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Automatic semantic feedback during visual word recognition

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Four experiments were conducted to determine whether semantic feedback spreads to orthographic and/or phonological representations during visual word recognition and whether such feedback occurs automatically. Three types of prime–target word pairs were used within the mediated-priming paradigm: (1) homophonically mediated (e.g., *frog*–[toad]–*towed*), (2) orthographically mediated (e.g., *frog*–[toad]–*told*), and (3) associatively related (e.g., *frog–toad*). Using both brief (53 msec; Experiment 1) and long (413 msec; Experiment 3) prime exposure durations, significant facilitatory-priming effects were found in the response time data with orthographically, but not homophonically, mediated prime–target word pairs. When the prime exposure duration was shortened to 33 msec in Experiment 4, however, facilitatory priming was absent with both orthographically and homophonically mediated word pairs. In addition, with a brief (53-msec) prime exposure duration, direct-priming effects were found with associatively (e.g., *frog–toad*), orthographically (e.g., *toad–told*), and homophonically (e.g., *toad–towed*) related word pairs in Experiment 2. Taken together, these results indicate that following the initial activation of semantic representations, activation automatically feeds back to orthographic, but not phonological, representations during the early stages of word processing. These findings were discussed in the context of current accounts of visual word recognition.

There is little disagreement among psychologists that the central function of the cognitive reading system is to extract meaning from visual symbols (i.e., written words). There is, however, considerable disagreement concerning the precise way in which meaning is accessed during reading. For example, the role of phonology and orthography in semantic access continues to be the focus of a great deal of controversy within the reading literature (see, e.g., Frost, 1998). Some theories hold that semantic access is mediated by phonology (e.g., Frost, 1995, 1998; Lukatela & Turvey, 1994a, 1994b; Van Orden, Pennington, & Stone, 1990), whereas other theories hold that phonological computation is unnecessary and that semantic information can be recovered directly from orthography (e.g., Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Forster, 1976). A related issue that has received considerably less attention is whether accessed semantic information influences orthographic or phonological processing. Thus, the present study has a twofold purpose: (1) to examine whether activated semantic information primarily influences phonological or orthographic processing via feedback activation, and (2) to determine whether semantic feedback occurs automatically during the initial stages of lexical processing.

Whether semantic processing is able to affect phonological or orthographic processing depends largely on the interactivity of representations that are stored in distinct groups or levels of representations within the visual word recognition system. Models of visual word recognition (both distributed and nondistributed) typically contain at least three distinct groups or levels of representation: orthographic, phonological, and semantic. Given that the integration of distinct information is an essential component of skilled reading, many prominent models of visual word recognition (e.g., Coltheart et al., 2001; Plaut, McClelland, Seidenberg, & Patterson, 1996; Seidenberg & McClelland, 1989; Stone, Vanhoy, & Van Orden, 1997; Van Orden & Goldinger, 1994) incorporate the general interactive-activation framework (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982). Because models that adopt the general interactive-activation framework (see Figure 1) contain feedforward and feedback connections, word recognition is viewed as a highly interactive process whereby the bidirectional flow of activation

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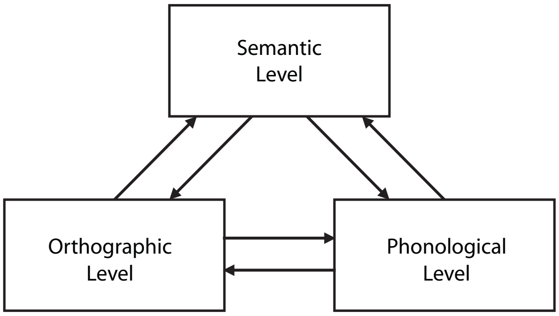

Figure 1. A partial model of visual word recognition based on the general interactive-activation framework. From "Developmental Changes in the Allocation of Semantic Feedback During Visual Word Recognition," by J. F. Reimer, 2006, *Journal of Research in Reading*, *29*, p. 195. Copyright 2006 by Blackwell Publishing for the United Kingdom Literacy Association. Adapted with permission.

helps ensure the selection of the most appropriate representation at each level. For example, activation not only is allowed to spread from orthographic and phonological representations to semantic representations, but also can spread from semantic representations back to phonological and orthographic representations.

Feedback activation during lexical processing has been used to account for multiple aspects of adult visual word recognition performance. For example, semantic feedback to orthographic representations has been used to account for the context × stimulus quality interaction at both long and short stimulus onset asynchronies (SOAs; Besner & Smith, 1992; Borowsky & Besner, 1993; Stolz & Neely, 1995) and has served as a central component in Besner and Smith's (1992; Borowsky & Besner, 1993; see also Stolz & Neely, 1995) multistage activation account of the joint effects of context, stimulus quality, and word frequency. In addition, accounts based on the modulation of semantic feedback to orthographic representations have been used to explain the effect of relatedness proportion (RP; Stolz & Neely, 1995) and awareness (Brown & Besner, 2002) on the context × stimulus quality interaction, as well as to explain the absence of semantic priming during a choice task procedure (Smith & Besner, 2001). Finally, within the parallel distributed processing framework, feedback activation from semantics to both orthography and phonology during word processing has been used to explain ambiguity effects (Hino & Lupker, 1996; Hino, Lupker, & Pexman, 2002; Pexman & Lupker, 1999), synonymy effects (Hino et al., 2002; Pecher, 2001), and effects based on the richness of semantic representations (Pexman, Lupker, & Hino, 2002).

Although semantic feedback has frequently been invoked as an explanatory mechanism in the word recognition literature, fundamental issues regarding semantic feedback remain unresolved. In particular, it is currently unknown whether semantic feedback spreads to orthographic or phonological representations (or both) during word processing and whether semantic feedback is engaged automatically during the initial stages of the visual word recognition process. Given the significant role that semantic feedback has played in the visual word recognition literature, such issues concerning the precise nature of semantic feedback need to be addressed. Unfortunately, studies that have been designed to directly examine the nature of semantic feedback have yielded ambiguous results.

Studies designed to examine semantic feedback during lexical processing have frequently utilized the mediated-priming paradigm (e.g., Farrar, Van Orden, & Hamouz, 2001; O'Seaghdha & Marin, 1997; Reimer, 2006; Reimer, Brown, & Lorsbach, 2001). Rather than possessing a direct relationship (e.g., *doctor–nurse*), primes and targets in the mediated-priming paradigm are related via a third mediating word. Take, for example, the mediated prime–target word pair *doctor*–[nurse]–*purse*.[1] In this case the prime, *doctor*, is associatively related to the mediating word, *nurse*, which in turn is orthographically and phonologically related to the target, *purse*. Because primes and targets within the mediated-priming paradigm (e.g., *doctor–purse*) are not directly related, this paradigm is useful for testing semantic feedback during word recognition. Specifically, the only way that prime processing may affect target processing in the mediated-priming paradigm is if activation spreads from the mediating word's semantic representation back to its corresponding phonological and/or orthographic representation. Thus, the presence of semantically mediated priming effects (either facilitatory or inhibitory in nature) provides evidence of semantic feedback.

O'Seaghdha and Marin (1997) used the mediated-priming paradigm to examine semantic feedback in a series of six experiments in which a naming task was utilized within the mediated-priming paradigm. In their mediated condition (e.g., *pen*–[ink]–*inch*), target words (e.g., *inch*) were both orthographically and phonologically related to a mediating word (e.g., *ink*), which, in turn, was a semantic associate of the prime word (e.g., *pen*). Although they were statistically reliable in only one experiment, O'Seaghdha and Marin found small facilitatory mediated-priming effects with this condition in four of their six experiments. Specifically, targets (e.g., *inch*) were named more quickly in related (e.g., *pen–inch*) than in unrelated (e.g., *star–inch*) word pairs. According to O'Seaghdha and Marin, these results indicate that semantic feedback is a general property of the visual word recognition process. Unfortunately, however, because mediating (e.g., *ink*) and target (e.g., *inch*) words shared both orthography and phonology, it is unclear whether O'Seaghdha and Marin's mediated effects were the result of semantic feedback to orthographic representations, phonological representations, or both.

In other studies, the mediated-priming paradigm has been used to examine semantic feedback during lexical processing as well. For example, Reimer et al. (2001; see also Reimer, 2006) and Farrar et al. (2001) examined the presence of semantic feedback through the use of multiple conditions within the mediated-priming paradigm. In one condition common to both studies, mediating and target words shared spelling bodies but not pronunciation rimes (e.g., *sofa*–[couch]–*touch*). Both investigations showed an inhibitory mediated-priming effect in this condition. Specifically, target words (e.g., *touch*) were named more slowly and/or less accurately when preceded by mediated primes (e.g., *sofa*) than when preceded by unrelated ones (e.g., *enemies*). Farrar et al. (see also Reimer, 2006) proposed that this inhibitory mediated-priming effect was the result of feedback activation from semantic to phonological representations during prime processing. According to their account, related semantic nodes (e.g., *couch*) became activated during prime (e.g., *sofa*) processing, which, in turn, via feedback activation, biased the word recognition system toward pronunciations of those semantic nodes (e.g., *couch*'s pronunciation). Thus, upon target presentation, competing pronunciations were activated: *touch*'s incorrect pronunciation (i.e., one that rhymes with *couch*), which became activated during prime processing, and *touch*'s correct pronunciation, which became activated during target processing. Competition between the two activated pronunciations resulted in slower and less accurate target word naming.

Critically, Farrar et al. (2001) tested their account by using a second mediated condition, in which mediating and target words shared pronunciation rimes and spelling bodies (e.g., *sofa*–[couch]–*pouch*). Farrar et al. reasoned that if their inhibitory mediated-priming effect was in fact caused by semantic feedback to phonological, as opposed to orthographic, representations during prime processing, "the naming of targets sharing the same phonology as the mediating word (e.g., *couch–pouch*) should be facilitated" (p. 535). As was predicted, a facilitatory mediated-priming effect was found in this condition and was offered as support for the interpretation that phonological representations of words associatively related to the prime were activated via semantic feedback during prime processing. However, as in O'Seaghdha and Marin's (1997) study, mediating and target words shared both phonology *and* orthography. Therefore, it is also possible that the facilitatory mediated-priming effect found in this condition resulted from semantic feedback to orthographic, as opposed to phonological, representations. Specifically, if semantic feedback spread to the orthographic representations of mediating words (e.g., *couch*), the naming of targets (e.g., *pouch*) sharing similar orthography with the mediating words (e.g., *couch*) would have been facilitated.

