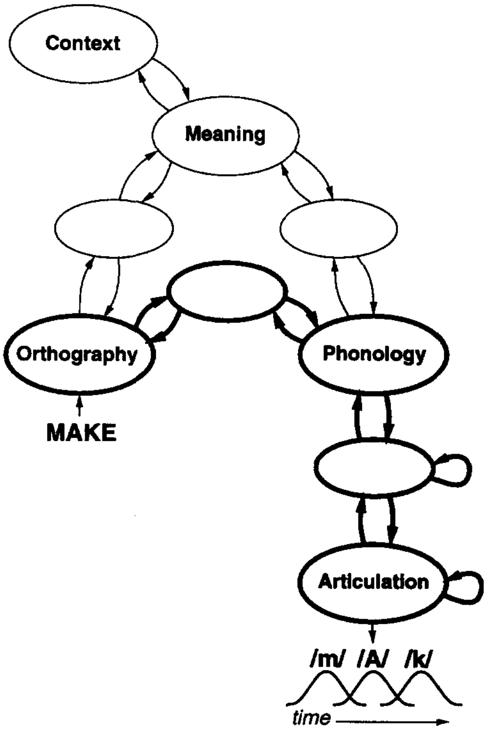

Figure 3. Pronunciation model including units and connections relevant to generating phonological and articulatory output.

These observations motivated Experiment 2, which replicated the naming study using both immediate and delayed naming conditions. The methodology was modeled on earlier studies using the delay paradigm by Balota and Chumbley (1985), McCann and Besner (1987), Monsell, Doyle, et al. (1989), and McRae, Jared, and Seidenberg (1990). In one of their experiments, for example, McRae et al. (1990) examined high- and low-frequency homophones such as *main* and *mane.* Lower frequency words such as *mane* produced longer immediate naming latencies than higher frequency words such as *main,* even though both involve the same articulatory motor output. This result suggested that frequency affects the ease of computing a word's phonological code. The homophones were named equally fast after a delay, however, indicating no residual effects of frequency on generating articulatory output. The prediction tested in Experiment 2 was that if the 15-ms pseudohomophone effect in naming for the stimuli used in Experiment 1 was solely due to processes involved in generating articulatory output, it would be the same magnitude in both immediate and delayed naming conditions.

Experiment 2

In this experiment, subjects named a stimulus nonword immediately after it appeared on the screen (as in Experiment 1) or after a short or long delay. Because subjects vary considerably in naming speeds, it is important to calibrate the delays to each subject's own naming speed (McRae et al., 1990). The short delay was set at 2 *SD* over the subject's baseline naming latency for a set of practice nonwords, and the long delay was 4 *SD* over this baseline. Subjects were signaled to respond by the appearance of brackets around the visual target, as in Balota and Chumbley (1985) and McRae et al. (1990); McCann and Besner (1987) used a tone for this purpose. In immediate naming, the stimulus appeared on the screen with brackets around it. In the delay conditions, the stimulus was presented without brackets, and then the brackets appeared after the short or long delay. Delays varied randomly from trial to trial so that subjects could not anticipate when they would have to begin responding. This procedure encourages subjects to begin computing the phonological code as soon as the nonword is presented, rather than waiting until the response signal appears before initiating this component of the naming process (see McRae et al., 1990; Monsell, Doyle, et al., 1989, for discussion).

Method

Subjects. Thirty-six subjects from the University of Southern California community were paid for their participation. All were native speakers of English.

Materials and procedure. The pseudohomophone and nonpseudohomophone stimuli from Experiment 1 were used as stimuli. Thirty additional pseudohomophones and nonpseudohomophones were used to establish each subject's baseline naming latency. Stimuli were presented on a Macintosh SE/30 computer using the PsyScope experiment control software (Cohen, MacWhinney, Flatt, & Provost, 1993). Real-time measurement was controlled by an external timing board interfaced to the computer. A microphone connected to a voice-activated relay was placed about 10 cm from the subject's mouth to record spoken responses.

The experiment involved two stages. Subjects were first presented with the randomized list of 30 pseudohomophones and nonpseudohomophones in an immediate naming procedure that was identical to that in Experiment 1. The mean and standard deviation of the subject's naming latency across correct trials were then calculated and used to establish the delay intervals used in the second stage of the experiment. The three delay conditions were immediate naming (no delay); short (2 *SD* over baseline), and long (4 *SD* over baseline). Across subjects, the average baseline naming latency was 583 ms and the short and long delays averaged 977 and 1,371 ms, respectively.

In the experiment proper, the stimulus quadruples were divided into four counterbalanced lists, with one member of each quadruple and equal numbers of pseudohomophones and nonpseudohomophones in each list. Each subject saw all four lists, with the order of lists varied across subjects. Each subject was presented with a third of the stimuli at each delay. Additional filler nonwords were added to equalize the number of stimuli per subject. Assignment of delay conditions to stimulus items was counterbalanced across subjects. Subjects were instructed to pronounce the nonword that appeared on the screen when the pair of brackets appeared around it. They were informed that the signal to respond would occur at different latencies and were given practice trials to adjust to the procedure.

