Journal of Experimental Psychology:
Learning, Memory, and Cognition
2002, Vol. 28, No. 3, 572–584

0278-7393/02/$5.00 DOI: 10.1037//0278-7393.28.3.572

Phonological Effects in Visual Word Recognition: Investigating the Impact of Feedback Activation

Penny M. Pexman
University of Calgary

Stephen J. Lupker
University of Western Ontario

Lorraine D. Reggin
University of Calgary

P. M. Pexman, S. J. Lupker, and D. Jared (2001) reported longer response latencies in lexical decision tasks (LDTs) for homophones (e.g., *maid*) than for nonhomophones, and attributed this homophone effect to orthographic competition created by feedback activation from phonology. In the current study, two predictions of this feedback account were tested: (a) In LDT, observe homophone effects should be observed but not regularity or homograph effects because most exception words (e.g., *pint*) and homographs (e.g., *wind*) have different feedback characteristics than homophones do, and (b) in a phonological LDT ("does it sound like a word?"), regularity and homograph effects should be observed but not homophone effects. Both predictions were confirmed. These results support the claim that feedback activation from phonology plays a significant role in visual word recognition.

The role of phonology in visual word recognition has long been an important issue in psycholinguistic research. A considerable amount of research evidence supports the idea that phonology is activated early in the word recognition process (e.g., Berent & Perfetti, 1995; Lukatela & Turvey, 2000; Perfetti & Bell, 1991), and there is also evidence that phonology mediates access to word meanings (e.g., Lesch & Pollatsek, 1998; Luo, Johnson, & Gallo, 1998; Van Orden, 1987). Other results, however, suggest that phonology may only be involved in accessing the meaning of low-frequency words (e.g., Jared & Seidenberg, 1991) or that phonology may not be involved at all when task demands discourage its use (e.g., McQuade, 1981; Pugh, Rexer, & Katz, 1994; Seidenberg, Waters, Barnes, & Tanenhaus, 1984). Thus, at present, our understanding of the role of phonology in visual word recognition is far from complete.

Penny M. Pexman and Lorraine D. Reggin, Department of Psychology, University of Calgary, Calgary, Alberta, Canada; Stephen J. Lupker, Department of Psychology, University of Western Ontario, London, Ontario, Canada.

Portions of the research described in this article were presented at the 11th Annual Conference of the European Society for Cognitive Psychology, Ghent, Belgium, September 1999, and at the Lexical Processing Workshop, Tucson, Arizona, November 1999. This research was supported in part by Natural Sciences and Engineering Research Council of Canada Grants 217309 and A6333 awarded to Penny M. Pexman and Stephen J. Lupker, respectively. We thank Ronald Peereman, Guy Van Orden, and three anonymous reviewers for their comments on earlier versions of this article.

Correspondence concerning this article should be addressed to Penny M. Pexman, Department of Psychology, University of Calgary, 2500 University Drive NW, Calgary, Alberta T2N 1N4, Canada. E-mail: pexman@ucalgary.ca

In a recent investigation of the role of phonology in visual word recognition, Pexman, Lupker, and Jared (2001) examined homophone effects in lexical decision tasks (LDTs). Homophones are words like *maid* and *made*, where a single pronunciation maps onto at least two spellings (and two meanings). These words are useful tools for investigating phonological processing, because if phonological codes do play a major role in word recognition, then confusion (and hence, longer latencies in speeded response tasks) may arise for homophones. However, if word recognition is primarily driven by orthographic codes, the standard expectation is that no such confusion should arise. Pexman et al.'s findings of longer latencies for homophones than nonhomophones in a number of LDT experiments support the conclusion that phonological codes do play an important role in word recognition. The purpose of the present research was to test the explanation of homophone effects offered by Pexman et al. and, in doing so, to further investigate the role of phonology in visual word recognition.

The Feedback Account

The aim of Pexman et al.'s (2001) experiments was to establish the conditions under which homophone effects arise in LDTs. They found, first, that low-frequency homophones (e.g., *maid*) that have high-frequency homophone mates (*made*) generate a homophone effect in a standard LDT (see also Davelaar, Coltheart, Besner, & Jonasson, 1978; Rubenstein, Lewis, & Rubenstein, 1971). The standard LDT includes as foils letter strings that are pronounceable but not pseudohomophonic (referred to here as pseudowords; e.g., *prane*). Pexman et al. also found that when pseudohomophone foils were used (e.g., *brane*), the homophone effect for low-frequency words typically increased and homophone effects were observed even for high-frequency words.

Pexman et al.'s (2001) finding of an enhanced homophone effect when pseudohomophones were used is opposite to the results reported by Davelaar et al. (1978). That is, Davelaar et al. observed a homophone effect in their pseudoword foil condition that then disappeared in their pseudohomophone foil condition. From these results, Davelaar et al. concluded that with pseudohomophone foils, their participants strategically deemphasized phonological processing, which eliminated the homophone effect. As Pexman et al. (Experiment 5) demonstrated, however, Davelaar et al.'s null homophone effect in their pseudohomophone foil condition was most likely due to their use of a particular set of homophones and control words that do not generate a homophone effect in any foil condition (due, in part, to poor matching of homophones and control words).

In their efforts to explain homophone effects, Pexman et al. (2001) first considered whether homophone effects might be due to semantic competition. That is, if phonological codes are the codes used to access meaning, homophones should activate multiple semantic representations. These activated semantic representations could create competition that might need to be resolved before a response was made, leading to slower lexical decision times for homophones. This type of account was rejected, however, because words that activate more than one meaning (polysemous words like *bank*) usually produce faster lexical decision times than nonpolysemous words (e.g., Borowsky & Masson, 1996; Hino & Lupker, 1996; Jastrzembski, 1981; Jastrzembski & Stanners, 1975; Kellas, Ferraro & Simpson, 1988; Rubenstein, Garfield, & Millikan, 1970). Thus, it would appear that homophone effects require a somewhat different explanation (see Pexman & Lupker, 1999, for an explanation of how both homophone and polysemy effects can be accounted for within a single framework).

The explanation that Pexman et al. (2001) devised was based on the notion of feedback within a highly interactive system, for example, a fully interactive, PDP- (parallel distributed processing) type model like that of Plaut, McClelland, Seidenberg, and Patterson (1996), which would have both feedforward and feedback connections between sets of units. What should be noted, however, is that there are also other models of word recognition (e.g., Coltheart, Rastle, Perry, Langdon, & Ziegler's, 2001, dual-route cascaded model) that incorporate feedforward and feedback connections. Thus, although Pexman et al. discussed their results within a PDP framework, there is no a priori reason that their results could not have been framed in terms of other, feedback-based models as well.

The idea that feedback connections might affect word recognition is not new (e.g., Andrews, 1992; Balota, Ferraro, & Connor, 1991; Gottlob, Goldinger, Stone, & Van Orden, 1999; Taft & van Graan, 1998; Van Orden & Goldinger, 1994) and was recently adopted as an important concept in the model of Stone, Vanhoy, and Van Orden (1997, see also Ziegler, Montant, & Jacobs, 1997). Stone et al. reported that words with bodies that can be spelled in more than one way (e.g., _*ade* in *fade* could be spelled _*aid* or _ _*ayed* as in *paid* or *swayed*, respectively) are responded to more slowly than words with bodies that can have only one spelling (e.g., _*imp* in *limp*). Thus, what they term "inconsistent" feedback from phonology to orthography seemed to slow processing (although see Peereman, Content, & Bonin, 1998, for a contrary view). Pexman et al.'s (2001) account of homophone effects was essentially an expansion of Stone et al.'s ideas (see Berent & Van Orden, 2000, and Taft & van Graan, 1998, for other discussions of feedback and homophony). That is, homophones represent the maximum degree of "feedback inconsistency" in that the entire word is feedback inconsistent (in contrast, the words Stone et al. tested were only body inconsistent). Thus, if feedback inconsistency does delay responding in LDT, homophones would be the words most likely to produce such an effect.