Similarly, semantic feedback to orthography, as opposed to phonology, also could have caused the inhibitory effect found in Farrar et al.'s (2001) first mediated-priming condition (e.g., *sofa*–[couch]–*touch*). Recall that in Farrar et al.'s account, their inhibitory effect was due to the activation of the phonological representations of mediating words (e.g., *couch*) via semantic feedback directly to phonology. However, it is also possible that the phonological representations of the mediating word were activated *after* semantic feedback first had spread to orthography. Such an initial spread of semantic feedback to orthography not only would result in the activation of the mediating word's (e.g., *couch*) orthographic representation, but also, via *feedforward* activation, would activate the mediating word's phonological representation (e.g., *couch*'s pronunciation) as well. Because the pronunciations of the mediating (e.g., *couch*) and target (e.g., *touch*) words are inconsistent, competition would arise during target processing and, as in Farrar et al.'s account, would result in slower and less accurate target naming. Thus, as with O'Seaghdha and Marin's (1997) mediated-priming effects, it is not clear whether Farrar et al.'s effects (see also Reimer et al., 2001) were caused by semantic feedback to orthographic or phonological representations.

In addition to whether semantic feedback spreads to either orthographic or phonological representations, a second important issue that remains unresolved is whether semantic feedback operates automatically during visual word recognition. Some theorists have proposed that semantic feedback (specifically, feedback to orthographic representations) may not be automatic or mandatory (e.g., Borowsky & Besner, 1993; Smith & Besner, 2001; Stolz & Neely, 1995; see also Buchanan & Besner, 1993). For example, Stolz and Neely posited that semantic feedback can be disengaged in order to conserve activation within the visual word recognition system. Specifically, on the basis of the assumption that semantic feedback to orthography aids in the processing of to-be-presented words, Stolz and Neely proposed that semantic feedback occurs only when an experiment contains a high proportion of associatively related prime–target word pairs (i.e., when RP is high). More recently, Brown and Besner (2002) argued that disengagement is the "default set" of semantic feedback and is engaged only when RP is high *and* participants are aware that many of the prime–target word pairs are related.

The results of multiple mediated-priming studies, however, suggest that semantic feedback may spread under low-RP conditions. For example, both Farrar et al. (2001) and O'Seaghdha and Marin (1997) found mediated-priming effects in the absence of any directly associated prime–target word pairs, whereas Reimer (2006) found mediated-priming effects under moderately low-RP (.33) conditions. The results of such studies provide support for the position that semantic feedback is not affected by factors that require the operation of a strategy-based expectancy mechanism but may, instead, operate automatically during visual word recognition (see also Hino et al., 2002). This conclusion is further supported by the fact that, in many cases, mediated-priming studies have incorporated relatively short SOAs. For example, Farrar et al. found evidence of semantic feedback through the use of a 250-msec SOA, whereas Reimer found evidence of semantic feedback using a 200-msec SOA. Furthermore, although their results were not statistically significant, O'Seaghdha and Marin found small mediated-priming effects using a 57-msec SOA. Given that use of a short SOA (e.g., $\leq$250 msec) generally has been found to preclude the operation of a slow-acting expectancy mechanism (den Heyer, Briand, & Dannenbring, 1983; Neely & Keefe, 1989; see also Neely, 1991), these findings support the view that semantic feedback may occur automatically.

The Present Study

One purpose of the present study was to determine whether activated semantic information primarily influences phonological or orthographic processing (or both) via feedback activation during visual word recognition. This issue was examined by separating the effects of orthography and phonology on target word naming within the mediated-priming paradigm. In order to do so, two mediated-priming conditions were used: (1) a homophone-mediated condition in which mediating and target words were homophonically related (e.g., *frog*–[toad]–*towed*) and (2) an orthographic-mediated condition in which mediating and target words were quasihomographically related (e.g., *frog*–[toad]–*told*). Because homophones possess a high degree of *feedback inconsistency* (i.e., the pronunciations of homophones map on to more than one spelling; see Pexman, Lupker, & Reggin, 2002; Stone et al., 1997), use of the homophone-mediated condition made it possible to test semantic feedback under conditions in which the amount of phonological similarity between mediating (e.g., *toad*) and target (e.g., *towed*) words was maximized, while, at the same time, minimizing the amount of orthographic overlap. If semantic feedback spreads to phonological representations during lexical processing, target naming should be faster and/or more accurate in the homophone condition (e.g., *frog–towed*) than in a control condition (e.g., *kite–towed*). Such facilitation would be expected due to the shared phonology of mediating and target words (see Farrar et al., 2001).

Unfortunately, because it is not possible to completely separate phonology from orthography within the English language, mediating (e.g., *toad*) and target (e.g., *towed*) words in the homophone condition possessed some degree of orthographic overlap as well. Thus, if a facilitatory mediated-priming effect is found in the homophone condition, the possibility will remain that the effect was due, at least in part, to semantic feedback to orthography. The additional use of an orthographic-mediated condition (e.g., *frog*–[toad]–*told*), however, allows one to disentangle the effects of semantic feedback to phonology and orthography in the mediated-priming paradigm. Mediating (e.g., *toad*) and target (e.g., *told*) words in the orthographic condition possess a high degree of orthographic similarity but are only moderately phonologically similar. Given the high degree of orthographic overlap between mediating and target words in the orthographic condition, if a facilitatory mediated-priming effect is found in the homophone, but not in the orthographic, condition, one can rule out the possibility that the mediated-priming effect found in the homophone condition is due to semantic feedback to orthographic representations.

Note that the same general logic as that used in the present study to examine whether feedback activation spreads directly from semantics to orthography or phonology has been used in other studies to examine whether *feedforward* activation spreads directly from orthography or phonology to semantics. For example, Lukatela and Turvey (1994a; see also Lesch & Pollatsek, 1993) used a naming task in which target words (e.g., *frog*) were preceded either by primes that were homophonous (e.g., *towed*) with associates (e.g., *toad*) of the target words or by primes that were orthographically related (e.g., *told*) to associates (e.g., *toad*) of the target words. Using a brief SOA, Lukatela and Turvey (1994a) found a facilitatory-priming effect in their homophonically related condition (e.g., *towed–frog*), but not in their orthographically related condition (e.g., *told–frog*). Because only homophonous primes facilitated the naming of targets, Lukatela and Turvey (1994a) argued that semantic access is mediated by phonology, not orthography (for more recent tests of this claim, see Frost, Ahissar, Gotesman, & Tayeb, 2003; Lukatela, Frost, & Turvey, 1998). Given that the mediated-priming conditions in the present study used prime–target word pairs (e.g., *frog–towed*; *frog–told*) that were the reverse of those used by Lukatela and Turvey (1994a; e.g., *towed–frog*; *told–frog*), finding a mediated-priming effect with homophonically, but not orthographically, mediated word pairs would provide evidence that semantic feedback spreads to phonology, and not to orthography.

Importantly, the same logic would apply to the opposite pattern of results. That is, finding a facilitatory mediated-priming effect in the orthographic-mediated condition, but not in the homophone condition, would indicate that feedback activation spread from semantic to orthographic, as opposed to phonological, representations. Because mediating (e.g., *toad*) and target (e.g., *told*) words in the orthographic condition were highly related orthographically, semantic feedback to orthographic representations would facilitate target naming in the orthographic condition (e.g., *frog–told*), relative to a control condition (e.g., *kite–told*). Furthermore, the absence of a mediated-priming effect in the homophone condition would rule out the possibility that the mediated-priming effect found in the orthographic condition was due to semantic feedback to phonological, as opposed to orthographic, representations. Specifically, if the mediated-priming effect in the orthographic condition was due to the phonological overlap between the mediating (e.g., *toad*) and target (e.g., *told*) words, a mediated-priming effect would also be expected to be found in the homophone condition, which contained greater phonological overlap between mediating (e.g., *toad*) and target (e.g., *towed*) words.

The second purpose of the present study was to examine whether feedback activation spreads automatically during the initial stages of lexical processing. In order to do so, the present study utilized a three-field masking procedure (Forster & Davis, 1984) within the mediated-priming paradigm. In this procedure, a pattern mask (e.g., ########) is presented immediately before each prime, which, in turn, is immediately followed by the target. Because prime words are both forward and backward masked, they are unidentifiable by participants when presented briefly in this procedure (e.g., Davis, Castles, & Iakovidis, 1998; Forster & Davis, 1984; Humphreys, Evett, & Taylor, 1982; Lukatela et al., 1998). As a result, the three-field masking procedure can be used to eliminate the effects of overt orthographic and phonological strategies (Frost et al., 2003), as well as other conscious processes, on word-naming performance (see Forster, 1998).

EXPERIMENT 1

The presence of feedback activation from semantics to phonology or orthography during lexical processing was examined using three types of prime–target word pairs: (1) homophonically mediated word pairs in which mediating and target words were homophonically related (e.g., *frog*–[toad]–*towed*), (2) orthographically mediated word pairs in which mediating and target words were orthographically related (e.g., *frog*–[toad]–*told*), and (3) associatively related word pairs in which primes and targets possessed a direct associative relationship (e.g., *frog–toad*). As was indicated above, the two types of mediated prime–target word pairs were used in order to determine whether feedback activation spreads to phonological or orthographic representations during lexical processing. The associatively related prime–target word pairs were included in order to ensure that the semantic representations of mediating words (e.g., *toad*) in the two types of mediated prime–target word pairs were activated during processing of the prime (e.g., *frog*). If semantic feedback spreads only to phonological representations, facilitatory-priming effects should be found with the associatively related and homophonically mediated prime–target word pairs, but not with the orthographically mediated word pairs. However, if semantic feedback spreads only to orthographic representations, facilitatory-priming effects should be found with the associatively related and orthographically mediated prime–target word pairs, but not with the homophonically mediated word pairs. Finally, if semantic feedback spreads to both orthographic and phonological representations, facilitatory-priming effects should be found with all three types of prime–target word pairs.

