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Strategic Effects in Associative Priming With Words, Homophones, and Pseudohomophones

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G. Lukatela and M. T. Turvey (1994a) showed that at a 57-ms prime-presentation duration, the naming of a visually presented target word (*frog*) is primed not only by an associate word (*toad*) but also by a homophone (*towed*) and a pseudohomophone (*tode*) of the associate. At a 250-ms prime presentation, priming with the homophone was no longer observed. In Experiment 1, the authors replicated these priming effects in the Dutch language. Next, the authors extended the priming paradigm to a word/legal-nonword lexical decision task (Experiments 2 and 3) and a word/pseudohomophone decision task (Experiment 4). Phonologically mediated associative priming was observed in all conditions with pseudohomophonic primes but not with homophonic primes. The latter did not prime at a 250-ms prime-presentation time and at 57 ms in the word/pseudohomophone task.

In the dual-route model of visual word recognition (Coltheart, 1978; Coltheart, Curtis, Atkins, & Haller, 1993; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001) it has been assumed that skilled readers prefer the direct visual route for visual word processing, because the indirect phonological route includes an additional conversion from orthography to phonology, making it potentially slower. This idea has dominated research on visual word processing for a long time, and some authors have even suggested that the existence of the phonological route could be rejected without loss of generalizability (e.g., Humphreys & Evett, 1985). Indications, however, exist that phonology plays a more crucial role in the process of visual word recognition.

Using a masked-priming paradigm, in which target words were preceded by a tachistoscopically presented prime, Humphreys, Evett, and Taylor (1982) discovered that more targets (e.g., *MADE*) were recognized when the prime was a homophone (e.g., *maid*) than when it was an unrelated word (e.g., *ship*) or a graphemic control word (e.g., *mark*). Therefore, automatic phonological priming existed in English, but was it lexical or nonlexical? To examine this question, Humphreys et al. designed the pseudohomophone test. If they could replicate the effect with homophonic nonword primes instead of homophonic word primes, then the phonological priming had to originate from a nonlexical route, because nonwords do not have a representation in the mental lexicon. However, Humphreys et al. failed to find such an effect, making them conclude that the priming they had found with homophones was a lexical effect. Almost a decade later, Perfetti and Bell (1991) replicated the null effect of Humphreys et al. but showed that this was true only for short prime-presentation times (up to 35 ms). When primes were presented for slightly longer durations (45 and 65 ms), a clear phonological priming effect was obtained with nonword primes.[1] Shortly afterward, Lukatela and Turvey (1994b) even found significant phonological priming with better controlled pseudohomophones at a prime-presentation time as short as 30 ms. Therefore, automatic phonological priming can occur through a nonlexical route. These results were in agreement with previous findings using the backward-masking paradigm (Perfetti, Bell, & Delaney, 1988).

Other important phonological effects were obtained with a rapid semantic categorization task. Van Orden (1987) discovered that participants frequently made errors in this task when homophones were used as stimulus materials. Participants were first shown the name of a category (e.g., *FLOWER*) followed by a target (e.g., *ROSE*), after which they had to decide as fast as possible whether the target belonged to the category. When appropriate target words (e.g., *ROSE*) were replaced by homophones (e.g., *ROWS*), the number of misclassifications was significantly higher than when target words were replaced by visual controls (e.g., *ROBS*). Van Orden attributed the extra percentage of misclassifications to the fact that visual letter strings must be converted into a phonological representation before they can make contact with stored word information. Because *ROSE* and *ROWS* activate the same prelexical phonological code, they are indistinguishable in the first stage of lexical access. When sufficient time is available, a spelling-verification process is thought to occur to resolve the ambiguity caused by the homophone. This explains why the error rate intro-

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[1] Besner, Dennis, and Davelaar (1985) were the first to show phonological priming with pseudohomophones in a lexical decision task. In this study, the pseudohomophone was presented on Trial *n* and the target word on Trial $n + 1$.

duced by homophones is low under free-viewing conditions and depends on the orthographic overlap between homophone and target word. The delayed spelling check also explains why the error rate increases dramatically when exposure time is limited and why under these conditions error rate no longer depends on the degree of orthographic overlap.

Lesch and Pollatsek (1993) reported further evidence for Van Orden's (1987) verification model using an associative-priming experiment. Participants had to name a target word (e.g., *sand*) as fast as possible. The target was preceded by a masked prime that belonged to one of three different categories: the appropriate associate prime (e.g., *beach*), a homophone of the associate prime (e.g., *beech*), or an orthographic control (e.g., *bench*). Lesch and Pollatsek found that if the prime was presented for a very short period of time (50 ms) targets were named faster both when they were preceded by the associate prime and when they were preceded by the homophone of the associate prime than when they were preceded by the orthographic control prime. In addition, the priming effect was equally strong for the homophones as for the true associates. However, when prime-presentation time was increased to 200 ms, there was no priming of the homophones anymore, whereas the effect of the associate primes remained significant. Lesch and Pollatsek considered their results as evidence for the verification model and ventured that at 200 ms the spelling-verification process had enough time to take place, whereas this was not the case at 50 ms.