More specifically, Pexman et al.'s (2001) feedback explanation of homophone effects would be as follows. When a homophone is presented (e.g., *maid*), there is an initial orthographic analysis of the word, followed quickly by activation of a corresponding phonological representation. This phonological representation then feeds activation back to the orthographic units through feedback connections. Although some activation is directed to the correct orthographic representation (*maid*), there is also activation directed to the orthographic representation of the homophone mate (*made*). As a result, there is competition between these orthographic representations. On the basis of Pexman et al.'s further assumption that responding in an LDT is normally based primarily on the activation within these orthographic units, the argument is that this competition causes the delay in responding for homophones.

This account can also explain why homophone effects are modulated by frequency. As mentioned, in a standard LDT, homophone effects are only observed when the low-frequency member of the pair is presented (Pexman et al., 2001). This result reflects two properties of the system. First, the orthographic representation for the low-frequency mate has a lower resting activation level than the orthographic representation for the high-frequency mate. Second, feedback from phonology to the orthographic level would be stronger for the high-frequency mate than for the low-frequency mate. Thus, the orthographic representation for the high-frequency mate would more readily achieve a level of activation that could produce competition than would the orthographic representation for the low-frequency mate. It should be noted again that an important assumption of this explanation is that lexical decisions are performed primarily on the basis of activity in the orthographic units.

As mentioned, Pexman et al. (2001) also found that homophone effects were larger with pseudohomophone foils (as compared with the effect sizes with pseudoword foils). An explanation of this result also follows from the feedback account. Overall response times (RTs) are typically slower with pseudohomophone foils (e.g., Gibbs & Van Orden, 1998; Pexman & Lupker, 1999; Pexman et al., 2001; Stone & Van Orden, 1993). According to the feedback explanation, this is because of the nature of the feedback from phonology to orthography that is generated by pseudohomophones. That is, a pseudohomophone (e.g., *brane*) will generate a phonological representation that feeds back to the orthographic representation for a real word (*brain*). Again, since lexical decisions are assumed to be based primarily on orthographic activity, the fact that a pseudohomophone activates (through feedback) the orthographic representation for a real word means that it will be more difficult to distinguish pseudohomophones from real words at the orthographic level (compared with the situation where it is pseudowords that must be distinguished from real words at the orthographic level). This would occur even when pseudowords and pseudohomophones are matched for orthographic characteristics, as they were in the Pexman et al. study. As a result, participants will be forced to adopt a higher criterion of orthographic activity before classifying a letter string as a word. The result is slower overall responding, and increased opportunity for feedback to affect processing of words. Hence, with pseudohomophone foils, homophone effects become larger, and can be observed even for high-frequency homophones.

Experiment 1

According to the feedback explanation, although homophone effects are "phonological" effects in that activity in phonological units plays an important role in generating these effects, they are different than other phonological effects whose source is competition in the phonological rather than the orthographic codes. That is, homophone effects are thought to arise because of the nature of *feedback activation* from phonology to orthography for homophones. In contrast, certain other phonological effects are assumed to arise because of the nature of *feedforward activation* from orthography to phonology. More specifically, regularity effects (e.g., Andrews, 1982; Baron & Strawson, 1976; Seidenberg et al., 1984), and homograph (e.g., *wind*) effects (Gottlob et al., 1999; Kawamoto & Zemblidge, 1992; Seidenberg et al., 1984) are thought to arise because of competition between phonological codes. This phonological competition is created by feedforward activation from the orthographic units to more than one phonological representation. For instance, for a homograph like *wind*, there is an initial orthographic representation that activates, through feedforward connections, phonological representations for both /wind/ and /wajnd/. When a task requires that phonological codes be fully determined (e.g., a naming task), then competition between the two phonological representations will need to be resolved before a response can be made. According to the feedback account, however, in a standard LDT, it is orthographic competition rather than phonological competition that primarily affects responding. Thus, the basic prediction of the feedback account would be that although homophone effects (which are due to orthographic competition created by feedback activation from phonology) will typically be observed in LDT, regularity and homograph effects (which are due to phonological competition created by feedforward activation from orthography) will not be.

This prediction about regularity effects is generally supported by past literature. For example, Seidenberg et al. (1984) reported regularity effects in LDT only when strange words (e.g., *aisle*) were included. Hino and Lupker (1996) reported regularity effects in LDT only when the stimuli were visually degraded. Berent (1997) found a null regularity effect in LDT with pseudoword foils, although there was a regularity effect in the error data (especially for the high-frequency words) with pseudohomophone foils.

Gibbs and Van Orden (1998, Experiment 2), however, found a regularity effect in LDT in errors but not in RTs with pseudoword foils and found a regularity effect in errors and RTs with pseudohomophone foils. In that experiment, however, Gibbs and Van Orden also included a set of strange words, whose presence, given Seidenberg et al.'s (1984) results, may have contributed to their regularity effect.

In Gibbs and Van Orden's (1998) Experiment 1, they examined consistency effects in LDT with no strange words included. Whereas regularity is defined in terms of whether a word follows spelling-sound rules, consistency is defined in terms of whether a word is pronounced in the same way as its body neighbors (e.g., *yell* is consistent with its body neighbors, e.g., *bell*, *cell*, *hell*, whereas *pint* is inconsistent with its body neighbors, e.g., *mint*, *lint*, *hint*). Although regularity and consistency are defined differently, many exception words are also inconsistent, and vice versa. In their Experiment 1, Gibbs and Van Orden reported null consistency effects with pseudoword foils but significant consistency effects in errors and RTs with pseudohomophone foils. On the basis of their full set of results, Gibbs and Van Orden argued that phonology normally plays a role in the LDT, and phonological effects will be more apparent with pseudohomophone foils because these foils create a more difficult decision.

According to Gibbs and Van Orden's (1998) argument, one would expect that homophone, regularity, and homograph effects will all appear in the LDT, although it might be necessary to use pseudohomophones as foils in order to observe them. It should be noted, however, that Gibbs and Van Orden's results were complicated by the fact that 33% of their exception words were homophones (e.g., *sew*, *steak*), and 36% of their inconsistent words were homophones (e.g., *lone*, *bough*). Thus, it is not clear to what extent their regularity effect (or their consistency effect) was actually a homophone effect. In addition, some of the error rates in Gibbs and Van Orden's experiments were unusually high (e.g., in Experiment 1: 25.2% for inconsistent words, 15.0% for consistent words; in Experiment 2: 23.8% for exception words, 14.2% for regular words). Thus, it is possible that many of their participants didn't actually know how to spell a number of the words used in these experiments. In any case, error rates of this magnitude do make the interpretation of RT data somewhat problematic.

The question of whether homophone, regularity, and homograph effects do occur simultaneously was the focus of the present Experiment 1. Given Gibbs and Van Orden's (1998) results, one might expect that the effects would co-occur in LDT. Alternatively, the feedback explanation, together with the assumption that responding in the LDT is based essentially on orthographic activity, predicts that the effects would not co-occur because they have different sources (competition created by feedback activation vs. competition created by feedforward activation). Experiment 1A was a naming task with the same homophones, exception words, homographs, and respective control words that were used in the LDTs of Experiments 1B (with pseudoword foils) and 1C (with pseudohomophone foils). Because regularity and homograph effects are usually observed in naming (e.g., Seidenberg et al., 1984), this naming task serves as a check that the exception words and homographs selected produce the typical effects. Further, because the feedback account explains homophone effects in terms of orthographic activation, whereas responding in the naming task is primarily based on phonological activation, a further expectation is that there will be no homophone effect in Experiment 1A.