In addition, a brief (53-msec) prime exposure duration was used in Experiment 1. The use of a brief prime exposure duration within the three-field priming procedure permits one to examine semantic feedback under conditions in which strategic or conscious processing are greatly reduced, because participants are not likely to be subjectively aware of the primes (see Forster, Davis, Schoknecht, & Carter, 1987; Merikle, Joordens, & Stolz, 1995). In addition to a brief SOA, a low RP (.10) was used. Thus, the presence of a mediated-priming effect in Experiment 1 would provide evidence that semantic feedback is engaged automatically during the initial stages of the visual word recognition process and that such feedback is not dependent on conscious awareness of the prime or a high RP (cf. Brown & Besner, 2002; Stolz & Neely, 1995).

Method

Participants. The participants were 52 college students enrolled at California State University, San Bernardino, who received partial course credit for their participation. All the participants were native English speakers and possessed normal or corrected-to-normal vision.

Design. A 3 (type of prime–target relationship: associatively related vs. homophonically mediated vs. orthographically mediated) × 2 (condition: experimental vs. control) within-subjects design was used. The levels of each variable were presented randomly throughout each test list. Response time (RT) and accuracy served as dependent variables and were measured on each trial.

Stimuli. The test stimuli used in the present experiment were generated from 36 word quadruplets (see Appendix A). Each quadruplet was constructed by first selecting an English homophone word pair (e.g., *toad–towed*). Using established word association norms (Nelson, McEvoy, & Schreiber, 1998), a third word was selected (e.g., *frog*) that possessed a strong associative relationship with the first word in each homophone pair (e.g., *toad*). In most cases (83%), the first word in each homophone word pair (e.g., *toad*) was the most probable word generated in response to its respective context word (e.g., *frog*). The mean strength of association for these two words (e.g., *frog–toad*) was .43 (SD = .19). In addition to an associatively related word (e.g., *frog*), a word (e.g., *told*) that possessed a strong orthographic relationship with the first word (e.g., *toad*) of each homophone pair was also selected. The average percentage of letters in these two words (e.g., *toad–told*) that matched and were in the same serial position was 75% (SD = 4%). From the resulting 36 word quadruplets (e.g., *frog–toad–towed–told*), each of the three types of prime–target word pairs (associatively related, homophonically mediated, and orthographically mediated) was generated. For the associatively related word pairs, the first and second words of each quadruplet were used, with the first word (e.g., *frog*) serving as the prime and the second word (e.g., *toad*) serving as the target. For the homophonically mediated word pairs, the first and third words of each quadruplet were used, with the first word (e.g., *frog*) serving as the prime and the third word (e.g., *towed*) serving as the target. And finally, for the orthographically mediated word pairs, the first and fourth words of each quadruplet were used, with the first word (e.g., *frog*) serving as the prime and the fourth word (e.g., *told*) serving as the target. The median frequencies of the target words in the associatively related, homophonically mediated, and orthographically mediated word pairs were 66 (SD = 153), 14 (SD = 201), and 29 (SD = 178) words per million, respectively (Kučera & Francis, 1967). Orthographic and phonological neighborhood characteristics were also calculated for targets in each type of prime–target word pair (see Table 1), using the Hoosier Mental Lexicon (Nusbaum, Pisoni, & Davis, 1984). As can be seen, homophonically and orthographically mediated targets are quite comparable with each of the four neighborhood characteristics. The one exception resides with phonological neighborhood density, where homophonically mediated targets (M = 5.8) have fewer phonological neighbors than do orthographically mediated targets (M = 13.3). However, on the basis of the available literature, it is unclear whether this characteristic alone exerts a systematic influence on visual word recognition performance (see Grainger, Muneaux, Farioli, & Ziegler, 2005; Yates, 2005).

Finally, for each experimental prime–target word pair (e.g., *frog–toad*, *frog–towed*, *frog–told*), a control prime–target word pair was generated (e.g., *kite–toad*, *kite–towed*, *kite–told*). Control prime–target word pairs (e.g., *kite–toad*) were constructed by assigning each target in the experimental word pairs (e.g., *frog–toad*) to a new,

Table 1
Mean Orthographic and Phonological Neighborhood Characteristics for Target Words in Each Type of Prime–Target Word Pair

	Neighborhood Characteristic			
	Orthographic		Phonological	
Type of Target Word	Density	Average Frequency	Density	Average Frequency
Associatively related	8.2	111	12.2	167
Homophonically mediated	6.5	110	5.8	87
Orthographically mediated	7.9	118	13.3	83

unrelated prime (e.g., *kite*). In each case, the control prime word (e.g., *kite*) possessed the same word length and frequency as the experimental prime (e.g., *frog*). Thus, the stimuli used in the present experiment consisted of 36 associatively related (e.g., *frog–toad*), 36 homophonically mediated (e.g., *frog–towed*), and 36 orthographically mediated (e.g., *frog–told*) experimental prime–target word pairs, as well as 36 corresponding associatively related (e.g. *kite–toad*), 36 homophonically mediated (e.g., *kite–towed*), and 36 orthographically mediated (e.g., *kite–told*) control prime–target word pairs.

From the complete list of 216 experimental and control prime–target word pairs, six test lists were constructed. Six test lists were required in order to (1) avoid presenting the same word twice, either as a prime or as a target, in a given test list and (2) ensure that each target word appeared equally often in the experimental and control conditions within a given type of prime–target word pair. The six test lists were used about equally often across participants. Each of the six test lists consisted of 36 critical prime–target word pairs: six experimental word pairs from each of the three types of prime–target word pairs (associatively related, homophonically mediated, and orthographically mediated) and six control prime–target word pairs from each of the three types of prime–target word pairs. In addition, each of the six test lists contained 24 unrelated filler prime–target word pairs, resulting in a total of 60 prime–target word pairs. Filler word pairs were included so that RP = .10 in each test list. Ten unrelated practice prime–target word pairs were also constructed. None of the words contained in the practice prime–target word pairs appeared in the test lists. In addition, practice and filler word pairs were excluded from all statistical analyses.

Apparatus. The presentation of the stimuli and the recording of both RT and accuracy data were accomplished using a Dell OptiPlex GX115 computer controlled by E-Prime 1.1 software (Schneider, Eschman, & Zuccolotto, 2002). The RTs of each participant were obtained by interfacing a microphone with the computer via a response box (Model 200A; Psychology Software Tools, Inc.). RTs were computed by measuring the amount of time that elapsed between the presentation of the target word and the onset of the participant's vocal response. The serial response box was used by the experimenter to record the accuracy of each response. The stimuli were displayed on a 15-in. CRT color monitor (Dell M570; refresh rate = 75 Hz) using white letters in Courier New font on a black background.

Procedure. The participants were tested individually in a quiet room. Each participant was seated approximately 50 cm from the computer monitor and was instructed to hold a microphone approximately 2 cm from his or her mouth. At this distance, stimuli, on average, subtended a visual angle of approximately 1.5º. At the beginning of the experimental session, instructions were verbally presented to the participant. The instructions were followed by the presentation of 10 practice trials and 60 test trials. Each trial began with the presentation of a forward mask, which consisted of a series of eight hashmarks (i.e., ########). After 710 msec, the mask disappeared and was immediately replaced by the prime word. Each prime was presented in lowercase letters for 53 msec and was immediately followed by the target word. Targets were presented in uppercase letters and remained visible on the computer monitor either for 500 msec or until the participant made his or her verbal response, depending on which came first. After the participant had responded, the experimenter coded the response for accuracy, using the response box. The participants were told that, on each trial, they would be presented with a row of hash marks (i.e., the forward mask), followed by two words, and were instructed to focus on the hash marks and name aloud the second word (target) as quickly as possible, without sacrificing accuracy. Once the participants had completed the 60 test trials, they were debriefed and excused. Each experimental session lasted approximately 20 min.

Results and Discussion

Trials on which the voice key was triggered by noise before the participant responded and trials on which there was a failure of the voice key to register the participant's response were excluded from the analyses (1.9%). In addition, correct RTs that were outside the range of two standard deviations above and below each participant's mean were excluded (4.7%). As in previous studies that have utilized the mediated-priming paradigm (e.g., Farrar et al., 2001; Reimer, 2006; Reimer et al., 2001), planned comparisons were used to test for direct- and mediated-priming effects within each type of prime–target word pair. Given that the items used in the present study were not randomly selected, tests using items as the random variable were not conducted in the present study (Wike & Church, 1976; see also Pexman, Lupker, & Reggin, 2002).

Mean RTs and error rates were computed for each participant and submitted to a 3 (type of prime–target relationship: associatively related vs. homophonically mediated vs. orthographically mediated) × 2 (condition: experimental vs. control) within-subjects ANOVA (see Table 2 for means). An alpha level of .05 was used for all the statistical tests reported in this and each subsequent experiment.

RTs. Only correct responses were included in the analysis of RT data. The two-way interaction between type of prime–target relationship and condition was not significant [$F(2,102) = 0.911$, $MS_e = 1{,}218.703$]. However, the main effect of type of prime–target relationship [$F(2,102) = 17.297$, $MS_e = 1{,}581.909$] was significant. Post hoc comparisons revealed that associatively related targets (M = 534 msec) were named significantly more quickly than orthographically mediated targets (M = 551 msec), which, in turn, were named significantly more quickly than homophonically mediated targets (M = 566 msec). As was previously indicated, the median word frequencies of the targets in associatively related, orthographically mediated, and homophonically mediated prime–target word pairs

Table 2
Mean Correct Response Times (RTs, in Milliseconds), Error Rates (%E), and Context Effects by Type of Prime–Target Relationship and Condition in Experiment 1 (With Standard Deviations)

Type of Prime–Target Relationship	Condition									
	Unrelated				Related				Context Effect	
	RT		%E		RT		%E			
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	RT	%E
Associative	541	88.9	4.6	9.0	526	85.0	1.3	5.6	+15*	+3.3
Homophonic	568	93.9	7.2	11.1	564	112.5	7.9	13.9	+4	−0.7
Orthographic	558	103.4	6.5	10.5	543	90.7	5.7	9.5	+15*	+0.8

Note—Context effect = unrelated − related. *$p < .05$.

were 66, 29, and 14 words per million, respectively. Given that previous studies have demonstrated that naming latencies decrease as word frequency increases (e.g., Forster & Chambers, 1973; Plaut & Booth, 2000; Scarborough, Cortese, & Scarborough, 1977), this effect was not at all surprising. The main effect of condition was also significant [$F(1,51) = 6.151$, $MS_e = 1{,}671.356$], with targets in the experimental condition ($M = 544$ msec) yielding significantly shorter RTs than did targets in the control condition ($M = 556$ msec). More important, planned comparisons revealed that RTs in the experimental condition were significantly shorter than those in the control condition, with both associatively related [$F(1,102) = 5.160$, $MS_e = 1{,}218.703$] and orthographically mediated [$F(1,102) = 4.771$, $MS_e = 1{,}218.703$] prime–target word pairs, but not with homophonically mediated word pairs ($F < 1$). No other significant effects were found in the RT data.