Lukatela and Turvey (1994a) expanded the results of Lesch and Pollatsek (1993) by showing that the same effects were obtained with pseudohomophones as primes (i.e., *tode*, a pseudohomophone of *toad*, primed the naming of the target word *frog*). In addition, they found that unlike homophone primes, pseudohomophone primes remained to have an effect at long prime-presentation durations (250 ms). To explain the difference between homophones and pseudohomophones, Lukatela and Turvey (1994a) proposed a model of visual word recognition in which a word's phonology is the initial, and perhaps solitary, code by which a word's representation in the internal lexicon is accessed. In their view, the role of a word's orthographic structure is restricted to reducing the noise in the lexicon if the phonological code results in multiple activations. The lexical representations activated by the phonological code inform about how the respective words are spelled. If a fit between the spelling retrieved by the phonological code and the presented visual form is achieved, a cleaning-up process is engaged, in which the competing patterns of lexical activity other than the pattern with the addressed spelling that fits the actual spelling are suppressed according to a winner-takes-it-all principle. It is important to note that in their model, orthographic input codes can affect the internal lexicon only after a particular kind of information (the addressed spelling) has been made available by the phonological access codes, and the cleaning-up process will start only if the addressed spelling matches the input. In addition, the cleaning-up process requires a certain period of time to be completed, which usually exceeds 50 ms, although occasionally the addressed spellings of some homophones may be checked against their visual forms within this time limit (Lukatela & Turvey, 1994a, p. 117).

A similar activation-verification model was proposed by Lee, Rayner, and Pollatsek (1999) to account for their findings with the fast-priming technique during text reading. Previous research by the authors (e.g., Pollatsek, Lesch, Morris, & Rayner, 1992) had shown that phonological codes are used in silent reading. Readers process a foveal word faster when a homophonic stimulus, rather than a nonhomophonic control, was presented in the parafovea at the time of the previous fixation. Thus, during reading, the gaze duration on the target word *rains* is shorter when, on the previous fixation, the word *reins* was presented in the parafovea rather than the orthographic control *ruins*. To study the time course of phonological priming in reading in greater detail, Lee et al. examined what happens when the prime is not shown in the parafovea but rather is shown for a very short time at the beginning of the fixation on the foveal word (i.e., the target word *beech* is replaced by the primes *beach* and *bench* for the first few milliseconds of the fixation). In addition, they looked at the time course of orthographic priming (by comparing processing time for the target word *angel* after the primes *angle* and *sport*) and semantic priming (by comparing the gaze duration on the target word *acre* after the primes *land* and *step*). Lee et al. found phonological priming for short prime durations of 29, 32, and 35 ms (but not for prime durations of 38 and 41 ms) and orthographic priming for all prime durations from 29 to 41 ms. Semantic priming was significant only at a 32-ms prime duration. According to Lee et al., these findings can be explained by assuming that in the first stage of visual word processing, the phonological code is accessed, which triggers a second spelling check stage in which the orthographic representation of the stimulus is compared with the orthographic representations of the various possibilities consistent with this phonological representation in order to select the appropriate stimulus. The major difference with Lukatela and Turvey (1994a) is that the spelling check seems to operate faster in normal reading (i.e., below 38 ms) than in Lukatela and Turvey's (1994a) naming task. (Lee et al., 1999, masked the target stimulus until it was fixated, so that there was no parafoveal preprocessing.)

Other evidence for the pivotal role of prelexical phonology in visual word recognition comes from experiments in which the reliance on phonological information was discouraged because the phonological information hindered accurate performance in the experimental task. For instance, Brysbaert (2001, Experiment 3; see also Xu & Perfetti, 1999) measured the phonological-priming effect by comparing the percentage correct identifications of tachistoscopically presented target words presented after a masked pseudohomophonic prime and after a nonhomophonic graphemic control prime (43-ms prime duration). The main manipulation of the experiment was whether the trials with phonologically related primes formed the majority of trials. This was achieved by using filler items in which the primes were either pseudohomophones of the targets (i.e., Dutch equivalents of the type *tode–TOAD*) or pseudohomophones of another, unrelated word (i.e., Dutch equivalents of *bern–TOAD*, in which *bern* is a pseudohomophone of *burn*). Brysbaert (2001) obtained exactly the same phonological priming effect in both conditions, despite the fact that in the condition with unrelated fillers 58% of the trials contained primes with a phonological code that pointed to a word other than the target word (and only 14% of the trials contained primes with a phonological code that pointed to the target word).