Method

Participants

The participants in Experiment 1A, 1B, and 1C were undergraduate students at the University of Calgary who participated in exchange for bonus credit in a psychology course. There were 26 participants in Experiment 1A, 36 participants in Experiment 1B, and 35 participants in Experiment 1C. Participants in each of these experiments had normal or corrected-to-normal vision and reported that English was their first language.

Stimuli

Words. There were six types of words used in these experiments. The first two types were low-frequency homophones and nonhomophonic control words. These 20 homophones (mean frequency = 8.35 per million; Kučera & Francis, 1967) and 20 control words (mean frequency = 8.55) were matched for frequency, length, and neighborhood size (Coltheart, Davelaar, Jonasson, & Besner, 1977) and were a subset of the stimuli used in Pexman et al. (2001). These low-frequency homophones all have high-frequency homophone mates, which were not presented. The next two word types were homographs and nonhomographic control words. These 12 homographs (mean frequency = 73.08) were used by Seidenberg et al. (1984). The frequency of each homograph was determined by the occurrence of the spelling, and so represents the sum frequency of all the meanings and pronunciations of the word. The 12 control words (mean frequency = 73.25) were selected specifically for this experiment and were matched with the homographs for frequency, length, and neighborhood size. The last two types of words were low-frequency exception and regular words. These 10 exception words (mean frequency = 10.50) and 10 regular words (mean frequency = 9.90) were a subset of the stimuli used in Pexman and Lupker (1998). The exception words in this set were all inconsistent, and the regular words were all consistent. The exception words and control words were matched for frequency, length, and neighborhood size.

The feedback inconsistency for homophones involves whole-word representations. Similarly, the feedforward inconsistency for homographs involves whole-word representations. Thus, the appropriate control words for these first two word types should be feedback consistent words (nonhomophones) and feedforward consistent words (nonhomographs), respectively, where consistency is defined at the *word* level. The situation is somewhat different for exception words. These words are considered to be feedforward inconsistent because the orthographic *body* can be pronounced more than one way. Thus, in selecting control words, consistency should be defined at the body level. The exception words we selected are typical exception words (i.e., they have been used in previous studies in the literature), and although all of them are feedforward body inconsistent, half of them also happen to be feedback body inconsistent (Ziegler, Stone, & Jacobs, 1997), in that the exceptional pronunciation for the body can be spelled in more than one way (e.g., the body /_∂Ωl/ in *bowl* could legally be spelled _*oal* as in *goal* or _*ole* as in *hole*). Although the regular words we selected were all feedforward body inconsistent, we chose regular words such that half were also feedback body inconsistent in order to match the exception words appropriately.

In this stimulus set, homophones are feedback inconsistent, whereas both exception words and homographs are feedforward inconsistent. We included relatively more homophones to approximately balance the proportion of feedback inconsistent words and feedforward inconsistent words in the list.

Foils. Foil stimuli were required for the LDTs in Experiments 1B and 1C. These foils were of two types: pseudowords (Experiment 1B) and pseudohomophones (Experiment 1C). There were 78 pseudowords and 78 pseudohomophones, taken from the foil stimuli created for Pexman et al. (2001). These foil stimuli were pilot tested by Pexman et al. to ensure that participants recognized that the pseudohomophones would sound like words if pronounced whereas the pseudowords would not. Each pseudoword used the same word body as a pseudohomophone (e.g., *prane* and *brane*) to ensure that the two types of foils were orthographically similar. All of the stimuli used in these experiments are listed in the Appendix.

Procedure

On each trial, a letter string was presented in the center of a 17-in. Sony Trinitron monitor controlled by a Macintosh G3 computer and presented using PsyScope (Cohen, MacWhinney, Flatt, & Provost, 1993). In all experiments, letters were approximately 0.50 cm high and at eye level for the participants. The distance between each participant and the monitor screen was approximately 40 cm. In Experiment 1A, naming responses were made into a microphone attached to a PsyScope response box. In Experiments 1B and 1C, lexical decision responses were made by pressing either the left button (labeled *NONWORD*) or the right button (labeled *WORD*) on a PsyScope response box.

Participants first completed 16 practice trials and were given verbal feedback if they responded incorrectly to any of the practice items. On each trial, the target was presented until the participant responded, and the intertrial interval was 1,500 ms. The stimuli were presented in a different random order for each participant.

Table 1
Mean Naming Latencies and Error Percentages (With Standard Errors in Parentheses) for Experiment 1A

Stimulus type	RT	Errors	RT effect
Homophone (*maid*)	543 (5.1)	0.4 (0.3)	
Nonhomophone (*mess*)	538 (4.9)	1.4 (0.5)	+5
Exception (*worm*)	536 (8.5)	3.1 (1.1)	
Regular (*wink*)	507 (5.7)	0.4 (0.4)	+29*
Homograph (*bow*)	562 (8.0)	1.0 (0.6)	
Nonhomograph (*beg*)	507 (5.1)	0.0 (0.0)	+55*

Note. RT = response time.
* $p < .05$.

Experiment 1A: Results and Discussion

In this experiment, a trial was considered an error, and was excluded from the latency analysis, if the naming latency was longer than 1,500 ms or shorter than 250 ms (1.24% of trials), or if the target was mispronounced (0.96% of trials). Mean naming latencies and mean error percentages are presented in Table 1. In all experiments, data were analyzed treating subjects as the only random factor. The criterion for statistical significance was $p < .05$. We do not report analyses treating items as a random factor because, in these experiments, items was not a random factor in any sense of the term. That is, the stimuli used in these experiments were selected specifically because they met a fairly large number of criteria. Further, in the case of the homographs, the stimuli selected virtually exhausted the pool of suitable English homographs. Thus, treating items as a random factor would violate most of the basic assumptions underlying the analysis of variance (ANOVA) model (see Wike & Church, 1976).

Comparison of naming latencies and error percentages for homophones and nonhomophone controls showed that there was no significant homophone effect in the latency analysis, $t(25) = 1.33$, $p = .19$, $SE = 4.48$, or in the error analysis, $t(25) = -1.79$, $p = .09$, $SE = 0.58$. Comparisons for the exception words and regular words, however, did show a significant regularity effect in the latency analysis, $t(25) = 4.02$, $SE = 7.14$, and an effect that approached significance in the error analysis, $t(25) = 1.95$, $p = .06$, $SE = 1.45$. Comparisons for the homographs and nonhomograph controls also showed a significant homograph effect in the latency analysis, $t(25) = 6.36$, $SE = 8.61$, and an effect that approached significance in the error analysis, $t(25) = 1.81$, $p = .08$, $SE = 0.53$.

There were significant regularity and homograph effects in the naming task in Experiment 1A. Therefore, the exception words

Table 2
Mean Decision Latencies and Error Percentages (With Standard Errors in Parentheses) for Experiments 1B and 1C as a Function of Foil Condition

	Experiment 1B (pseudoword foils)			Experiment 1C (pseudohomophone foils)		
Stimulus type	RT	Errors	RT effect	RT	Errors	RT effect
Homophone (*maid*)	645 (7.9)	8.2 (1.0)		726 (11.8)	14.3 (1.3)	
Nonhomophone (*mess*)	619 (8.4)	8.1 (1.0)	+26*	675 (10.1)	10.7 (1.2)	+51*
Exception (*worm*)	579 (9.4)	4.2 (1.0)		628 (9.4)	4.9 (1.1)	
Regular (*wink*)	582 (8.8)	3.9 (1.0)	−3	645 (11.4)	2.0 (0.7)	−17
Homograph (*bow*)	568 (9.6)	1.6 (0.6)		637 (11.3)	3.1 (0.8)	
Nonhomograph (*beg*)	564 (6.8)	3.5 (0.9)	+4	629 (10.4)	2.9 (0.8)	+8
Foil	682 (4.0)	5.7 (0.4)		759 (5.1)	7.9 (0.5)	

Note. RT = response time.
* $p < .05$.

and homographs selected for this experiment generate the typical effects observed in naming tasks. In contrast, there was no evidence of a homophone effect, as predicted by the feedback account. In Experiments 1B and 1C, the same stimuli were used in an LDT, and given previous findings (e.g., Pexman & Lupker, 1999; Pexman et al., 2001), we expected a homophone effect in that task. However, according to the feedback account, no regularity or homograph effects were expected.