Each trial proceeded as follows: After a 200-ms fixation cross and a 50-ms blank screen, the nonword appeared in the center of the screen. After the appropriate delay, the brackets appeared around the nonword; in the immediate naming condition, the brackets and the nonword appeared simultaneously. Naming latencies were measured from the presentation of the brackets to the initiation of the subject's response, which caused the nonword to be removed from the screen. The experimenter then pressed a key on the keyboard to record whether the trial was correct, incorrect, or spoiled (typically a result of the microphone not registering the subject's speech). The software was programmed to not register input from the voice key until the brackets appeared around the target. Therefore, if subjects responded prematurely, the screen would not clear and the latency would not be recorded.

Results

Trials on which the subject responded before the brackets appeared or when the subject's response failed to register (1.6% of trials) were excluded from the latency analyses, as were trials when the subject named the nonword incorrectly (2.4% of trials). Both trimmed and untrimmed data were analyzed, as in Experiment 1, and they yielded very similar results. Using the 3 *SD* cutoff for outliers resulted in excluding 19 scores, 11 from the pseudohomophones and 8 from the nonpseudohomophones. Analyses using the trimmed data set are reported. Results are summarized in Figure 4. The variables in the ANOVA were Delay (immediate, short, or long); List (1–4), Block (1–4), and Type (pseudohomophone or nonpseudohomophone). The list and block variables did not yield significant main effects or interactions with other factors and are not considered further. There was a main effect of Delay, $F_1(2, 64) = 189.78$, $MSE = 21{,}322.4$, $p < .001$; $F_2(2, 126) = 1{,}825$, $p < .001$, and means in the immediate, short, and long conditions were 631, 437, and 417 ms, respectively. There was a main effect of stimulus type, $F_1(1, 32) = 7.61$, $MSE = 3{,}157.1$, $p < .01$; $F_2(1, 63) = 11.45$, $MSE = 5{,}453.4$, $p < .001$, because pseudohomophones were named faster than nonpseudohomophones. The effects in the immediate, short, and long delay conditions were 16, 9, and 9 ms, respectively. The interaction between delay and stimulus type did not approach significance ($Fs < 1$).

Subjects again made few errors. Performance was slightly better on pseudohomophones (98.7% correct) than on nonpseudohomophones (98.2%), but the difference was nonsignificant. Error rates were also very similar across delays: 97.9, 98.5, and 98.9% correct for the immediate, short, and long conditions, respectively. Correlations between naming latencies and the two measures of frequency were again small and nonsignificant; the correlations with immediate naming were −.01 and .11 for the Kučera and Francis (1967) and *Wall Street Journal* corpora (Marcus et al., 1993), respectively.

Discussion

The experiment yielded a significant pseudohomophone effect that was essentially flat across delay conditions, as it was across subject groups in Experiment 1. Whereas the effects in the previous experiment were −15, −14, and −16 ms for the slow, medium, and fast subjects, in the present experiment

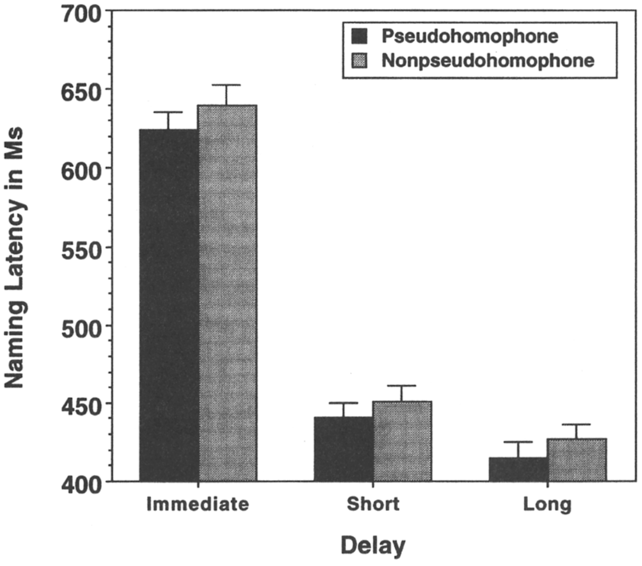

Figure 4. Mean naming latencies and standard errors, Experiment 2.