Error rates. With the error rate data, the two-way interaction between type of prime–target relationship and condition was not significant ($F < 1$). However, the main effect of type of prime–target relationship was significant [$F(2,102) = 5.964$, $MS_e = 0.009$]. Post hoc tests revealed that associatively related targets ($M = 3.0\%$) yielded significantly fewer naming errors than did orthographically mediated targets ($M = 6.2\%$), which, in turn, yielded significantly fewer errors than did homophonically mediated targets ($M = 7.5\%$). As with the RT data, this effect was expected, given the median differences in frequency between targets in each type of prime–target relationship. Planned comparisons did not reveal significant differences in error rates between the experimental and the control conditions within each type of prime–target relationship (all Fs < 1). No other significant effects were found in the error rate data.

In Experiment 1, significant facilitatory-priming effects were shown in the RT data with associatively related (e.g., *frog–toad*) and orthographically mediated prime–target word pairs (e.g., *frog–told*), but not with homophonically mediated prime–target word pairs (e.g., *frog–towed*). Taken together, the results of the present experiment suggest that semantic feedback spreads to orthographic representations, but not to phonological representations, during lexical processing. Specifically, because primes and targets were not directly related in orthographically mediated prime–target word pairs (e.g., *frog–told*), the only way that prime processing could have affected target processing was if feedback activation spread from the mediating words' (e.g., *toad*) semantic representations to their corresponding orthographic representations. Evidence that activation spread to the semantic representations of mediating words during prime (e.g., *frog*) processing was provided by the fact that a priming effect was found with associatively related prime–target word pairs (e.g., *frog–toad*). Evidence that feedback activation spread from the semantic representations of mediating words to their corresponding orthographic representations was provided by a priming effect that was found with target words (e.g., *told*) sharing orthography (but not semantics) with the mediating words (e.g., *toad*).

Given that mediating (e.g., *toad*) and target (e.g., *told*) words in the orthographically mediated prime–target word pairs (e.g., *frog–told*) also possessed some phonological overlap, it is possible that the mediated priming found with orthographically mediated word pairs was due to semantic feedback to phonology, as opposed to orthography. However, this possibility can be ruled out, because mediated priming was not found with homophonically mediated prime–target word pairs (e.g., *frog–towed*). If the mediated-priming effect found with orthographically mediated prime–target word pairs was due to semantic feedback's spreading to phonological representations, a mediated-priming effect also should have been found with homophonically mediated word pairs in which mediating (e.g., *toad*) and target (e.g., *towed*) words shared considerably more phonology. Furthermore, it is important to note that the absence of mediated priming with homophonically mediated word pairs could not have been due to a lack of phonological activation during target processing, given that the naming task explicitly requires the activation of phonological information (e.g., Frost et al., 2003; Pexman, Lupker, & Reggin, 2002).

As was previously indicated, in addition to possessing complete phonological overlap, mediating and target words in the homophonically mediated condition (e.g., *frog–towed*) possessed some degree of orthographic overlap as well. In fact, on average, 53% of the letters in the mediating (e.g., *toad*) and target (e.g., *towed*) words within this condition matched and were in the same serial position. As a result, if semantic feedback spreads to orthography during lexical processing, one might expect to find evidence of such feedback with homophonically mediated word pairs, as well as with orthographically mediated word pairs. It is possible, however, that in order for the effect of semantic feedback to orthography to be found, substantial orthographic overlap must exist between mediating and target words. This proposal is consistent with the results of O'Seaghdha and Marin's (1997) study, in which small but reliable mediated-priming effects were found in their mediated condition (e.g., *pen–inch*) only after statistical power was increased by pooling data from six experiments. In that study, the average amount of orthographic overlap between mediating (e.g., *ink*) and target (e.g., *inch*) words (57%) was comparable to that of the homophonically mediated word pairs used in the present experiment (53%), but somewhat less than the amount of orthographic overlap between mediating (e.g., *toad*) and target (e.g., *told*) words in orthographically mediated prime–target word pairs (75%). Thus, with enough statistical power, it is possible that a small mediated-priming effect could be found in homophonically mediated word pairs.

In addition to demonstrating that semantic feedback spreads only to orthographic representations, the results of Experiment 1 also indicate that semantic feedback is both fast and automatic. Specifically, given that the primes were presented for only 53 msec, it appears that feedback activation spreads from semantic to orthographic representations very quickly during the initial stages of the visual word recognition process. Moreover, because the primes were largely unidentifiable by the participants, the present results also indicate that, rather than being dependent on participants' awareness of the relationship between primes and targets (cf. Brown & Besner, 2002), semantic feedback occurs automatically. Such feedback appears to occur even when RP is low (.10).

EXPERIMENT 2

A facilitatory-priming effect was found with orthographically, but not homophonically, mediated prime–target word pairs in Experiment 1. This pattern of results suggests that semantic feedback spreads to orthography, but not to phonology, during visual word recognition. However, the results of a recent study of homophone interference effects by Edwards, Pexman, and Hudson (2004) suggest an alternate explanation. Using a single-word naming paradigm, Edwards et al. observed that homophones were named more slowly than their nonhomophone controls (but see Pexman, Lupker, & Reggin, 2002). Edwards et al. attributed the slower naming of homophones to competition among orthographic representations caused by feedback activation from phonology (see also Pexman & Lupker, 1999; Pexman, Lupker, & Jared, 2001; Pexman, Lupker, & Reggin, 2002). Due to the fact that homophones (e.g., *toad*) are feedback inconsistent (i.e., the phonology of homophones maps onto more than one spelling), feedback from phonology results in the activation of multiple orthographies (e.g., *toad* and *towed*). Assuming that rapid word naming depends on the formation of a stable orthographic representation, such orthographic competition presumably slows the naming of homophones.

When Edwards et al.'s (2004) homophone interference effects are considered in the context of the mediated-priming paradigm, it is possible that semantic feedback spread to phonology in homophonically mediated word pairs (e.g., *frog*–[toad]–*towed*) but that the facilitatory effect of such feedback was eliminated during the processing of homophonically mediated targets (e.g., *towed*).[2] Specifically, upon presentation of the prime (*frog*), the mediating word's (*toad*) semantic representation is activated. Given that the word *toad* is feedback inconsistent, subsequent feedback from phonology to orthography would result in the activation of two spellings (*toad* and *towed*). Such orthographic competition could have eliminated any facilitatory effect that semantic feedback may have had on the phonological processing of the target (*towed*). Furthermore, previous research (Pexman et al., 2001; see also Jared, Levy, & Rayner, 1999) has shown that the homophone interference effect is strongest for homophones that possess a low printed frequency and have a high-frequency homophone mate. Presumably, this is the case because the orthographic representations of the high-frequency homophone are stronger competitors than the representations of their corresponding low-frequency homophone mates. Thus, it is important to note that although not all targets within the homophonically mediated word pairs in Experiment 1 were low-frequency homophones, many (64%) of these targets (e.g., *towed*) possessed a relatively lower word frequency than did their corresponding mediating words (e.g., *toad*).

The primary purpose of Experiment 2 was to test the alternate explanation (i.e., orthographic competition) of the null priming effect that was found with homophonically mediated word pairs in Experiment 1. According to the orthographic competition account, the activation of the mediating words' phonology resulted in orthographic competition that eliminated the facilitatory effect of semantic feedback to phonology on target naming. Because of automatic feedback from phonology to orthography, orthographic competition should be present during target (e.g., *towed*) naming regardless of whether the mediating word's (e.g., *toad*) phonology was originally activated via semantic feedback (i.e., top-down activation) or via direct visual presentation of the mediating word (i.e., bottom-up activation). Thus, according to the orthographic competition explanation, a null (or possibly inhibitory) priming effect also should be present when the mediating word (e.g., *toad*) is presented directly as a masked prime to the homophonically mediated target (e.g., *towed*). Unfortunately, however, rather than finding null or inhibitory effects, studies in which direct homophone priming (e.g., *toad–towed*) has been examined have shown facilitation effects (e.g., Lukatela & Turvey, 1994b; Rastle & Coltheart, 1999). In fact, facilitatory homophone-priming effects appear to be quite robust, having been found across multiple (e.g., 30-, 60-, 250-, and 900-msec) SOAs (Lukatela & Turvey, 1994b; Rastle & Coltheart, 1999) and, more important, do not appear to depend on word frequency (Lukatela & Turvey, 1994b).

Experiment 2A tested the orthographic competition account by examining direct homophone priming, using the stimuli from Experiment 1. Specifically, homophonically related prime–target word pairs (e.g., *toad–towed*) were constructed from the homophonically mediated word pairs (e.g., *frog*–[toad]–*towed*). If the orthographic competition explanation of the null effect found with homophonically mediated word pairs in Experiment 1 is correct, a null or inhibitory effect also should be found with homophonically related prime–target word pairs (e.g., *toad–towed*) in Experiment 2A. On the other hand, finding a facilitatory effect not only would replicate the results of other studies, but also would provide evidence that activating the phonology of the mediating word (e.g., *toad*) facilitates the naming of a homophonically related word (e.g., *towed*), regardless of the various stimulus characteristics (e.g., word frequency) these words might possess.

In Experiment 2B, the same direct priming was examined within orthographically mediated word pairs. In order to do so, orthographically related prime–target word pairs (e.g., *toad–told*) were constructed from the orthographically mediated word pairs (e.g., *frog*–[toad]–*told*) that were used in Experiment 1. Given that an orthographically mediated priming effect was found in Experiment 1 and that direct orthographic priming has been found in other studies (e.g., Forster et al., 1987; Forster & Veres, 1998), it was expected that a facilitatory-priming effect would be found with orthographically related word pairs in Experiment 2B. That is, if the activation of the mediating word's (e.g., *toad*) orthography via semantic feedback facilitated target (e.g., *told*) processing in the orthographically mediated word pairs, it was expected that the activation of the mediating word's orthography via direct visual presentation would facilitate target processing as well.