Experiment 1B: Results and Discussion

In this experiment, a trial was considered an error, and was excluded from the latency analysis, if the RT was longer than 2,000 ms or shorter than 250 ms (1.20% of trials), or if participants made an incorrect response (5.11% of trials). Mean response latencies and mean error percentages are presented in Table 2.

Comparison of response latencies and error percentages for homophones and nonhomophone control words showed that there was a significant homophone effect in the latency analysis, $t(35) = 2.70$, $SE = 9.32$, but not in the error analysis ($t < 1$). Comparisons for the exception words and regular words, however, did not show a significant regularity effect in the latency analysis or in the error analysis (both $t < 1$). Comparisons for the homographs and nonhomograph control words showed that there was no significant homograph effect in the latency analysis ($t < 1$), and a marginally significant effect in the wrong direction, with more errors for nonhomographs, in the error analysis, $t(35) = -1.96$, $p = .06$, $SE = 0.94$. This reverse homograph effect may be attributable to the polysemous nature of the homographs. That is, in addition to having two correct pronunciations, homographs have (at least) two different meanings. In a standard LDT, polysemous words are responded to more quickly than nonpolysemous words (e.g., Borowsky & Masson, 1996; Hino & Lupker, 1996; Jastrzembski, 1981; Jastrzembski & Stanners, 1975; Kellas et al., 1988; Rubenstein et al., 1970). In tasks in which orthographic activation is the primary basis for responding (such as LDT), and phonological competition does not usually influence responses, there will likely be occasions where the polysemous nature of homographs creates a small reverse homograph effect, as we saw here in the error data.

If these words are polysemous, one might wonder why there were not more reliable reverse homograph effects in the LDT (i.e., why did the effect not arise in the latency data?). One possible explanation is based on the fact that, like the homographs, many of the nonhomograph control words were also polysemous. In fact, as an examination of any dictionary demonstrates, most English words are polysemous. (Thus, when selecting stimuli for an experiment in which polysemy is investigated, it is actually more difficult to select the nonpolysemous words than the polysemous words.) As a result, the polysemy difference between the homograph condition and the nonhomograph control condition would have been relatively small.

The results of Experiment 1B show a significant homophone effect (replicating previous findings, Pexman & Lupker, 1999; Pexman et al., 2001) together with null effects of both regularity and homography. Although we used exactly the same word stimuli in the naming task and the LDT, we obtained opposite results in the two tasks. This result is consistent with the predictions of the feedback account.

Although regularity and homograph effects were not observed in Experiment 1B, it is possible that they might arise in LDT if processing were relatively more extensive. That is, it is possible that homophone effects are simply stronger effects in LDT than are regularity or homograph effects. Thus, although these three effects did not co-occur in Experiment 1B, they might co-occur in an LDT that requires more extensive processing. This notion gains support from the finding that high-frequency homophones only produce a homophone effect in the LDT when the foils are pseudohomophones (Pexman et al., 2001). With pseudohomophone foils, RTs are longer because of the fact that more processing is required to distinguish the words from the nonwords. Thus, it is possible that regularity and homograph effects might also only emerge with pseudohomophone foils. This notion also gains support from Gibbs and Van Orden's (1998) finding that the regularity effect (and the consistency effect) was only significant in RTs and errors with pseudohomophone foils, and from Berent's (1997) finding that a regularity effect (in the error data only) emerged with pseudohomophone foils. This possibility was tested in Experiment 1C.

Experiment 1C: Results and Discussion

In this experiment a trial was considered an error, and was excluded from the latency analysis, if the RT was longer than 2,000 ms or shorter than 250 ms (1.24% of trials), or if participants made an incorrect response (6.67% of trials). Mean response latencies and mean error percentages are presented in Table 2.

Comparison of response latencies and error percentages for homophones and nonhomophone control words showed that there was a significant homophone effect in the latency analysis, $t(34) = 3.90$, $SE = 12.79$, and in the error analysis, $t(34) = 2.58$, $SE = 1.38$. Comparisons for the exception words and regular words, however, did not show a significant regularity effect in the latency analysis ($t < 1$). In fact, the 17-ms difference that did exist went in the wrong direction. There was, however, a significant regularity effect in the error analysis, $t(34) = 2.14$, $SE = 1.33$. This effect was due to the fact that there was a total of 17 errors to exception words and 7 errors to regular words in this experiment. This effect was in the opposite direction of the nonsignificant 17-ms effect in the latency data, suggesting a speed–accuracy trade-off. Comparisons for the homographs and nonhomograph control words showed that there was no significant homograph effect in the latency analysis or in the error analysis (both $t < 1$).

These results show that, even with the more extensive processing demanded by the presence of pseudohomophone foils, the homophone, regularity, and homograph effects did not co-occur. This dissociation between homophone effects and other phonological effects supports the feedback activation account. Phonological activation for homophones slows processing because of the competition created at the orthographic level by feedback from phonological codes.

Experiments 1B and 1C Combined Analysis

Analyses were next conducted to examine the impact of the change from pseudoword foils (Experiment 1B) to pseudohomophone foils (Experiment 1C). As noted, if we have selected good pseudohomophone foils (foils that are genuinely pseudohomophonic), the expectation is that the latencies will be longer (for both nonword and word responses), and the homophone effect sizes will be larger with those foils than with the pseudoword foils. First, the analysis of nonword responses showed that response latencies were significantly longer for pseudohomophones than for pseudowords, $F(1, 69) = 7.17$, $MSE = 15{,}655.41$, and although there were slightly more errors for pseudohomophones than for pseudowords, the error difference was not significant, $F(1, 69) = 2.19$, $p = .14$, $MSE = 37.15$.

Second, in the analysis of word responses, there was a Homophony × Foil Condition interaction that was marginal in the latency analysis, $F(1, 69) = 2.46$, $p = .12$, $MSE = 2{,}204.21$, and significant in the error analysis, $F(1, 69) = 3.90$, $p = .05$, $MSE = 26.83$. The nature of this interaction was that the homophone effect was larger in the pseudohomophone foil condition. There was also a main effect of homophony in the latency analysis, $F(1, 69) = 22.68$, $MSE = 2{,}204.21$, and in the error analysis, $F(1, 69) = 4.55$, $MSE = 26.83$. For the homophone and nonhomophone control words, there was also a significant main effect of foil condition in the latency analysis, $F(1, 69) = 5.89$, $MSE = 26{,}631.57$, and in the error analysis, $F(1, 69) = 8.10$, $MSE = 88.83$. That is, word latencies were longer and error rates were higher with pseudohomophone foils.

As expected, the Regularity × Foil Condition interaction—for latencies, $F < 1$; for errors, $F(1, 69) = 1.56$, $p = .22$, $MSE = 37.77$—and the main effect of regularity—for latencies, $F < 1$; for errors, $F(1, 69) = 2.31$, $p = .13$, $MSE = 37.77$—were nonsignificant. For regular and exception words, the main effect of foil condition was significant in the latency analysis, $F(1, 69) = 5.59$, $MSE = 16{,}010.67$, but not in the error analysis ($F < 1$). That is, word latencies were longer with pseudohomophone foils.