they were −16, −9, and −9 ms across the three delays. Hence, these stimuli yielded very similar effects regardless of subject speed or naming condition. The mean effect across the six conditions, 13 ms, is close to the 11-ms effect that McCann and Besner (1987) observed in their Experiment 1 delay condition. McCann and Besner obtained a much larger 35-ms effect in immediate naming, however. The sources of these effects can be understood in terms of the framework illustrated in Figure 3. The stimuli in both the McCann and Besner and the present studies consisted of items whose pronunciations are familiar, overlearned articulatory motor programs (pseudohomophones) and stimuli whose pronunciations are unfamiliar (nonpseudohomophones). There are small differences between familiar and unfamiliar monosyllables with regard to ease of pronunciation, on the order of 10–15 ms across studies. These effects will be present whenever an overt pronunciation must be generated; thus, they are found in both immediate and delayed naming conditions. These persistent differences in ease of articulation are apparently not related to differences in decoding ability (i.e., ability to recognize letters and perform orthographic-to-phonological conversion); the effects were the same size for subjects whose naming latencies differed by literally hundreds of milliseconds in Experiment 1. Within the Figure 3 framework, these effects arise in the computation from phonological code to articulatory output. In a sense, this difference between familiar pronunciations (associated with words and pseudohomophones) and unfamiliar pronunciations (associated with nonpseudohomophones) represents a coarse-grained effect of frequency on the generation of articulatory output. A familiar pattern is one that has occurred more frequently than an unfamiliar pattern and will have a bigger impact on the settings of the weights mediating the production of articulatory output. Like McCann and Besner, however, we did not observe a significant correlation between pseudohomophone naming latencies and base word frequencies. The difference between familiar pronunciations and novel pronunciations was only about 13 ms, suggesting why it might be difficult to detect even smaller effects that are due to differences in the relative frequencies of familiar pronunciations.

Stimuli can also differ in terms of factors that influence the ease of generating the phonological code that is the input to the articulatory component. Such factors include the frequency and consistency of spelling–sound correspondences, length, and orthographic redundancy. Here, McCann and Besner's (1987) stimuli differed from our own. Their pseudohomophones are more wordlike than their nonpseudohomophones (see Appendix A), making it easier to generate the phonological codes for the pseudohomophones. The 35-ms effect in McCann and Besner's Experiment 1 immediate naming condition thus reflects differences in both ease of computing phonological codes from orthography and ease of generating articulatory output. When the former differences are eliminated by using more closely controlled stimuli or by requiring a delayed response, only the latter effect remains.

McRae et al.'s (1990) studies shed further light on the bases of these effects. McRae et al. examined matched homophone–pseudohomophone pairs such as *prove–pruve* and *pearl–pirl*. The stimuli in these conditions differ in terms of ease of computing the phonological code, because the homophones are familiar orthographic patterns and the pseudohomophones are not; however, they involve the same articulatory motor programs. The homophones yielded significantly faster immediate naming latencies than did the pseudohomophones (35 ms in one experiment, 52 ms in another), but the effect was eliminated in delayed naming. In contrast, the *hoap–hoak* stimuli used in the present experiments are similar in terms of ease of computing the phonological code but differed with respect to ease of generating articulatory output (because half the stimuli have unfamiliar pronunciations). They therefore yielded the same size effect in both immediate and delayed naming. Finally, McCann and Besner's (1987) pseudohomophones and nonpseudohomophones differed in terms of both ease of computing phonology and generating articulatory output. They therefore yielded a larger difference in immediate naming than in delayed naming.

General Discussion

The experiments we have described replicate major aspects of the McCann and Besner (1987) and McCann et al. (1988) studies but provide additional data and analyses bearing on the locus of pseudohomophone effects in naming and lexical decision. McCann and colleagues interpreted their data as indicating that (a) processing a pseudohomophone involves accessing the base word that it sounds like, and (b) lexical access is not frequency sensitive. Their conclusions about models of word recognition followed from these main results. Besner et al. (1990) later argued that pseudohomophone effects are incompatible with the absence of lexical nodes in the Seidenberg and McClelland (1989) model. However, the present studies suggest a somewhat different interpretation of pseudohomophone effects. Nonword pronunciation makes use of knowledge that is acquired in learning to read and normally used in reading words. The difficulty of pronouncing a nonword therefore depends on the extent to which it resembles (i.e., shares structure with) known words. We have isolated two components of the naming process that are influenced by the degree to which nonword stimuli are "wordish": the computations from orthography to phonology and from phonology to articulatory output. Pseudohomophones necessarily differ from nonpseudohomophones in terms of factors that affect the second component because the former necessarily have more familiar phonological and articulatory representations. By contrast, these two types of nonwords need not differ in terms of factors that influence the mapping from orthography to phonology. McCann and Besner's stimuli happened to differ with regard to such factors; our stimuli do not.