Method

Participants. The participants in Experiment 2A were 33 college students enrolled at the University of Nebraska at Omaha or California State University, San Bernardino. The participants in Experiment 2B were 27 college students enrolled at California State University, San Bernardino. All the participants received partial course credit for their participation, were native English speakers, and possessed normal or corrected-to-normal vision.

Design. In Experiment 2A, a 2 (type of prime–target relationship: associatively related vs. homophonically related) × 2 (condition: experimental vs. control) within-subjects design was used. Similarly, in Experiment 2B, a 2 (type of prime–target relationship: associatively related vs. orthographically related) × 2 (condition: experimental vs. control) within-subjects design was used. In both experiments, the levels of each variable were presented randomly throughout each test list. Accuracy and RT served as dependent variables and were measured on each trial.

Stimuli and Apparatus. Three types of prime–target word pairs (associatively related, homophonically related, and orthographically related) were generated from the 36 word quadruplets (e.g., *frog–toad–towed–told*) used in Experiment 1. The associatively related word pairs in Experiment 1, both experimental (e.g., *frog–toad*) and control (e.g., *kite–toad*), were again used as associatively related word pairs in Experiments 2A and 2B. The second and third words of each quadruplet were used as homophonically related word pairs in Experiment 2A, with the second word (e.g., *toad*) serving as the prime and the third word (e.g., *towed*) serving as the target. For orthographically related word pairs in Experiment 2B, the second word (e.g., *toad*) in each quadruplet served as the prime, and the fourth word (e.g., *told*) served as the target (see Appendix B).

For homophonically (e.g., *toad–towed*) and orthographically (e.g., *toad–told*) related word pairs, controls were generated for each of the experimental prime–target word pairs by assigning the target in each experimental word pair to a new, unrelated prime. As in Experiment 1, each control prime word (e.g., *wick*) possessed the same word length and frequency as its corresponding experimental prime (e.g., *toad*). Thus, the stimuli consisted of 36 associatively related (e.g., *frog–toad*), 36 homophonically related (e.g., *toad–towed*), and 36 orthographically related (e.g., *toad–told*) experimental prime–target word pairs, as well as 36 corresponding associatively related (e.g. *kite–toad*), 36 homophonically related (e.g., *wick–towed*), and 36 orthographically related (e.g., *wick–told*) controls, for a total of 216 prime–target word pairs.

Using the list of 216 experimental and control prime–target word pairs, three test lists were generated for Experiment 2A, and three for Experiment 2B. Three test lists were necessary in order to avoid presenting the same word twice, either as a prime or as a target, and to ensure that each target word appeared equally often in the experimental and control conditions within a given type of prime–target word pair. The three test lists were used equally often across participants. Three tests lists were constructed for Experiments 2A and 2B by randomly selecting, without replacement, 72 prime–target word pairs from the list of 216 word pairs. Each of the three 72-item lists in Experiment 2A contained 24 experimental prime–target word pairs (12 associatively related and 12 homophonically related) and 24 prime–target controls (12 associative controls and 12 homophonic controls). The remaining 24 items in a list consisted of unrelated filler prime–target word pairs. For each test list, RP = .17. This same procedure was used to construct the three test lists in Experiment 2B. In this case, each of the three 72-item test lists was constructed by selecting 12 experimental word pairs from each of two types of prime–target word pairs (associatively related and orthographically related) and 12 word pairs for both the associatively related and orthographically related controls. The 24 remaining items were unrelated filler prime–target word pairs.

The 10 practice trials used in Experiment 1 were again used in Experiments 2A and 2B. Practice and filler word pairs were excluded from all statistical analyses. The same apparatus as that in Experiment 1 was used in Experiment 2.

Procedure. The procedure was the same as that used in Experiment 1, except that 72, as opposed to 60, test trials were presented.

Experiment 2A: Results and Discussion

Trials on which the voice key was triggered by noise before the participant responded and trials on which there was a failure of the voice key to register the participant's response were excluded from the analyses (2.0%). In addition, correct RTs that were outside the range of two standard deviations above and below each participant's mean were excluded (5.2%). As in Experiment 1, planned comparisons were used to test for priming effects within each type of prime–target word pair. Mean RTs and error rates were computed for each participant and submitted to a 2 (type of prime–target relationship: associatively related vs. homophonically related) × 2 (condition: experimental vs. control) within-subjects ANOVA (see Table 3 for means).

RTs. Only correct responses were included in the analysis of RT data. The two-way interaction between type of prime–target relationship and condition was not significant ($F < 1$). The main effect of type of prime–target relationship also was not significant [$F(1,32) = 2.189$, $MS_e = 817.645$]; however, a significant main effect of condition was found [$F(1,32) = 11.504$, $MS_e = 447.133$]. Post hoc comparisons revealed that experimental targets ($M = 515$ msec) were named more quickly than control targets ($M = 527$ msec). Most important, planned comparisons confirmed that RTs in the experimental condition were significantly shorter than those in the control condition

Table 3
Mean Correct Response Times (RTs, in Milliseconds), Error Rates (%E), and Context Effects by Condition and Type of Prime–Target Relationship in Experiments 2A and 2B (With Standard Deviations)

Type of Prime–Target Relationship	Condition								Context Effect	
	Unrelated				Related					
	RT		%E		RT		%E		RT	%E
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*		
Experiment 2A										
Homophonic	531	71.4	8.8	11.1	519	77.7	5.2	5.8	+12*	+3.6
Associative	523	65.2	4.8	6.9	511	62.5	2.7	4.6	+12*	+2.1
Experiment 2B										
Orthographic	531	77.9	6.3	7.5	516	76.1	6.0	8.2	+15*	+0.3
Associative	529	80.1	3.6	5.0	517	59.3	1.6	3.5	+12*	+2.0

Note—Context effect = unrelated − related. *$p < .05$.

with both associatively related [$F(1,32) = 4.985$, $MS_e = 518.437$] and homophonically related [$F(1,32) = 4.937$, $MS_e = 518.437$] prime–target word pairs. No other significant effects were found in the RT data.

Error rates. The interaction between type of prime–target relationship and condition was not significant ($F < 1$). However, a significant main effect of type of prime–target relationship was found [$F(1,32) = 6.672$, $MS_e = 0.005$]. Post hoc comparisons revealed that fewer naming errors were made with associatively related ($M = 3.7\%$) than with homophonically related ($M = 7.0\%$) targets. Given the differences in median word frequency across targets within each type of prime–target word pair (see Experiment 1), this effect was not at all surprising. In addition, a significant main effect of condition was found [$F(1,32) = 4.545$, $MS_e = 0.006$], with experimental targets ($M = 3.9\%$) yielding fewer naming errors than control targets ($M = 7.0\%$). No other significant effects were found in the error rate data.

In Experiment 2A, facilitatory-priming effects were found in the RT data with both associatively (e.g., *frog–toad*) and homophonically (e.g., *toad–towed*) related prime–target word pairs. In addition to replicating the results of previous studies (e.g., Lukatela & Turvey, 1994b; Rastle & Coltheart, 1999), finding a facilitatory-priming effect in homophonically related word pairs is important because it suggests that the null effect found with homophonically mediated word pairs (e.g., *frog*–[toad]–*towed*) in Experiment 1 was not due to orthographic competition. Rather, the presence of direct homophone priming in the present experiment provides support for the claim that the absence of a homophonically mediated priming effect in Experiment 1 resulted from a lack of semantic feedback to phonology. The failure of semantic feedback to activate the phonology of mediating (e.g., *toad*) words can be the only reason for the absence of a priming effect with homophonically mediated word pairs (e.g., *frog–towed*) in Experiment 1.

Experiment 2B: Results and Discussion

As in Experiment 2A, trials on which the voice key was triggered by noise before the participant responded and trials on which there was a failure of the voice key to register the participant's response were excluded from the analyses (2.5%). Correct RTs that were outside the range of 2 standard deviations above and below each participant's mean were excluded (5.4%). As in the previous experiments, planned comparisons were used to test for direct- and mediated-priming effects within each type of prime–target word pair. Mean RTs and error rates were computed for each participant and submitted to a 2 (type of prime–target relationship: associatively related vs. orthographically related) × 2 (condition: experimental vs. control) within-subjects ANOVA (see Table 3 for means).

RTs. Only correct responses were included in the analysis of RT data. The two-way interaction between type of prime–target relationship and condition was not significant ($F < 1$). The main effect of type of prime–target relationship also was not significant ($F < 1$). However, a significant main effect of condition was again found [$F(1,26) = 7.349$, $MS_e = 688.061$]. Post hoc comparisons revealed that experimental targets ($M = 517$ msec) were named more quickly than control targets ($M = 530$ msec). Also, planned comparisons revealed that RTs in the experimental condition were significantly shorter than those in the control condition with both associatively related [$F(1,26) = 4.696$, $MS_e = 447.851$] and orthographically related [$F(1,26) = 6.682$, $MS_e = 447.851$] prime–target word pairs. No other significant effects were found in the RT data.

Error rates. The interaction between type of prime–target relationship and condition was not significant ($F < 1$). However, a significant main effect of type of prime–target relationship was found [$F(1,26) = 10.820$, $MS_e = 0.003$]. Post hoc comparisons revealed that fewer naming errors were made with associatively related ($M = 2.6\%$) than with orthographically related ($M = 6.1\%$) targets. Again, this effect was expected, given that the median word frequency of targets within associatively related word pairs was higher than that of targets within orthographically related word pairs. No other significant effects were found in the error rate data.

Facilitatory-priming effects were found in the RT data with both associatively (e.g., *frog–toad*) and orthographically (e.g., *toad–told*) related prime–target word pairs in Experiment 2B. Importantly, the size of the direct orthographic-priming effect (+15 msec) was identical to the size of the mediated orthographic-priming effect (+15 msec) found in Experiment 1. That is to say, under masked prime conditions, target (e.g., *told*) naming was facilitated equally regardless of whether it was preceded by an orthographically related prime (e.g., *toad*) or a semantic associate of the orthographically related prime (e.g., *frog*). Collectively, the results of Experiments 1 and 2 provide support for the claim that semantic feedback spreads to orthography, but not to phonology, during visual word recognition.