The Homography × Foil Condition interaction was also nonsignificant—for latencies, $F < 1$; for errors, $F(1, 69) = 1.97$, $p = .17$, $MSE = 19.72$—as was the main effect of homography—for latencies, $F < 1$; for errors, $F(1, 69) = 1.17$, $p = .28$, $MSE = 19.72$. For homographs and nonhomograph control words, the main effect of foil condition was significant in the latency analysis, $F(1, 69) = 8.90$, $MSE = 18{,}337.27$, but not in the error analysis ($F < 1$). That is, once again, word latencies were longer with pseudohomophone foils. Thus, these results clearly indicate that, as expected, our pseudohomophone foils did create a more difficult LDT in Experiment 1C than that created by the pseudoword foils in Experiment 1B.

The fact that, in Experiment 1C, the homophone effect was larger than in Experiment 1B whereas the regularity and homograph effects were nonsignificant in both experiments follows from the feedback account. That is, pseudohomophone foils are assumed to increase the impact of feedback to the orthographic level and whereas homophone effects are caused by this feedback activation, regularity and homograph effects are not. As noted, a further prediction was that the situation would be very different in a task in which phonological codes must be fully determined (e.g., the naming task in Experiment 1A). Experiment 2 provides a further examination of this prediction.

Experiment 2

The goal in Experiment 2 was to use a task that clearly required the use of phonological codes and yet was as similar as possible to the LDT. In such a task the prediction is that the data pattern will be more similar to the pattern in naming than the usual pattern in LDT. The task selected was a phonological lexical decision task (PLDT), where participants indicate whether a particular letter string "sounds like a word." Spelling is not important and participants are expected to respond "yes" to both words and pseudohomophones. Presumably, participants generate a relatively complete phonological code and then evaluate that code in order to respond, but they do not articulate it. Thus, the task is primarily dependent on phonological codes rather than on orthographic codes. As such, we predicted that, as compared with effect sizes in an LDT, homophone effects (which, we argue, are generated because of feedback activation from phonology to orthography) in a PLDT would be small or nonexistent, whereas regularity and homograph effects (which are generated because of feedforward activation from orthography to phonology) should emerge. To evaluate this prediction and further test the feedback account, Experiment 2 involved the same word stimuli in two different tasks: an LDT and a PLDT.

Table 3
Mean Decision Latencies and Error Percentages (With Standard Errors in Parentheses) for Experiment 2 as a Function of Task

	LDT			PLDT		
Stimulus type	RT	Errors	RT effect	RT	Errors	RT effect
Homophone (*maid*)	637 (8.4)	7.7 (1.0)		683 (7.8)	0.7 (0.3)	
Nonhomophone (*mess*)	615 (8.4)	9.1 (1.1)	+22*	689 (9.5)	1.9 (0.5)	−6
Exception (*worm*)	581 (9.0)	6.9 (1.4)		669 (13.2)	1.1 (0.5)	
Regular (*wink*)	593 (9.7)	3.7 (1.0)	−12	648 (11.9)	0.6 (0.4)	+21*
Homograph (*bow*)	570 (8.7)	2.9 (0.8)		639 (10.2)	0.2 (0.2)	
Nonhomograph (*beg*)	570 (9.3)	1.9 (0.7)	0	615 (7.4)	1.2 (0.5)	+24*
Filler word (*brain*)	539 (3.3)	1.7 (0.3)				
Pseudohomophone (*brane*)				937 (8.3)	12.7 (0.7)	
Pseudoword (*prane*)	676 (3.2)	5.7 (0.4)		1288 (8.0)	15.2 (0.5)	

Note. LDT = lexical decision task; PLDT = phonological lexical decision task; RT = response time.
* $p < .05$.

Method

Participants

In Experiment 2, there were 35 participants who completed the LDT and 38 who completed the PLDT. Two participants in the PLDT condition had unusually slow RTs for nonwords (mean RT over 2,400 ms for nonword responses) and so their data were not included in the analyses. All participants were undergraduate students at the University of Calgary who received bonus credit in a psychology course in exchange for their participation.

Stimuli

Words. The words in this experiment were the same word stimuli used in Experiment 1.

Foils. For the PLDT, both pseudohomophones and pseudowords were required. In this task, "yes" responses should be made to the words and pseudohomophones, and "no" responses should be made to the pseudowords. The pseudohomophones were included to ensure that readers actually decided whether the stimuli *sounded* like words and did not simply treat the task as an LDT. Fifty pseudohomophones were chosen from the set developed by Pexman et al. (2001), which, when combined with the 84 word stimuli, produced a total of 134 "yes" trials in the task. We chose 120 pseudowords, from the set developed by Pexman et al., to roughly balance the number of "yes" and "no" trials. For the LDT in this experiment, only words and pseudowords were required, and so the same foil stimuli as in the PLDT were used but the pseudohomophones were changed into words that were used as fillers. For example, the pseudohomophone *brane* in the PLDT was changed into the filler word *brain* in the LDT.

Procedure

The procedure for this experiment was the same as that described for Experiment 1B, except that in the PLDT the instructions were changed so that participants were asked to decide whether each letter string *sounded* like a word or a nonword.

Results and Discussion

In this experiment, a trial was considered an error, and was excluded from the latency analysis, if the RT was longer than 2,500 ms or shorter than 250 ms (less than 1.00% of trials), or if participants made an incorrect response (5.55% of trials). Mean RTs and mean error percentages are presented in Table 3.

ANOVAs were conducted to test for each effect (Homophony, Regularity, and Homography). Task was also included as a factor to test whether the effects differed in the LDT and PLDT.

The homophone effect was not significant across tasks in the latency analysis, $F(1, 69) = 1.26$, $p = .26$, $MSE = 2{,}128.16$, but approached significance in the error analysis, $F(1, 69) = 3.38$, $p = .07$, $MSE = 18.82$, although it should be noted that the error effect was in the wrong direction, with more errors to nonhomophones than to homophones. The Homophony × Task interaction was significant in the latency analysis, $F(1, 69) = 3.97$, $MSE = 2{,}128.16$, but not significant in the error analysis ($F < 1$). The nature of this effect was that the homophone effect was larger in the LDT than the PLDT. Planned comparisons showed that the homophone effect was only significant in the LDT—for latencies, $t(34) = 3.10$, $SE = 7.78$; for errors, $t(34) = -1.09$, $p = .28$, $SE = 1.31$. In addition, participants took longer to respond, but made fewer errors on word trials in the PLDT and hence the main effect of task was significant in both the latency analysis, $F(1, 69) = 7.56$, $MSE = 16{,}872.65$, and the error analysis, $F(1, 69) = 46.46$, $MSE = 38.61$.

The regularity effect was not significant in the latency analysis ($F < 1$) but was significant in the error analysis, $F(1, 69) = 5.01$, $MSE = 24.23$. The Regularity × Task interaction was significant in the latency analysis, $F(1, 69) = 4.29$, $MSE = 3{,}108.00$, and approached significance in the error analysis, $F(1, 69) = 2.45$, $p = .12$, $MSE = 24.23$. Planned comparisons showed that the regularity effect was only significant in the PLDT—for latencies, $t(35) = 2.05$, $SE = 14.10$; for errors, $t < 1$. In addition, participants took longer to respond but made fewer errors in the PLDT and, hence, the main effect of task was significant in both the latency analysis, $F(1, 69) = 12.87$, $MSE = 15{,}781.59$, and the error analysis, $F(1, 69) = 19.86$, $MSE = 35.42$.

The homograph effect was significant in the latency analysis, $F(1, 69) = 3.95$, $p = .05$, $MSE = 1{,}654.88$, but not in the error analysis ($F < 1$). The Homography × Task interaction was significant in the latency analysis, $F(1, 69) = 3.89$, $p = .05$, $MSE = 1{,}654.88$, and approached significance in the error analysis, $F(1, 69) = 3.26$, $p = .07$, $MSE = 9.60$. Planned comparisons showed that the homograph effect was significant only in the PLDT—for latencies, $t(35) = 3.05$, $SE = 8.57$; for errors, $t(35) = -1.67$, $p = .06$, $SE = 0.52$. Participants took longer to respond and made fewer errors in the PLDT and hence the main effect of task was significant in the latency analysis, $F(1, 69) = 6.87$, $MSE = 16{,}376.29$, and in the error analysis, $F(1, 69) = 8.51$, $MSE = 11.85$.