The lexical-decision results are different, insofar as the mere fact that a nonword sounds like a word has an impact on processing, even with other aspects of lexical structure controlled. Thus, the fact that *brane* sounds like a known word with a known meaning interferes with deciding that it is a nonword. Similar effects have been observed by Van Orden et al. (1988) and others in studies using semantic-decision tasks. These results reflect the fact that orthographic codes rapidly activate phonological information that can, when the stimulus is a pseudohomophone, result in the activation of semantic information. However, the other major finding from the lexical-decision experiment was that there was no pseudohomophone effect for the fastest subjects. These more skilled readers can identify a pseudohomophone as a nonword without interference from knowledge of the homophone. The bases for these subjects' responses may include recognition that the pseudohomophone's orthographic code is unfamiliar or the failure of this orthographic code to activate semantic information.

With this account of the basic phenomena in hand, we can now reconsider some of the theoretical implications that have been attached to pseudohomophone effects.

Are There Lexical Nodes in Lexical Memory?

The existence of pseudohomophone effects is sometimes taken as evidence that the lexicon must include word-specific representations such as lexical entries or logogens and as a problem for models that do not include such representations (e.g., Plaut et al., in press; Seidenberg & McClelland, 1989). This conclusion needs to be reconsidered in light of the present results. The data for the naming task indicate no effect of pseudohomophony on the computation of phonological codes from orthographic input, a result that does not demand the introduction of word-specific representations. There are differences in the ease of producing familiar and unfamiliar pronunciations, and introducing word-specific representations that are accessed in generating articulatory output would be one way to accommodate these effects. However, these results can also be explained using the principles already known to govern the Seidenberg and McClelland model. Our account of pseudohomophone effects in naming suggests that they are actually frequency effects in the articulatory domain: Nonword pronunciations are lower frequency patterns than word pronunciations. The effects should therefore be explained by the same factors that govern frequency effects in other domains. It was once thought that other sorts of frequency effects (e.g., on "lexical access") also require the assumption that there are word-specific lexical entries that keep a record of how often words are used (e.g., Forster, 1976; Morton, 1969); however, neural networks using distributed representations show that this intuition is incorrect. The Seidenberg and McClelland model, for example, produces robust effects of lexical frequency without using word-specific representations. What is important in producing the effect is that word frequency have an impact on the knowledge represented in the network (by virtue of its effects on the weights during training), not that the knowledge representations themselves be word specific.

We have interpreted the word–nonword differences in producing articulatory motor output in terms of recurrent neural networks, which produce sequential output (see Jordan, 1986; also Cleeremans & McClelland, 1991; Cleeremans, Servan-Schreiber, & McClelland, 1989; Elman, 1990, 1991; Pearlmutter, 1989). This architecture was initially developed with tasks such as speech production in mind (Jordan, 1986). Instead of learning a pattern associated with a pronunciation, such networks learn to produce a trajectory of outputs, such as an integrated sequence of articulatory movements. The execution of such trajectories is influenced by the same factors that give rise to frequency effects in feedforward networks (see, e.g., Cleeremans & McClelland, 1991). Thus, frequency effects involving different types of information can all be seen as deriving from facts about how frequency affects the settings on weights in certain types of connectionist models. In summary, it is important to understand different kinds of frequency effects, but it does not follow from such evidence that models of this knowledge necessarily require word-specific representations.

Simulations Using Recent Models

Our interpretation of pseudohomophone effects is also supported by the results of simulation experiments using the Seidenberg and McClelland (1989) and Plaut et al. (in press) models. It is well known that the Seidenberg and McClelland model's accuracy in pronouncing the McCann and Besner (1987) nonwords was poorer than peoples' accuracy (Besner et al., 1990). There are some uncertainties about how to score the model and subjects' responses equivalently (see Seidenberg & McClelland, 1990; Seidenberg, Plaut, Petersen, McClelland, & McRae, 1994), but by the strictest scoring criteria, the model produced correct output for only about 60% of these nonwords. The model's errors were due to deficiencies in its phonological representation that caused it to produce small deviations from intended targets (Seidenberg & McClelland, 1990); improved phonological representations yield accuracy comparable to peoples' accuracy (Plaut et al., in press). Leaving aside the accuracy issue, it is worth noting that the Seidenberg and McClelland model did exhibit a pseudohomophone effect even though it lacks lexical representations: It performed better on pseudohomophones than on nonpseudohomophones, in terms of both accuracy and the orthographic and phonological error scores that reflect goodness of fit to target patterns. The model produced these effects because it picked up on the systematic orthographic and phonological differences between McCann and Besner's two types of nonwords.