EXPERIMENT 3

The results of Experiment 1 indicate that automatic semantic feedback spreads to orthographic, but not phonological, representations during lexical processing. However, it is possible that semantic feedback spreads to phonological representations as well but that such feedback (1) follows a different time course (i.e., requires more time to engage) and/or (2) is engaged only when overt phonological strategies or conscious expectancy processes are operating. In order to test this possibility, Experiment 3 utilized the same stimuli and procedure as those in Experiment 1, with the exception that a longer (413-msec) prime exposure duration was used. A 413-msec prime duration was chosen because it would provide sufficient time for slower-acting semantic feedback to occur and for strategy-based conscious processes to become operational (Neely, 1991). If semantic feedback spreads to phonological representations under such conditions, facilitatory-priming effects should be found with phonologically mediated prime–target word pairs (e.g., *frog–towed*). With respect to semantic feedback to orthography, it is possible that the effect of such feedback remains stable or changes with a longer prime duration.

Finally, as was indicated above, Stolz and Neely (1995) proposed that RP affects whether or not semantic feedback occurs during word processing. Specifically, they posited that semantic feedback is blocked when RP is low. Despite the fact that evidence of semantic feedback was found under low-RP conditions in Experiment 1, it is possible that the prime exposure duration was too brief (53 msec) for RP to prevent semantic feedback from occurring. If semantic feedback is blocked under low-RP conditions, a longer prime duration should provide enough time for this to occur. Thus, a low RP (.10), in conjunction with a longer (413-msec) prime duration, was used in Experiment 3.

Method

Participants. The participants were 40 college students enrolled at California State University, San Bernardino, who received partial course credit for their participation. All the participants were native English speakers and possessed normal or corrected-to-normal vision.

Design. A 3 (type of prime–target relationship: associatively related vs. homophonically mediated vs. orthographically mediated) × 2 (condition: experimental vs. control) within-subjects design was used. The levels of each variable were presented randomly throughout each test list. Accuracy and RT served as dependent variables and were measured on each trial.

Stimuli and Apparatus. The stimuli and apparatus were the same as those in Experiment 1.

Procedure. The procedure was the same as that used in Experiment 1, with two exceptions. First a 413-msec prime exposure duration was used. Second, because the primes were clearly visible using this long exposure duration, the participants were asked to read the prime silently.

Results and Discussion

Trials on which the voice-key was triggered by noise before the participant responded and trials on which there was a failure of the voice key to register the participant's response were excluded from the analyses (2.2%). In addition, correct RTs that were outside the range of two standard deviations above and below each participant's mean were excluded (5.1%). As in Experiment 1, planned comparisons were used to test for direct- and mediated-priming effects within each type of prime–target word pair. Mean RTs and error rates were computed for each participant and submitted to a 3 (type of prime–target relationship: associatively related vs. homophonically mediated vs. orthographically mediated) × 2 (condition: experimental vs. control) within-subjects ANOVA (see Table 4 for means).

RTs. Only correct responses were included in the analysis of RT data. The two-way interaction between type of prime–target relationship and condition was not significant [$F(2,78) = 1.579$, $MS_e = 1{,}105.127$]. However, the main effect of type of prime–target relationship [$F(2,78) = 10.490$, $MS_e = 1{,}039.854$] was significant. As in Experiment 1, post hoc comparisons revealed that associatively related targets ($M = 473$ msec) were named significantly more quickly than orthographically mediated targets ($M = 484$ msec), which, in turn, were named significantly more quickly than homophonically mediated targets ($M = 496$ msec). Again, given the differences in median word frequency across each type of prime–target word pair, this effect was not at all surprising. The main effect of condition also was significant [$F(1,39) = 10.215$, $MS_e = 580.125$], with targets in the experimental condition ($M = 479$ msec) yielding significantly shorter RTs than did targets in the control condition ($M = 489$ msec). Most important, planned comparisons revealed that RTs in the experimental condition were significantly shorter than those in the control condition with both associatively related [$F(1,78) = 4.178$, $MS_e = 1{,}105.127$] and orthographically mediated [$F(1,78) = 4.312$, $MS_e = 1{,}105.127$] prime–target word pairs, but not with homophonically mediated word pairs ($F < 1$). No other significant effects were found in the RT data.

Error rates. The interaction between type of prime–target relationship and condition was not significant ($F < 1$), nor were the main effects of type of prime–target relationship [$F(2,78) = 2.644$, $MS_e = 0.010$] and condition [$F(1,39) = 1.075$, $MS_e = 0.010$]. As in Experiment 1, planned comparisons did not reveal significant differences in error rates between the experimental and the control conditions with associatively related ($F < 1$), homophonically mediated [$F(1,78) = 1.251$, $MS_e = 0.013$], and orthographically mediated ($F < 1$) word pairs. No other significant effects were found in the error rate data.

The pattern of results in Experiment 3 was identical to that found in Experiment 1. Specifically, significant facilitatory-priming effects were found in the RT data with both associatively related (e.g., *frog–toad*) and orthographically mediated (e.g., *frog–told*) prime–target word pairs, but not with homophonically mediated prime–target word pairs (e.g., *frog–towed*). Given that the primes were presented for 413 msec, the failure to find an effect with homophonically mediated word pairs could not have been the result of slower-acting semantic feedback or the absence of conscious expectancy processes. Therefore, the

Table 4
Mean Correct Response Times (RTs, in Milliseconds), Error Rates (%E), and Context Effects by Type of Prime–Target Relationship and Condition in Experiment 3 (With Standard Deviations)

Type of Prime–Target Relationship	Condition: Unrelated RT *M*	*SD*	Unrelated %E *M*	*SD*	Related RT *M*	*SD*	Related %E *M*	*SD*	Context Effect RT	Context Effect %E
Associative	481	71.1	4.1	7.7	465	72.5	3.1	6.8	+16*	+1.0
Homophonic	496	82.6	5.6	12.3	497	79.8	8.5	14.0	−1	−2.9
Orthographic	491	82.5	5.3	10.2	476	81.4	7.5	9.4	+15*	−2.2

Note—Context effect = unrelated − related. *$p < .05$.

results of the present experiment provide further evidence that semantic feedback spreads only to orthographic representations during visual word recognition. Moreover, given that the size of the priming effect (+15 msec) found with orthographically mediated word pairs was the same in Experiments 1 and 3, the present results also indicate that the effect of semantic feedback to orthography does not dissipate quickly. However, within time frames longer than those used in the present study (e.g., 800 msec), or when primes are not masked, it is unclear whether this is the case (see Reimer, 2006; Reimer et al., 2001). Finally, the results of the present experiment indicated that when a longer prime duration was used, evidence of semantic feedback was again found under low-RP conditions (cf. Stolz & Neely, 1995).

EXPERIMENT 4

The results of the previous experiments demonstrated that two steps are involved in mediated priming. According to this *two-step* account of mediated priming, activation first spreads from the prime's semantic representation (e.g., *frog*) to the mediating word's (e.g., *toad*) semantic representation, followed by a second step in which activation spreads from the mediating word's semantic representation to its corresponding orthographic representation. Given that these two steps occur over time, there should exist a point during word processing at which activation has spread among semantic representations but has not yet spread to orthographic representations. Thus, through the use of a very brief prime exposure duration (i.e., <53 msec), it may be possible to find a facilitatory-priming effect with associatively related (e.g., *frog–toad*), but not with orthographically mediated (e.g., *frog–told*), word pairs within the mediated-priming paradigm.

Precisely how brief the prime exposure duration must be in order for this pattern of results to emerge is not entirely clear. However, the results of Brown and Besner's (2002) study suggest that a prime duration of approximately 34 msec should be used. In their second experiment, Brown and Besner found that a 34-msec prime duration led to reliable effects of both semantic context and stimulus quality, but not to a context × stimulus quality interaction. Given that the context × stimulus quality interaction is presumed to be driven by semantic feedback to orthographic representations (e.g., Besner & Smith, 1992; Borowsky & Besner, 1993; Stolz & Neely, 1995), Brown and Besner proposed that context and stimulus quality failed to interact in their experiment because semantic feedback was not operational. As was previously indicated, Brown and Besner argued that semantic feedback is not engaged unless participants are subjectively aware of the primes. Unfortunately, Brown and Besner's account is not consistent with the results of Experiment 1 of the present study, where clear evidence of semantic feedback was found, despite the fact that the participants were not likely to be subjectively aware of the primes (see Merikle et al., 1995). It is possible, however, that the absence of a context × stimulus quality interaction in Brown and Besner's experiment was due to the time-sensitive nature of the two-step process described above. That is to say, by the time the primes were replaced by the backward mask (i.e., 34 msec into prime processing), activation had spread among semantically related representations, but a sufficient amount of feedback activation had not yet reached the corresponding orthographic representations.

Thus, a 33-msec prime exposure duration was used in Experiment 4 in order to test the present two-step account of mediated priming. If a facilitatory-priming effect were to be found with associatively related (e.g., *frog–toad*), but not with orthographically (or homophonically) mediated (e.g., *frog–told*), prime–target word pairs, it would provide support for the two-step account. Specifically, such a pattern of results would indicate that although the first step of the semantic feedback process had occurred in a condition in which a very brief prime exposure duration was used, subsequent feedback activation required additional time to fully activate orthographic representations. In addition, together with the results of Experiment 1, this pattern of results would indicate that Brown and Besner's (2002) failure to find a context × stimulus quality interaction was not due to a failure of semantic feedback to engage, but rather to the fact that feedback had insufficient time to adequately spread to orthography because the prime duration was too brief.

Method

Participants. The participants were 47 college students enrolled at California State University, San Bernardino, or the University of Nebraska at Omaha, who received partial course credit for their participation. All the participants were native English speakers and possessed normal or corrected-to-normal vision.

Stimuli. The stimuli were the same as those used in Experiments 1 and 3, except that each test list contained 24 associatively related, as opposed to 24 unrelated, filler prime–target word pairs. As a result, each test list contained an RP of .50. Recall that Stolz and Neely (1995) proposed that semantic feedback spreads only under high-RP conditions, regardless of the SOA. Thus, a high RP was used in Experiment 4 in order to ensure that the appropriate conditions (as specified by Brown & Besner, 2002, and Stolz & Neely, 1995) existed for semantic feedback.