Three points should be made about the results from Experiment 2. First, as was necessary, readers did indeed switch their basis of responding from orthography (in the LDT) to phonology (in the PLDT). Evidence of this switch is the fact that readers were able to successfully distinguish pseudohomophones from pseudowords in the PLDT, responding positively to the former and negatively to the latter.

Second, as a result of this switch of emphasis in the LDT, where orthographic activation is primarily the basis for responding, only the homophone effect was observed, whereas in the PLDT, where phonological activation was primarily the basis for responding, only the regularity and homograph effects were observed.

Third, these findings are exactly as predicted by the feedback account. Homophone effects are expected to arise in situations where feedback activation from phonology to orthography creates competition at the orthographic level, and responding is based primarily on activation at that level (i.e., in an LDT). Regularity and homograph effects, however, are expected to arise in situations where feedforward activation from orthography to phonology creates competition at the phonological level, and responding is based primarily on activation at that level (i.e., in a PLDT or a naming task).

General Discussion

The purpose of the present research was to evaluate the feedback account and, in doing so, to extend our understanding of the role of phonology in visual word recognition.

The Feedback Account

The experiments reported here provide support for the suggestion that feedback from phonology plays a role in visual word recognition because in the LDT we generally only found effects of phonology if those effects could be attributed to feedback. More specifically, we found homophone effects in tasks that could be performed primarily on the basis of orthographic activation. There were moderate homophone effects in LDT with pseudoword foils and larger homophone effects in LDT with pseudohomophone foils. These homophone effects are presumed to arise because the initial orthographic activation stimulates corresponding phonological activation. This phonological activation then feeds back to the orthographic level reinforcing orthographic patterns consistent with the phonology. For a homophone target like *maid* the activation of the phonological representation /mejd/ will activate the orthographic representations for both *maid* and *made*. This creates confusion and slows processing for the homophone target because the competition between the two orthographic representations will generally need to be resolved before a lexical decision response can be made.

Exception words and homographs do not create the same problem that homophones do and so regularity and homograph effects were neither expected nor observed in LDTs. Rather, exception words and homographs create competition at the level of the phonological codes. The expectation was that in the PLDT, when phonological codes become the basis for responding, regularity and homograph effects would be observed whereas homophone effects would not be. That is, although feedback from phonology would certainly still be operating in this task, it would have little impact on processing because readers are not relying on orthographic activation to accomplish the task. Thus, the results in the PLDT should be, and were, identical to those in the naming task.

One issue that we have not attempted to resolve is the grain size of the orthographic units to which phonological codes generate feedback. In other words, at what level (or levels) of orthographic units do homophones create competition? The units could, for instance, be strictly lexical, whole-word units. The units could also (or alternatively) be sublexical: onsets and word bodies, or smaller, grapheme-level units. Stone et al. (1997) assumed that the body-level representations were important for feedback effects, but acknowledged that other levels of representation may also play a role. Ziegler, Montant, and Jacobs (1997) suggested that there were two feedback mechanisms; one sublexical and one lexical. The sublexical mechanism involves mappings between phoneme units and letter units, for example, the phoneme /i/ maps onto the letter units *ea* and *ee,* and competition between these representations may slow processing. Their lexical mechanism involves activation of phonological neighborhoods and feedback to whole-word orthographic units. For instance, the word *heap* activates the phonological representation for /hip/ as well as the phonological representations for phonological neighbors /dip/, /kip/, and so on. Feedback from phonology to orthographic representations for these words causes competition with the orthographic representation for the presented word.

What should also be noted here is that Peereman et al. (1998) have presented results suggesting that there were methodological problems in the experiments suggesting sublexical feedback (i.e., Stone et al., 1997; Ziegler, Montant, & Jacobs, 1997). On the basis of their results, Peereman et al. concluded that, although it was still possible that there might be a sublexical feedback mechanism, there was evidence only for lexical feedback. Our data show evidence for word-level orthographic competition (between the spellings of a homophone) created by feedback activation and, hence, those data are consistent with Peereman et al.'s basic conclusion. In addition, although our goal in this research was not to investigate sublexical versus lexical feedback mechanisms, our data do speak to the issue of sublexical feedback, albeit indirectly. That is, it is generally assumed that for exception words and homographs, more than one phonological representation is activated. If a sublexical feedback mechanism were in place, this could lead (through feedback activation) to activation of a large number of orthographic units, which could all potentially compete with each other. In comparison, regular words and nonhomographs, for which only one phonological representation is activated, would produce (through feedback activation) far less orthographic competition. As a result, one might expect to see regularity and homograph effects in tasks like LDT, where orthographic activity is the primary basis for responding. Yet we observed no such effects. This fact is consistent with the conclusion that feedback only influences responding when it strengthens activation of orthographic representations that correspond to whole words. These issues of representational grain size and the nature of the competition process are ones that will need to be addressed more precisely in future research.

The Role of Phonology in Visual Word Recognition

In the past, the absence of regularity effects in LDT has been interpreted as evidence that phonological processing does not play a role in silent reading (e.g., Baron, 1973; Seidenberg, 1985; Seidenberg et al., 1984). What the present results indicate is that even in situations in which there is no evidence of a regularity effect one can find evidence of phonological processing (i.e., homophone effects). Thus, these results illustrate a scenario described by Stone et al. (1997): "If feedback consistency effects are robust under conditions that produce small, unreliable feedforward consistency effects, it is no longer the case that an unreliable feedforward consistency effect implies the general absence of phonology in visual word recognition" (p. 343).

What now seems clear is that regularity effects are simply not a sensitive marker of phonological processing (see also Berent, 1997) in LDT. In contrast, homophone effects do appear to be a sensitive marker, essentially because of the way that the task demands interact with the phonological processing that is occurring. In a standard LDT, there is no reason to develop phonological codes to anywhere near the extent that is necessary in a task requiring the activation of phonology (e.g., naming). Thus, in the terminology of Frost (1998), the phonological codes that emerge essentially automatically in LDT would be considered "impoverished." Nonetheless, such codes would be sufficient to cause homophone effects as long as they were able to provide feedback to orthography. Regularity and homograph effects, however, only arise in tasks in which fully resolved phonological codes are required. More specifically, regularity and homograph effects arise when two (or more) phonological codes have been activated from one orthographic pattern and competition between the phonological codes must be resolved. Thus, in general, neither regularity nor homograph effects would be expected in visual word recognition tasks unless the nature of the task required participants to generate phonological codes to a somewhat more complete level (e.g., Hino & Lupker, 1996; Seidenberg et al., 1984).

Conclusions

The experiments reported in this article provide further support for the suggestion that feedback activation from phonology influences orthographic processing in visual word recognition. Our results also suggest that phonological effects in visual word recognition are dependent on an interaction between the feedforward and feedback characteristics of the words presented and the task demands.

References

Andrews, S. (1982). Phonological recoding: Is the regularity effect consistent? *Memory & Cognition, 10,* 565–575.

Andrews, S. (1992). Frequency and neighborhood effects on lexical access: Lexical similarity or orthographic redundancy? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18,* 234–254.

Balota, D. A., Ferraro, F. R., & Connor, L. T. (1991). On the early influence of meaning in word recognition: A review of the literature. In P. J. Schwanenflugel (Ed.), *The psychology of word meanings* (pp. 187–222). Hillsdale, NJ: Erlbaum.

Baron, J. (1973). Phonemic stage not necessary for reading. *Quarterly Journal of Experimental Psychology, 25,* 241–246.