We also examined how the newer model described by Plaut et al. (in press) performed on pseudohomophones and nonpseudohomophones. This model, like Seidenberg and McClelland's (1989), consists of a network using distributed representations that takes orthographic patterns as input and produces phonological patterns as output, after training on a substantial corpus of monosyllabic words using an error-correcting learning algorithm. It uses a phonological representation that eliminates most of the deficiencies of the representation used in the earlier model. Like that model, however, the newer one does not implement the process of generating articulatory output. Plaut et al. used the model to examine how the availability of an alternative orthography → semantics → phonology pathway affects the behavior of the orthography → phonology pathway. This semantically mediated naming process may be relevant to the processing of some lower frequency irregular words (Strain et al., 1995). To test the hypothesis that the data in both our studies and in McCann and Besner's (1987) reflect stimulus properties that affect the orthography → phonology computation, we disabled the semantically based pathway. The model was trained on a large corpus of monosyllabic words using the backpropagation through time algorithm (Pearlmutter, 1989). The model learned to correctly produce phonological codes for about 99% of the items in the training set. The model was then tested on both sets of stimuli. The prediction regarding McCann and Besner's stimuli is that the model should produce a pseudohomophone advantage because of the systematic orthographic and phonological differences between the two types. The prediction for the stimuli in the present experiments is that there should be no pseudohomophone–nonpseudohomophone difference, because the stimuli are equated with respect to these types of information. (The stimuli differ with regard to factors affecting the production of articulatory output, but the implemented model does not include this component.) The model was tested after 400, 800, and 2,000 epochs of training. Table 2 presents data concerning the model's accuracy and cross-entropy error (a measure of goodness of fit; see Plaut et al., in press) for each set of stimuli, averaged over the three tests. For the McCann and Besner stimuli, the model produced a higher percentage of correct pronunciations for pseudohomophones than for nonpseudohomophones, $t(158) = 2.06, p < .05$, but it performed equally well on the two groups of stimuli used in the above experiments, $t < 1$. Because the stimuli were matched pairs of items, in calculating the cross-entropy error scores, we included all pairs for which the model got both members correct. Scores greater than 2 *SD* above the mean were replaced with the 2 *SD* value. For McCann and Besner's stimuli, the mean cross-entropy error for the pseudohomophones was lower than for the nonpseudohomophones at all three levels of training: at 400 epochs, $t(62) = 2.78, p < .01$; at 800 epochs, $t(59) = 2.27$, $p < .05$; and at 2,000 epochs, $t(55)$, $= 1.87, p < .07$. There were no statistically reliable differences between the pseudohomophones and nonpseudohomophones used in the present experiment, all ps $> .10$. Thus, the model captures how the stimuli differ with respect to factors influencing the computation of the phonological code and reproduces McCann and Besner's pseudohomophone effect without lexical nodes.

Strategy Effects

Our results suggest that the effects of pseudohomophony on overt naming are quite limited under the conditions we have studied: They are specific to generating articulatory output. Taking into account differences between the stimuli that were used, the results are consistent with those of McCann and Besner (1987). Our results do not implicate the use of semantic information associated with the base words in naming pseudohomophones. In contrast, the lexical-decision results suggest that pseudohomophones sometimes activate the meanings associated with their base words, thus interfering with the lexical decision.

Table 2
Performance of Plaut et al. (in press) Model on Two Sets of Stimuli

Performance measures	McCann & Besner (1987)		Present study	
	PH	NONPH	PH	NONPH
% correct	90.4	79.6	93.2	93.8
Mean CE error	0.698	0.794	0.633	0.665

Note. PH = pseudohomophone; NONPH = nonpseudohomophone; CE = cross-entropy.

A number of recent studies have examined how additional factors affect participants' performance on the lexical-decision and naming tasks. Considerable attention has been focused on the strategies that participants develop explicitly in response to manipulations of the instructions and materials. The possibility that performance might vary in response to such manipulations first arose in connection with the lexical-decision task (see, for example, James, 1975; Seidenberg, Waters, Sanders, & Langer, 1984; Shulman, Hornak, & Sanders, 1978; Waters & Seidenberg, 1985) and more recently with regard to naming (e.g., Baluch & Besner, 1991; Monsell, Patterson, et al., 1989). The fact that different results can be obtained under other conditions is not itself surprising, but it does raise a question about the generality of the results presented here and of the framework we have used to interpret them (see Seidenberg, 1995, for additional discussion).

The basic methodology in both our naming studies and McCann and Besner's (1987) involved presenting randomly intermixed pseudohomophones and nonpseudohomophones and asking participants to name them aloud using their knowledge of English spelling–sound correspondences. It is clear that participants can be induced to change their strategies for performing the naming task either through explicit instruction (e.g., Monsell, Patterson, Tallon, & Hill, 1989, instructed participants to pronounce exception words such as *pint* as if they were rule governed) or implicitly by means of manipulations of the types of stimuli included in an experiment (e.g., Monsell, Patterson, Graham, Hughes, & Milroy, 1992, obtained different effects depending on whether nonword and exception word stimuli were blocked or intermixed; see also Baluch & Besner, 1991). It is easy to imagine conditions that would promote larger effects of semantic information in naming pseudohomophones than we have observed—for example, presenting both pseudohomophones and nonpseudohomophones but instructing participants to only name aloud the pseudohomophones. Under these modified conditions, factors such as the frequency of the base word or its concreteness would be more likely to affect performance. Such strategic effects on pronunciation were not the focus of the Seidenberg and McClelland (1989) or Plaut et al. (in press) modeling work, but they can be easily accommodated within the framework they established. Our models attempt to account for the representation and processing of information in lexical memory. "Strategies" reflect additional processes typically related to either stimulus encoding (e.g., allocating attention to smaller orthographic units, as in the Monsell, Patterson, et al., 1989, study) or how the information that is computed is used in making a response (such as a lexical decision). Indeed, insofar as reading normally does not involve making word–nonword discriminations, all lexical-decision performance reflects the use of strategies in conjunction with the kind of lexical knowledge addressed by our models.[3]