Apparatus. The apparatus was the same as that in the previous experiments, with the exception that the computer monitor's refresh rate was changed from 75 to 60 Hz.

Procedure. With the exception that a 33-msec prime exposure duration was used, the procedure was the same as that in Experiments 1 and 3.

Results and Discussion

Trials on which the voice key was triggered by noise before the participant responded and trials on which there was a failure of the voice key to register the participant's response were excluded from the analyses (2.0%). In addition, correct RTs that were outside the range of two standard deviations above and below each participant's mean were excluded (4.6%). Data from 1 participant who committed an excessive amount of naming errors were discarded. Mean RTs and error rates were computed for each participant and submitted to a 3 (type of prime–target relationship: associatively related vs. homophonically mediated vs. orthographically mediated) × 2 (condition: experimental vs. control) within-subjects ANOVA (see Table 5 for means). Planned comparisons were used to test for direct- and mediated-priming effects within each type of prime–target word pair.

RTs. Only correct responses were included in the analysis of RT data. The two-way interaction between type of prime–target relationship and condition [$F(2,92) = 1.258$, $MS_e = 550.560$] was not significant, nor was the main effect of condition [$F(1,46) = 1.137$, $MS_e = 1,020.140$]. However, a significant main effect of type of prime–target relationship was found [$F(2,92) = 8.429$, $MS_e = 957.073$]. Post hoc comparisons showed that both associatively related ($M = 501$ msec) and orthographically mediated ($M = 507$ msec) targets were named significantly more quickly than homophonically mediated ($M = 519$ msec) targets. More important, planned comparisons revealed that RTs in the experimental condition were significantly shorter than those in the control condition with associatively related word pairs [$F(1,92) = 4.613$, $MS_e = 550.560$], but not with homophonically mediated ($F < 1$) or orthographically mediated ($F < 1$) word pairs. No other significant effects were found in the RT data.

Error rates. The interaction between type of prime–target relationship and condition was not significant [$F(2,92) = 2.365$, $MS_e = 0.008$], nor was the main effect of condition ($F < 1$). However, the main effect of type of prime–target relationship was significant [$F(2,102) = 5.964$, $MS_e = 0.009$]. Post hoc tests showed that homophonically mediated targets ($M = 8.5\%$) yielded significantly more naming errors than did associatively related ($M = 4.6\%$) and orthographically mediated ($M = 5.2\%$) targets. Planned comparisons revealed that significantly more naming errors were produced in the control condition ($M = 6.5\%$) than in the experimental condition ($M = 2.6\%$) with associatively related word pairs [$F(1,92) = 4.409$, $MS_e = 0.008$], but not with orthographically ($F < 1$) or homophonically ($F < 1$) mediated word pairs. No other significant effects were found in the error rate data.

As in Experiments 1 and 3, significant facilitatory-priming effects were found with associatively related (e.g., *frog–toad*) prime–target word pairs, but not with homophonically mediated word pairs (e.g., *frog–towed*). However, unlike in those two previous experiments, a mediated-priming effect was not found with orthographically mediated prime–target word pairs (e.g., *frog–told*). The presence of semantic priming, along with the absence of orthographically mediated priming effects, is consistent with a two-step process of mediated priming. Specifically, although a 33-msec prime duration provided sufficient time for semantic associates to be automatically activated (see also Brown & Besner, 2002, for evidence of associative priming under similar conditions), an insufficient amount of semantic feedback had spread to orthography. Thus, the present results suggest that the absence of a context × stimulus quality interaction under a very brief prime duration is not due to a failure of semantic feedback to engage (cf. Brown & Besner, 2002). Rather, a brief prime duration does not allow enough time for a sufficient amount of semantic feedback to spread to orthographic representations. According to the present account, given that a mediated-priming effect was found with orthographically mediated prime–target word pairs when a 53-msec prime duration was used in Experiment 1, context and stimulus quality should interact when the prime duration is 53 msec. Unfortunately, to the best of our knowledge, this specific prime duration has not been used in any previous tests of the context × stimulus quality interaction.

GENERAL DISCUSSION

In the present study, the direct- and mediated-priming paradigms were used in a series of four experiments to determine whether semantic feedback spreads to orthographic and/or phonological representations and whether such feedback occurs automatically during the initial stages of lexical processing. The use of a 53-msec prime exposure duration in Experiment 1 produced associatively related (e.g., *frog–toad*) and orthographically mediated (e.g., *frog–told*) priming effects, but not a homophonically mediated (e.g., *frog–towed*) priming effect. These results demonstrate that there is an automatic spread of activation to orthographic, but not phonological, representations during the initial stages of the word recognition process. The results of Experiment 1 are consistent with models of visual word recognition that include fully interactive connections between semantic and orthographic representations (e.g., Coltheart et al., 2001; Seidenberg & McClelland, 1989; Stone et al., 1997; Van Orden & Goldinger, 1994) and provide support for accounts that invoke semantic-to-orthographic feedback in order to explain aspects of visual word recognition performance (e.g., Besner & Smith, 1992; Borowsky & Besner, 1993; Brown & Besner, 2002; Stolz & Neely, 1995). However, the results are inconsistent with accounts of visual word recognition performance that also include semantic feedback to phonological representations (e.g., Farrar et al., 2001; Hino & Lupker, 1996; Hino et al., 2002; Pecher, 2001; Pexman & Lupker, 1999; Pexman, Lupker, & Hino, 2002).

Table 5
Mean Correct Response Times (RTs, in Milliseconds), Error Rates (%E), and Context Effects by Type of Prime–Target Relationship and Condition in Experiment 4 (With Standard Deviations)

Type of Prime–Target Relationship	Condition: Unrelated RT *M*	*SD*	Unrelated %E *M*	*SD*	Related RT *M*	*SD*	Related %E *M*	*SD*	Context Effect RT	Context Effect %E
Associative	506	84.3	6.5	10.3	496	80.2	2.6	6.2	+10*	+3.9*
Homophonic	519	94.8	7.5	12.7	518	91.4	9.3	11.6	+1	−1.8
Orthographic	507	95.1	5.7	12.4	506	86.8	4.8	10.7	+1	+0.9

Note—Context effect = unrelated − related. * $p < .05$.

Using the mediating words and their respective targets from Experiment 1, direct homophone- and orthographic-priming effects were found in Experiment 2. These direct-priming effects demonstrated that the mediating words (e.g., *toad*) used in Experiment 1 were able to prime both homophonically (e.g., *towed*) and orthographically (e.g., *told*) related targets. The direct-priming effects found in Experiment 2 indicate that the null priming effect found with homophonically mediated word pairs in Experiment 1 was not due to orthographic interference caused by semantic feedback to phonology. Rather, these results indicate that semantic feedback failed to spread to phonology in Experiment 1.

With a relatively long prime exposure (413 msec), Experiment 3 replicated the results of Experiment 1 by showing significant facilitatory-priming effects with associatively related and orthographically, but not homophonically, mediated prime–target word pairs. Given that a 413-msec prime duration was used, these results demonstrate that even when a relatively long prime duration is used, semantic feedback does not spread to phonology. In addition, the results of Experiment 3 indicate that the effects of semantic feedback extend beyond the initial stages of visual word recognition and remain present after slower-acting conscious expectancy processes become operational. The extended effect of semantic feedback on word processing suggests either that semantic feedback continues to spread as word processing progresses or that semantic feedback has a relatively long-lasting effect despite its quick emergence during the early stages of word recognition.

Finally, Experiment 4 tested a two-step account of the mediated-priming results obtained in Experiments 1 and 3. By this account, activation first spreads from the prime's semantic representation to the mediating word's semantic representation, which is followed by a second step in which activation quickly spreads from the mediating word's semantic representation to its corresponding orthographic representation. In the fourth experiment, a very brief (33-msec) prime exposure duration was used in an attempt to capture semantic activation before it had an opportunity to sufficiently spread to the orthographic representation of the mediating word. By showing facilitatory priming with associatively related, but not orthographically mediated, words, Experiment 4 successfully isolated the first step of mediated priming.

Semantic Feedback and the Facilitation of Orthographic Processing

The nature of semantic feedback is best described within the sequence of events that occurs when a word is read. As was noted previously in this article, skilled reading performance depends on the ability to rapidly integrate distinct groups or levels of information (e.g., semantic, orthographic, and phonological). This rapid integration of information is made possible by a word recognition system that allows the bidirectional flow of activation between levels of representation (see, e.g., Coltheart et al., 2001; Plaut et al., 1996; Seidenberg & McClelland, 1989; Stone et al., 1997; Van Orden & Goldinger, 1994). Assuming that processing within the visual word recognition system is cascaded (see Coltheart et al., 2001; McClelland, 1979), the visual presentation of a word initiates orthographic processing, which, in turn, quickly activates corresponding semantic information, either directly or via phonology (depending on whether one adheres to the dual-route or the strong phonological theory). In addition, related semantic representations receive activation through automatic spreading activation (Collins & Loftus, 1975; Neely, 1976, 1977; Posner & Snyder, 1975). Along with the results of other priming studies (e.g., Brown & Besner, 2002), those of the present investigation (Experiment 4) indicate that the activation of such semantic information can occur very rapidly during visual recognition (e.g., 33 msec after a word is presented). More important, the results of the present study (Experiment 1) indicate that when activation reaches the semantic representations of both the current word and its associates, activation also feeds back automatically to the respective orthographic representations of those words. The present results indicate that semantic feedback spreads to orthography within the first 53 msec of lexical processing.

According to the present account, therefore, the primary role of semantic feedback is to facilitate ongoing orthographic processing (see also Hino & Lupker, 1996; Hino et al., 2002; Pecher, 2001; Pexman & Lupker, 1999; Pexman, Lupker, & Reggin, 2002). As soon as semantic information is activated, semantic feedback immediately begins to provide top-down support for orthographic processing. The combination of both top-down and bottom-up activation during word processing helps ensure that the most appropriate orthographic representation is activated. This account of semantic feedback is similar to other theories of visual word recognition in which feedforward and feedback have been proposed to codetermine the final output of a process (see, e.g., McClelland & Rumelhart, 1981; Stone et al., 1997). Note that semantic feedback could aid in orthographic processing through the activation of whole-word orthographic representations or through the activation of orthographic subunits, such as letters or feature representations.