Baron, J., & Strawson, C. (1976). Use of orthographic and word-specific knowledge in reading words aloud. *Journal of Experimental Psychology: Human Perception and Performance, 2,* 386–393.

Berent, I. (1997). Phonological priming in the lexical decision task: Regularity effects are not necessary evidence for assembly. *Journal of Experimental Psychology: Human Perception and Performance, 23,* 1727–1742.

Berent, I., & Perfetti, C. A. (1995). A rose is a REEZ: The two-cycles model of phonology assembly in reading English. *Psychological Review, 102,* 146–184.

Berent, I., & Van Orden, G. C. (2000). Homophone dominance modulates the phonemic-masking effect. *Scientific Studies of Reading, 4,* 133–167.

Borowsky, R., & Masson, M. E. J. (1996). Semantic ambiguity effects in word identification. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22,* 63–85.

Cohen, J. D., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: A new graphic interactive environment for designing psychology experiments. *Behavioral Research Methods, Instruments, and Computers, 25,* 257–271.

Coltheart, M., Davelaar, E., Jonasson, J. T., & Besner, D. (1977). Access to the internal lexicon. In S. Dornic (Ed.), *Attention and performance VI* (pp. 535–555). Hillsdale, NJ: Erlbaum.

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A dual route cascaded model of visual word recognition and reading aloud. *Psychological Review, 108,* 204–256.

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

Frost, R. (1998). Toward a strong phonological theory of visual word recognition: True issues and false trails. *Psychological Bulletin, 123,* 71–99.

Gibbs, P., & Van Orden, G. C. (1998). Pathway selection's utility for control of word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 24,* 1162–1187.

Gottlob, L. R., Goldinger, S. D., Stone, G. O., & Van Orden, G. C. (1999). Reading homographs: Orthographic, phonologic, and semantic dynamics. *Journal of Experimental Psychology: Human Perception and Performance, 25,* 561–574.

Hino, Y., & Lupker, S. J. (1996). Effects of polysemy in lexical decision and naming: An alternative to lexical access accounts. *Journal of Experimental Psychology: Human Perception and Performance, 22,* 1331–1356.

Jared, D., & Seidenberg, M. S. (1991). Does word identification proceed from spelling to sound to meaning? *Journal of Experimental Psychology: General, 120,* 358–394.

Jastrzembski, J. E. (1981). Multiple meanings, number of related meanings, frequency of occurrence, and the lexicon. *Cognitive Psychology, 13,* 278–305.

Jastrzembski, J. E., & Stanners, R. F. (1975). Multiple word meanings and lexical search speed. *Journal of Verbal Learning and Verbal Behavior, 14,* 534–537.

Kawamoto, A. H., & Zemblidge, J. (1992). Pronunciation of homographs. *Journal of Memory and Language, 31,* 349–374.

Kellas, G., Ferraro, F. R., & Simpson, G. B. (1988). Lexical ambiguity and the timecourse of attentional allocation in word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 14,* 601–609.

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

Lesch, M. F., & Pollatsek, A. (1998). Evidence for the use of assembled phonology in accessing the meaning of printed words. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24,* 573–592.

Lukatela, G., & Turvey, M. T. (2000). An evaluation of the two-cycles model of phonological assembly. *Journal of Memory and Language, 42,* 183–207.

Luo, C. R., Johnson, R. A., & Gallo, D. A. (1998). Automatic activation of phonological information in reading: Evidence from the semantic relatedness decision task. *Memory & Cognition, 26,* 833–843.

McQuade, D. V. (1981). Variable reliance on phonological information in visual word recognition. *Language and Speech, 24,* 99–109.

Peereman, R., Content, A., & Bonin, P. (1998). Is perception a two-way street? The case of feedback consistency in visual word recognition. *Journal of Memory and Language, 39,* 151–174.

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

Pexman, P. M., & Lupker, S. J. (1998). Word naming and memory load: Still searching for an individual differences explanation. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24,* 803–821.

Pexman, P. M., & Lupker, S. J. (1999). Ambiguity and visual word recognition: Can feedback explain both homophone and polysemy effects? *Canadian Journal of Experimental Psychology, 53,* 323–334.

Pexman, P. M., Lupker, S. J., & Jared, D. (2001). Homophone effects in lexical decision. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27,* 139–156.

Plaut, D. C, McClelland, J. L., Seidenberg, M. S., & Patterson, K. (1996). Understanding normal and impaired word reading: Computational principles in quasi-regular domains. *Psychological Review, 103,* 56–115.

Pugh, K. R., Rexer, K., & Katz, L. (1994). Evidence of flexible coding in visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 807–825.

Rubenstein, H., Garfield, L., & Millikan, J. A. (1970). Homographic entries in the internal lexicon. *Journal of Verbal Learning and Verbal Behavior, 9,* 487–494.

Rubenstein, H., Lewis, S. S., & Rubenstein, M. A. (1971). Evidence for phonemic recoding in visual word recognition. *Journal of Verbal Learning and Verbal Behavior, 6,* 645–657.

Seidenberg, M. S. (1985). The time course of phonological code activation in two writing systems. *Cognition, 19,* 1–30.

Seidenberg, M. S., Waters, G. S., Barnes, M. A., & Tanenhaus, M. K. (1984). When does irregular spelling or pronunciation influence word recognition? *Journal of Verbal Learning and Verbal Behavior, 23,* 383–404.

Stone, G. O., Vanhoy, M., & Van Orden, G. C. (1997). Perception is a two-way street: Feedforward and feedback phonology in visual word recognition. *Journal of Memory and Language, 36,* 337–359.

Stone, G. O., & Van Orden, G. C. (1993). Strategic control of processing in word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 19,* 744–774.

Taft, M., & van Graan, F. (1998). Lack of phonological mediation in a semantic categorization task. *Journal of Memory and Language, 38,* 203–224.

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

Van Orden, G. C., & Goldinger, S. (1994). Interdependence of form and function in cognitive systems explains perception of printed words. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 1269–1291.

Wike, E. L., & Church, J. D. (1976). Comments on Clark's "The language-as-fixed-effect fallacy." *Journal of Verbal Learning and Verbal Behavior, 15,* 249–255.

Ziegler, J. C., Montant, M., & Jacobs, A. M. (1997). The feedback consistency effect in lexical decision and naming. *Journal of Memory and Language, 37,* 533–554.

Ziegler, J. C., Stone, G. O., & Jacobs, A. M. (1997). What is the pronunciation for *–ough* and the spelling for /u/? A database for computing feedforward and feedback consistency in English. *Behavior Research Methods, Instruments, and Computers, 29,* 600–618.

(*Appendix follows*)