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[3] The strategy issue arises in connection with some recent experiments by Herdman, LeFevre, and Greenham (1994). Their partici-

In summary, the conditions we have studied provide information relevant to identifying how certain types of knowledge are represented in lexical memory and used in performing simple tasks. The experiments provide evidence concerning the locus of the pseudohomophone effects obtained under different conditions. It is clear that the conditions we have studied do not exhaust the range of possibilities afforded by these tasks, however.

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pants named aloud McCann and Besner's (1987) pseudohomophone and nonpseudohomophone stimuli; however, Herdman et al. included a second condition in which words were intermixed among these nonwords. In both conditions, pseudohomophones were named more rapidly than nonpseudohomophones, as in McCann and Besner's study, and the effects were larger for slower participants than for faster participants. With words intermixed among the nonwords, only the slower participants exhibited a significant effect of base word frequency for the pseudohomophones, with pseudohomophones derived from high-frequency words yielding longer latencies than those derived from lower frequency words. Herdman et al.'s overall results are consistent with ours, but there are some differences in detail. Given that they used McCann and Besner's stimuli, the overall advantage for pseudohomophones compared to nonpseudohomophones is expected because of the structural differences between them identified in Appendix A. The fact that the effect was larger for slower participants suggests that they were more affected by these stimulus characteristics, which also is consistent with our account. However, we did not observe an effect of base word frequency in any study, even for the slowest participants. This effect may reflect a greater degree of activation from orthography to phonology to semantics for the slower participants compared to the faster ones. In effect, including words among the stimuli to be named makes this task more like lexical decision, where the frequency of the base word affects performance in a similar way. However, Herdman et al.'s results need to be interpreted cautiously; although their experiments included all 80 pseudohomophones from McCann and Besner's list, they assessed the effects of base word frequency by comparing only the 10 items with the highest and lowest frequency base words. They did not report correlations between base word frequencies and naming latencies. The slower mean naming latencies for the items derived from higher frequency words compared with lower frequency words might reflect effects of the base word but could also reflect other structural differences between the two small sets of stimuli.

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(*Appendixes follow on next page*)

Appendix A

Issues in Comparing Pseudohomophones and Nonpseudohomophones

McCann and Besner (1987) were careful to assess whether their results could have been due to the use of different onsets in the pseudohomophone and nonpseudohomophone items. First, they calculated mean bigram frequencies, using the Mayzner and Tresselt (1965) norms. The pseudohomophones had a slightly higher mean summed positional bigram frequency (147) than did the nonpseudohomophones (125), but this difference was discounted because it was not significant by a t test. A problem with accepting this negative finding is that it is questionable whether the Mayzner and Tresselt norms, which date from 1965 and were based on a corpus of 20,000 words, provide a robust estimate of bigram frequencies. We recomputed the bigram frequencies using the 1 million word Kučera and Francis (1967) corpus. The algorithm examined each bigram in a letter string, searched the Kučera and Francis corpus for the words of the same length that had the same bigram in the same position, and summed their frequencies. The mean summed positional bigram frequency for the nonpseudohomophone items is 3,711, the mean for the pseudohomophone items is 4,397, and the difference is statistically reliable, $t(79) = 2.98, p < .01$.

This orthographic difference also appeared when the calculation was based instead on the frequencies of the onsets alone. For this analysis, we counted the number of words in the Kučera and Francis (1967) corpus beginning with each onset (e.g., *pr__* in *preet; p__* in *pait*). The mean number of words containing the nonpseudohomophone onsets is 972, the mean for the pseudohomophone onsets is 1,223, and the difference is statistically reliable, $t(79) = -2.98, p < .01$. We obtained similar results when, instead of counting the number of types containing the onsets, we summed the frequencies of the tokens: For the nonpseudohomophone stimuli the mean summed frequency is 20,096, for the pseudohomophone stimuli it is 24,332, and the difference approaches significance, $t(79) = -1.74, p < .09$. In summary, McCann and Besner's (1987) null effect of bigram frequency appears to have derived from a lack of robustness in the estimates provided by Mayzner and Tresselt (1965). Estimates based on larger samples indicate a systematic difference between the stimuli.