Although the purpose of semantic feedback to orthography may be to facilitate the word recognition process, the question of why semantic feedback spreads to orthography and not to phonology should be addressed. Given that the main purpose of the visual word recognition system is to access meaning from visual symbols, initially such access necessarily depends on some orthographic processing. This is true even if semantic access primarily depends on prelexical phonological computation, as is the case in the strong phonological framework (Frost, 1995, 1998; Frost et al., 2003; Van Orden et al., 1990). In fact, Frost et al. have pointed out that "phonological computation is contingent on the accurate registration of orthographic information from the visual array" (p. 357). Therefore, regardless of how semantic access is ultimately accomplished (e.g., via orthography or phonology), by preactivating orthographic representations, semantic feedback will help constrain (either directly or indirectly) those critical processes on which semantic access depends. Consequently, the results of the present study are not necessarily inconsistent with either the strong phonological or the dual-route (Coltheart et al., 2001; Zorzi, Houghton, & Butterworth, 1998) framework.

Semantic Feedback to Orthography and the Effects of Ambiguity and Synonymy

Recent accounts of visual word recognition performance (Hino & Lupker, 1996; Hino et al., 2002; Pecher, 2001; Pexman & Lupker, 1999; Pexman, Lupker, & Hino, 2002) have invoked semantic feedback to orthography and phonology in order to account for the effects of both ambiguity and synonymy on visual word recognition performance. For example, according to Hino et al. (2002; see also Hino & Lupker, 1996), the ambiguity effect (i.e., the processing advantage found for words having multiple meanings over words having few meanings) is due to the fact that ambiguous words possess multiple semantic representations that map onto one orthographic and phonological representation. The ambiguity effect is attributed to semantic feedback's providing greater activation of orthographic and phonological information in ambiguous words, relative to unambiguous words. In contrast, according to Hino et al. (2002; see also Pecher, 2001), the synonymy effect (i.e., the processing disadvantage found in words with a synonym, relative to words without a synonym) is due to the fact that synonyms possess one semantic representation that maps onto multiple orthographic and phonological representations. Thus, the synonymy effect is due to semantic feedback's producing competition during orthographic and phonological processing in words with a synonym, but not in words without a synonym. Hino et al.'s (2002) proposal that semantic feedback spreads to both orthography and phonology is based on the fact that ambiguity (e.g., Gottlob, Goldinger, Stone, & Van Orden, 1999; Hino & Lupker, 1996; Hino, Lupker, Sears, & Ogawa, 1998; Rubenstein, Garfield, & Millikan, 1970) and synonymy (e.g., Hino et al., 2002; Pecher, 2001) effects have been found with both lexical decision tasks and naming tasks.

The results of the present study suggest that Hino et al.'s (2002) account of ambiguity and synonymy effects may require some modification. In the present study, performance in the naming task was found to be influenced by semantic feedback to only orthography. This finding raises the possibility that semantic feedback to orthography not only may influence responses in tasks that have been assumed to be based on orthographic processing (i.e., lexical decision tasks), but also can affect responses in tasks that have been assumed to be based primarily on phonological processing (i.e., naming tasks). Despite the fact that responses in the naming task are dependent on the use of phonological codes, as was previously indicated, during printed word processing the construction of such codes necessarily relies on some initial orthographic processing. Thus, if semantic feedback to orthography increases the amount of activation of only one orthographic representation, as with ambiguous words, such activation should facilitate a response (at least to some degree), regardless of whether the response is ultimately based on orthography (e.g., in lexical decision tasks) or phonology (e.g., in naming tasks). Similarly, if semantic feedback to orthography increases the activation of multiple orthographic representations, as in the case of words with synonyms, such activation should hinder a response, regardless of whether a response is ultimately based on orthography or phonology. Therefore, it is possible that feedback to orthography alone can be used account for ambiguity and synonymy effects found in both lexical decision and naming tasks.

In addition, it is important to note that although semantic variables (e.g., synonymy and imageability) have been shown to influence processing in both lexical decision and naming tasks, the effect of such variables occasionally has been found to be stronger in the lexical decision task than in the naming task (e.g., de Groot, 1989; Pecher, 2001). The present account of semantic feedback is also consistent with this finding. Specifically, if semantic feedback spreads only to orthography, one would expect that semantic variables should have a larger effect in tasks that are based primarily on orthographic processing (e.g., lexical decision tasks) than in tasks that involve both orthographic and phonological processing (e.g., naming tasks).

Semantic Feedback and RP

Finally, as was previously indicated, the presence of semantic feedback to orthography was found under low-RP conditions in Experiments 1 and 3 (see also Farrar et al., 2001; O'Seaghdha & Marin, 1997). This finding is inconsistent with Stolz and Neely's (1995) data, in which evidence of semantic feedback was found under high- (.50), but not low- (.25), RP conditions.[3] Given that previous studies (Keefe & Neely, 1990; see also Neely, 1991) have demonstrated that the effect of RP is weaker in the naming task than in the lexical decision task, the use of a naming task in the present study may be one reason why semantic feedback was found under low-RP conditions. Thus, it is possible that RP does modulate semantic feedback but that RP exerted only a weak effect in the present study. It is important to note, however, that even if this was the case, the results of Experiments 1 and 3 indicate that the default set is for semantic feedback to spread (cf. Brown & Besner, 2002). The only question that remains is whether or not a low RP is able to disengage semantic feedback.

Conclusions

The central findings of the present investigation were (1) that semantic feedback spreads to orthography, but not to phonology, and (2) that such feedback occurs automatically during the initial stages of visual word processing. Although further research is required to examine semantic feedback under other conditions, the results provide important constraints for models of visual word recognition, particularly regarding the nature of interactivity among components of the visual word recognition system.

AUTHOR NOTE

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NOTES

1. Note that in examples of mediated prime–target word pairs provided throughout this article, mediating words are placed in brackets. These mediating words are not presented to participants within the mediated-priming paradigm.

2. We thank an anonymous reviewer for suggesting this alternate account.

3. However, it should be noted that the way in which RP modulates semantic feedback is not clear (see Stolz & Neely, 1995, pp. 608–609, for a discussion).

APPENDIX A
Thirty-Six Word Quadruplets and Corresponding Unrelated Primes

1. socks (tiger)–feet–feat–feed	19. bucket (turtle)–pail–pale–pair
2. airport (mustard)–plane–plain–plate	20. live (east)–die–dye–dim
3. shopping (reporter)–mall–maul–mill	21. female (driver)–male–mail–make
4. diamond (coconut)–ring–wring–rung	22. butcher (garbage)–meat–meet–melt
5. zero (jump)–none–nun–note	23. sky (leg)–blue–blew–blur
6. gun (eye)–shoot–chute–shook	24. fix (gum)–break–brake–bleak
7. book (fire)–read–reed–rear	25. shine (groom)–sun–son–sum
8. highway (display)–road–rode–roam	26. wag (zip)–tail–tale–tall
9. saddle (jersey)–horse–hoarse–house	27. coffee (secret)–tea–tee–ten
10. comb (sofa)–hair–hare–hail	28. fishing (courage)–pole–poll–poke
11. sour (clam)–sweet–suite–sweat	29. bargain (royalty)–sale–sail–salt
12. frog (kite)–toad–towed–told	30. ocean (smell)–sea–see–set
13. deer (cake)–doe–dough–dog	31. listen (stream)–hear–here–heap
14. dig (hip)–hole–whole–hope	32. umbrella (curtains)–rain–rein–rail
15. sand (dawn)–beach–beech–bench	33. print (angel)–write–right–wrote
16. buy (fit)–sell–cell–seal	34. vision (review)–sight–site–sighs
17. tulip (pizza)–flower–flour–flowed	35. step (army)–stair–stare–stain
18. strong (modern)–weak–week–wear	36. method (square)–way–weigh–wax

Note—Each word quadruplet lists, in order, the related prime, the unrelated prime (in parentheses), the associatively related target, the homophonically mediated target, and the orthographically mediated target.

APPENDIX B
Homophonically (Experiment 2A) and Orthographically (Experiment 2B) Related Prime–Target Word Pairs Used in Experiment 2

Experiment 2A			Experiment 2B		
Related Prime	Unrelated Prime	Target	Related Prime	Unrelated Prime	Target
1. feet	past	feat	1. feet	past	feed
2. plane	staff	plain	2. plane	staff	plate
3. mall	germ	maul	3. mall	germ	mill
4. ring	cook	wring	4. ring	cook	rung
5. none	deep	nun	5. none	deep	note
6. shoot	fiber	chute	6. shoot	fiber	shook
7. read	data	reed	7. read	data	rear
8. road	idea	rode	8. road	idea	roam
9. horse	march	hoarse	9. horse	march	house
10. hair	sent	hare	10. hair	sent	hail
11. sweet	drawn	suite	11. sweet	drawn	sweat
12. toad	wick	towed	12. toad	wick	told
13. doe	zip	dough	13. doe	zip	dog
14. hole	busy	whole	14. hole	busy	hope
15. beach	metal	beech	15. beach	metal	bench
16. sell	vice	cell	16. sell	vice	seal
17. flower	genius	flour	17. flower	genius	flowed
18. weak	coal	week	18. weak	coal	wear
19. pail	brim	pale	19. pail	brim	pair
20. die	box	dye	20. die	box	dim
21. male	core	mail	21. male	core	make
22. meat	load	meet	22. meat	load	melt
23. blue	hour	blew	23. blue	hour	blur
24. break	cover	brake	24. break	cover	bleak
25. sun	hit	son	25. sun	hit	sum
26. tail	bend	tale	26. tail	bend	tall
27. tea	cow	tee	27. tea	cow	ten
28. pole	wing	poll	28. pole	wing	poke
29. sale	path	sail	29. sale	path	salt
30. sea	arm	see	30. sea	arm	set
31. hear	food	here	31. hear	food	heap
32. rain	song	rein	32. rain	song	rail
33. write	scene	right	33. write	scene	wrote
34. sight	build	site	34. sight	build	sighs
35. stair	chunk	stare	35. stair	chunk	stain
36. way	how	weigh	36. way	how	wax

Note—Associatively related word pairs used in Experiments 2A and 2B were the same as those used in Experiment 1.

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