Appendix

Experiments 1 (A, B, C) and 2 Word Stimuli and Item Means

	Experiment 1A		Experiment 1B		Experiment 1C		Experiment 2			
	Naming RT	Naming errors	LDT RT	LDT errors	LDT RT	LDT errors	LDT RT	LDT errors	PLDT RT	PLDT errors
Homophones										
blew	514	0	656	11	708	9	535	0	657	0
bored	521	0	583	3	605	0	648	0	622	0
brake	535	0	583	0	641	6	581	0	654	0
coarse	588	0	704	11	820	6	593	3	669	0
deer	504	0	537	3	600	0	570	0	563	3
feat	604	0	722	28	934	51	625	37	783	0
hare	606	0	771	14	789	26	597	6	760	0
haul	539	0	654	11	677	17	563	9	630	0
hire	490	0	595	3	669	6	658	0	603	0
ladder	512	0	624	0	673	9	608	0	634	0
leased	553	0	622	3	645	3	548	0	791	3
maid	497	0	549	3	594	0	596	0	598	0
mane	518	0	687	17	709	29	573	14	692	0
mined	575	4	679	6	812	9	500	11	724	0
mourning	550	0	681	0	880	9	516	3	706	0
reed	538	0	685	19	900	37	509	17	660	6
reel	532	0	687	11	857	37	605	26	657	3
seam	565	0	652	3	759	11	595	11	720	0
sighs	597	4	642	6	773	11	578	6	818	0
sole	541	0	638	14	734	11	661	11	713	0
Nonhomophone control words										
baked	531	0	550	3	614	3	630	0	633	0
boil	546	0	660	3	690	0	609	0	627	0
bleed	510	4	514	6	592	9	568	6	598	3
cheese	544	5	515	0	589	0	531	0	573	0
deed	525	5	673	25	741	26	655	3	665	0
flip	557	0	593	0	625	3	588	0	677	0
hack	512	0	630	8	673	9	521	11	750	0
hoop	536	0	579	0	588	6	739	9	630	0
heap	553	0	588	6	676	0	617	17	659	0
locate	496	0	573	3	638	3	615	0	642	0
loomed	542	0	700	11	815	17	671	23	764	11
maze	492	0	669	3	638	9	705	3	652	0
mess	486	0	601	3	631	0	597	3	606	0
mounting	531	0	709	0	833	0	636	0	786	0
mused	576	12	709	31	921	23	577	29	791	11
rail	513	0	681	6	689	0	608	0	669	0
rude	500	0	551	0	590	3	509	0	609	0
seal	553	0	555	0	579	9	565	3	693	0
seep	638	4	790	44	706	66	652	51	972	8
skids	628	0	771	11	827	31	514	26	846	6
Exception words										
bowl	543	19	540	3	577	3	649	3	676	0
bush	564	4	610	0	620	3	627	3	658	0
comb	538	0	568	8	599	9	656	6	649	3
deaf	524	0	581	3	664	3	652	9	686	0
doll	517	4	566	0	620	3	516	3	587	0
pint	615	0	652	11	679	20	576	17	775	3
warn	565	0	618	14	667	3	509	14	784	0
wasp	495	0	603	0	697	6	779	11	665	6
wool	501	0	544	0	600	0	678	3	607	0
worm	503	4	528	3	575	0	559	0	601	0

Appendix (*continued*)

	Experiment 1A		Experiment 1B		Experiment 1C		Experiment 2			
	Naming RT	Naming errors	LDT RT	LDT errors	LDT RT	LDT errors	LDT RT	LDT errors	PLDT RT	PLDT errors
					Regular control words					
beam	524	0	589	0	668	0	706	0	644	0
dock	511	0	592	0	702	3	502	3	615	0
dusk	480	0	558	3	604	0	573	3	636	3
hunt	495	0	527	0	542	0	805	3	551	0
rust	498	0	527	3	606	0	538	0	635	0
sank	538	0	625	8	707	6	654	9	700	0
stab	566	0	586	6	610	0	675	0	636	0
wick	496	0	711	11	791	6	566	17	886	3
wink	473	4	553	3	592	0	514	3	595	0
yell	493	0	565	6	639	6	653	0	590	0
					Homographs					
bases	724	0	784	3	877	0	564	0	715	0
bow	572	0	580	0	643	3	689	0	713	0
close	533	0	497	0	539	0	605	3	600	0
dove	535	0	552	0	587	0	587	0	638	0
excuse	594	5	645	3	675	0	728	0	690	0
lead	530	0	539	0	601	0	993	3	640	0
live	537	0	503	0	546	3	763	6	593	0
read	524	4	519	3	619	0	788	3	593	0
sow	610	0	654	11	844	31	622	20	699	3
tear	574	0	553	0	589	0	674	0	577	0
wind	484	0	495	0	573	0	613	0	589	0
wound	534	4	513	0	617	0	560	0	619	0
					Nonhomograph control words					
boots	504	0	551	0	621	3	568	3	608	0
beg	497	0	610	0	694	6	540	0	603	0
clear	511	0	509	0	553	0	612	0	568	0
dime	520	0	576	0	596	3	613	0	603	0
exact	540	0	556	3	693	0	779	0	634	0
lack	470	0	547	6	628	0	518	0	561	3
lost	504	0	520	3	525	0	594	0	599	0
rate	534	0	617	6	729	9	577	9	645	0
sag	546	0	646	14	757	11	548	9	667	8
tank	506	0	522	0	565	0	590	0	635	3
wage	473	0	565	3	590	3	561	0	619	0
worst	473	0	563	8	626	0	516	3	639	0

Note. RT = response time; LDT = lexical decision task; PLDT = phonological lexical decision task.

Experiment 1B Foil Stimuli: Pseudowords

nace, cade, naff, spail, blain, gair, jair, nait, swait, lale, drale, clane, tane, brate, brax, treal, feap, meap, ched, ped, gree, weech, deef, meef, jeek, fleek, geel, greel, neem, feen, cleep, zeer, geet, reet, sern, ferse, fet, shet, pife, thipe, jite, noak, loak, broal, troar, froar, foast, loast, shong, klor, prore, bort, borze, shung, turge, turl, blurse, murt, furt, rutch, blaie, taige, draive, balce, nande, varck, dawlt, chedd, bleez, lerce, creth, goarn, soize, tooce, trownd, murld, bruve, chyze.

Experiment 1C Foil Stimuli: Pseudohomophones

chace, rade, laff, scail, sain, shair, squair, hait, mait, jale, trale, brane, rane, wate, trax, wheal, sleap, keap, ded, hed, plee, teech, greef, cheef, bleek, speek, deel, meel, creem, cleen, leep, heer, heet, neet, lern, kerse, swet, thret, nife, tipe, tite, joak, smoak, boal, floar, scoar, koast, goast, rong, bor, rore, cort, noze, yung, murge, gurl, vurse, shurt, durt, tutch, plaie, raige, braive, falce, sande, darck, fawlt, redd, pleez, perce, breth, hoarn, noize, jooce, fownd, wurld, pruve, pryze.

Experiment 2 Foil Stimuli: Pseudowords

wace, naff, spail, tain, nait, lale, danned, brate, ganned, shate, fawk, plawk, breal, grawl, lawl, weam, heam, yitch, sitch, bawn, vawn, draze, taze, fean, ched, grean, spee, seech, creef, jeek, geel, leem, reen, meep, serm, zeer, preeze, reeze, geet, sern, berge, herge, ferse, hent, foat, soat, nerm, fie,

(*Appendix continues*)

twie, froan, thoan, shet, shight, pife, yight, thipe, rirk, fipe, sirk, jite, nirl, tirl, loak, chirth, sirth, woal, critch, troar, yitch, brize, foast, grize, thoaled, yong, woaled, thoo, boam, soam, klor, doan, froan, prore, trocks, procks, bort, dode, fode, broze, boke, doke, shung, lole, wole, broop, doop, coom, goom, bope, vope, mun, comp, tomp, poon, woon, gurge, turl, blurse, fooze, murt, smooze, rutch, fosh, sosh, clum, tund, grum, klune, wune, furch, wurch.

Experiment 2 Foil Stimuli: Pseudohomophones

chace, pade, rade, laff, scail, sain, shair, cair, dait, jale, gane, brane, crax, trax, sheal, grean, keap, sleap, ded, teech, greef, bleek, deel, creem, cleen, leep, reer, heet, lern, kerse, ment, thret, nife, tite, smoak, hoal, floar, koast, rong, croo, bor, rore, cort, noze, yung, murge, gurl, vurse, shurt, tutch.

Experiment 2 Foil Stimuli: Fillers

chase, paid, raid, laugh, scale, sane, share, care, date, jail, gain, brain, cracks, tracks, wheel, green, keep, sleep, dead, teach, grief, bleak, deal, cream, clean, leap, rear, heat, learn, curse, meant, threat, knife, tight, smoke, hole, floor, coast, wrong, crew, bore, roar, court, nose, young, merge, girl, verse, shirt, touch.

Received December 6, 2000
Revision received August 30, 2001
Accepted September 4, 2001 ■