McCann and Besner (1987) also assessed whether the stimuli differ in terms of another measure of orthographic structure, Coltheart's N (Coltheart et al., 1977), which is the number of words that can be derived from a letter string by making one-letter substitutions. McCann and Besner reported that their stimuli differed significantly on the N measure: The pseudohomophone items have higher N values than the nonpseudohomophone items. However, they also performed post hoc analyses indicating that whereas N was significantly correlated with latencies and errors on nonpseudohomophone items, it was not for pseudohomophones (see McCann & Besner, 1987, p. 18, Figures 1 and 2). Given the lack of an effect of N on the pseudohomophone items, they concluded that it could not be the source of the overall pseudohomophone–nonpseudohomophone difference. The problem with the regression plotted in their figures, however, is that it compares Coltheart N and the mean response latency for all of the items with a given N. The number of items contributing to each mean therefore varied. We recalculated the correlations between Coltheart N and the actual item means for these stimuli. The Coltheart Ns for this analysis were generated using the algorithm for this purpose in the Medical Research Council Psycholinguistics Database (Coltheart, 1981) and differed slightly from those reported by McCann and Besner but yielded similar results. The correlation between Coltheart N and latency for the nonpseudohomophone items, −.27, was significant, whereas the correlation for the pseudohomophone items, −.11, was not, replicating McCann and Besner's findings. However, the effect for the nonpseudohomophone items was due to the items with no neighbors (i.e., Coltheart N values of 0), of which there were 16 in the nonpseudohomophone list and 7 among the pseudohomophones. When we excluded these no-neighbor items from the nonpseudohomophone list, the correlation between Coltheart N and latency became −.075, which also was nonsignificant. Thus, it appears that the differences between the pseudohomophone and nonpseudohomophone stimuli were due to differences in the number of no-neighbor items.

Finally, McCann and Besner (1987) included two additional experimental conditions to assess the effects of the confounds between the stimuli. The first was the delayed naming condition, which yielded a significant residual pseudohomophone effect that was smaller in magnitude than in immediate naming. These results are discussed in the Experiment 2 section of this article. Second, McCann and Besner conducted a control experiment because, as they noted,

> Although the advantage [for pseudohomophone nonwords in Experiment 1] was significantly reduced [in the delayed naming condition], it might be argued that the additional emphasis on speed of responding in the delayed condition would reduce the magnitude of any stimulus effect compared with online responding (p. 17).

The additional controls in Experiment 2 involved deriving new nonpseudohomophones from the pseudohomophone and nonpseudohomophone stimuli by changing the vowels but retaining the onsets. Thus, *fownd* became *foind* and *yownd* became *yoind.* Latencies for these stimuli did not differ. This indicated that the pseudohomophone advantage in the original experiment was not due to the differences between the onsets used in the two lists of stimuli. These control stimuli introduce a new problem, however: Although they retain the onsets from the originals, they contain different vowels. The effect of this change was to eliminate the difference in Coltheart N between the two lists. The mean for the nonpseudohomophone-derived stimuli was 3.2 and the mean for the pseudohomophone-derived stimuli was 3.5; this difference was not significant, $t(79) = 1.31, p > .15$.

In summary,

1. McCann and Besner's (1987) pseudohomophone and nonpseudohomophone stimuli consisted of pairs of items with the same rimes and different onsets. The same stimuli with slight modifications were used in studies by McCann et al. (1988) and Fera and Besner (1992).
2. The pseudohomophone stimuli have higher frequency onsets, higher bigram frequencies, and more neighbors defined in terms of Coltheart N.
3. The correlation between Coltheart N and latencies for the nonpseudohomophones derived from the fact that there were more of these items with no neighbors. Eliminating these items also eliminated the correlation.
4. The control stimuli in Experiment 2 retained the same onsets as the original stimuli but eliminated the difference in Coltheart N. This also eliminated the differences in latency and errors.

Thus, the pseudohomophone effect in the original McCann and Besner (1987) experiment appears to have been due to the fact that the stimuli differed in terms of orthographic properties indexed by measures such as Coltheart N and bigram frequency, not the fact that the pseudohomophones sounded like words. This conclusion is also consistent with the results of the experiments described in the text.

These confounds between the pseudohomophone and nonpseudohomophone stimuli are also relevant to the study by Fera and Besner (1992) that used these materials. Fera and Besner found that the magnitude of the difference between the pseudohomophone and nonpseudohomophone conditions was not affected by the degree of overlap between words and nonwords. This contradicted a prediction by Seidenberg and McClelland (1990) concerning the conditions under which pseudohomophones will activate semantic information. Again, however, it is not clear whether these results reflect the pseudohomophony factor or the other differences between the stimuli.

Appendix B

Latency Data by Items, Experiments 1 and 2

Pseudo-homophone	Experiment 1		Experiment 2			Nonpseudo-homophone	Experiment 1		Experiment 2		
	LD	Name	None	+2 *SD*	+4 *SD*		LD	Name	None	+2 *SD*	+4 *SD*
waid	714	550	580	414	374	gaid	695	584	594	494	478
gaim	740	556	628	445	346	waim	618	518	620	472	412
staige	742	582	649	498	504	shaige	630	668	704	544	552
shaip	665	581	739	431	492	staip	725	642	710	431	448
paije	630	682	643	420	382	baije	624	780	727	479	471
baik	651	679	714	421	441	paik	666	593	615	425	395
stail	942	564	704	469	435	blail	739	632	600	412	326
blaim	926	534	566	403	382	staim	717	599	652	489	484
caim	781	607	728	427	392	haim	625	614	611	405	373
haiz	659	723	563	451	468	caiz	620	620	714	519	380
taim	691	576	570	406	410	raim	685	584	473	380	356
raiz	568	591	644	430	411	taiz	584	597	662	454	395
mault	953	588	692	388	406	cault	821	568	604	436	447
caust	805	571	579	400	452	maust	682	772	588	412	403
shaym	648	595	667	504	464	playm	606	691	787	498	492
playt	628	585	613	424	430	shayt	587	623	745	530	466
chayn	622	606	676	541	451	tayn	612	1025	575	518	454
tayp	660	616	732	401	410	chayp	549	704	699	415	427
meak	790	540	547	381	385	keak	638	645	618	464	502
keap	749	570	622	650	391	meap	714	518	610	393	365
feal	863	609	673	459	434	greal	853	553	653	473	432
grean	709	562	607	369	430	fean	704	588	749	426	502
pleed	700	562	655	524	431	dreed	758	580	680	450	426
dreem	880	562	572	408	356	pleem	706	561	585	502	434
leef	683	571	609	410	386	weef	648	544	579	433	377
weet	693	507	574	459	381	leet	700	540	565	428	375
teem	677	559	598	429	413	leem	807	523	559	356	413
leep	662	536	565	376	346	teep	677	582	653	474	382
thefe	739	736	698	408	394	flefe	639	702	738	592	458
fleze	672	594	634	432	398	theze	664	624	582	459	526
refe	620	635	617	436	416	mefe	678	560	600	464	339
mene	618	688	607	517	370	rene	667	589	695	444	426
wen	699	529	602	470	359	sen	626	619	727	532	449
sez	611	575	644	471	441	wez	643	515	670	351	468
ment	849	495	565	382	340	hent	682	616	596	412	376
hert	743	569	574	722	356	mert	774	492	626	396	368
lerk	842	539	568	472	430	ferk	754	561	606	419	438
ferm	980	593	654	410	454	lerm	673	504	694	396	372
joak	662	597	662	544	445	hoak	786	568	644	387	404
hoap	712	639	647	463	466	joap	699	532	666	482	427
soal	822	583	589	453	473	groal	733	532	641	438	386
groaz	641	550	745	442	398	soaz	623	649	705	528	468
lofe	677	523	499	430	464	kofe	621	569	666	428	448
kome	648	619	688	458	378	lome	731	534	535	405	414
fome	711	560	716	380	439	bome	692	589	621	451	420
bote	673	601	582	422	434	fote	737	565	721	447	447
toob	673	614	640	424	460	croob	650	619	612	444	468

(*Appendix B continues on next page*)

Appendix B (*continued*)

Pseudo-homophone	Experiment 1		Experiment 2			Nonpseudo-homophone	Experiment 1		Experiment 2		
	LD	Name	None	+2 *SD*	+4 *SD*		LD	Name	None	+2 *SD*	+4 *SD*
crood	825	608	612	496	482	tood	710	646	622	434	453
stuk	642	636	722	487	450	fruk	718	648	713	677	449
frum	689	686	748	449	441	stum	807	596	593	525	483
suk	638	973	707	519	450	wuk	588	600	664	410	387
wurch	618	582	605	433	397	surch	761	595	670	475	465
brume	661	630	604	425	440	trume	680	654	608	430	427
trupe	782	624	654	444	414	brupe	709	696	665	548	398
purch	832	555	570	479	420	furch	704	621	594	449	439
furst	706	576	646	406	391	purst	670	617	665	419	452
wurk	592	589	593	439	364	durk	661	538	560	399	388
durt	738	524	579	400	437	wurt	644	534	615	424	352
wurth	666	537	583	383	415	surth	711	616	630	521	459
wuz	626	576	579	444	412	suz	617	667	669	489	495
luse	639	524	663	502	399	pruse	730	584	651	497	453
pruve	707	632	618	459	402	luve	714	591	805	431	458
pryde	607	616	627	426	434	gryde	576	688	683	464	428
grype	714	557	625	506	370	prype	586	670	603	466	456

Note. LD = lexical decision task; Name = naming task. None, +2 *SD*, and +4 *SD* are delay intervals.

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