The mandatory reliance on phonology in the masked-priming paradigm contrasts with the strategic effects that have been documented in a variety of other tasks such as lexical decision, word naming, and perceptual identification without masked priming. In these tasks, effects of phonology can be eliminated by changing the stimulus set of the experiment so that the use of phonology hurts performance (for reviews, see Berent & Perfetti, 1995; Brysbaert, 2001; and Frost, 1998). To explain the difference between mandatory use of phonology in the very first stages of visual word recognition (as suggested by the findings with the masked-priming paradigm) and the strategic use in later stages (as suggested by the other tasks), proponents of the strong phonological view of visual word recognition have argued that lexical access may be based on a partial phonological code (Berent & Perfetti, 1995; Frost, 1998). Berent and Perfetti (1995), for instance, hypothesized that the prelexical phonological code mainly consists of information related to the consonants, leaving out most of the information conveyed by the vowels (because in English this tends to be more ambiguous). The partial code is automatically activated and used for lexical access. Lexical information then helps to complete the impoverished code. In this view, strategic phonological effects will be observed when the experimental task requires a complete phonological representation (e.g., in word naming), but automatic effects will be seen if the task taps into the very first, prelexical stages of word processing. The prototypical task of the latter type is the masked-priming paradigm, in which target words are immediately preceded by barely visible primes that need not be processed consciously.

Berent (1997) directly addressed the issue of mandatory prelexical phonological assembly versus strategic reliance on postlexical phonology by running a lexical decision task in which the target words were preceded by masked primes. Some of the target words had a regular pronunciation (e.g., *scoop*), others had an irregular pronunciation (e.g., *glove*); some target words were preceded by a homophonic prime, whereas some were preceded by a graphemic control prime. Although Berent failed to find an effect of the spelling-sound regularity of the target words with legal nonword foils (indicating that the lexical decision did not incorporate this kind of phonological information), she obtained faster decision times after homophonic primes than after graphemic control primes (indicating that prelexical phonology assembly did matter in the task).

In our experiments, we further explored the strong phonological theory of visual word processing and concentrated on three questions. First, is it possible to replicate Lukatela and Turvey's (1994a) findings in the Dutch language? Second, is the phonological priming effect confined to word naming, or can it be extended to lexical decision? Third, what happens if we discourage reliance on phonological information by having participants exclusively decide between words and pseudohomophones in the lexical decision task? The first question was addressed in Experiment 1. Although Lukatela and Turvey's (1994a) finding of a dissociation between homophones and pseudohomophones at longer stimulus onset asynchronies (SOAs) is the core argument for the activation-verification hypothesis, thus far the finding has not been replicated in a language other than English. Therefore, empirical corroboration from another alphabetical language, like Dutch, would help to firmly establish the argument. One reason why the processes of word recognition in Dutch may deviate from those in English is that Dutch-speaking university students usually understand (and read) more than one language. In Belgium, Dutch-speaking students have had extensive teaching in French, English, and to a lesser extent German in primary and secondary education (besides Latin and sometimes ancient Greek). Very little is known about the issue of phonological coding in multilinguals (see Brysbaert, in press, for a review), but an undeniable feature of mastering several languages with a similar script is that the number of conflicting letter-sound mappings multiplies (e.g., the graphemes /ee/ and /oo/ are pronounced differently in English and Dutch). This may not be without consequences for the issue of phonological coding in written-word processing. Therefore, it seemed necessary to us first to find out whether we could replicate Lukatela and Turvey's (1994a) associative priming by homophones and pseudohomophones in the naming task (Experiment 1: naming, 57-ms prime duration).

Experiment 1

As indicated in the introduction, Lukatela and Turvey (1994a) found evidence of phonologically mediated associative priming in the naming task. Target-word naming (e.g., *frog*) was about 10 ms faster not only when the word was combined with a real associative prime (e.g., *toad*) but also when it was combined with a homophone of the associate (e.g., *towed*) or a pseudohomophone of the associate (e.g., *tode*). Prime-exposure duration was 50 ms. This experiment was set up to replicate the effect in Dutch.

Method

Participants. Participants were 39 first-year students at Ghent University, Ghent, Belgium, who participated for course credits. All were native Dutch speakers.

Stimulus materials. Because Lukatela and Turvey's (1994a) findings in the first place depend on the availability of good pairs of associated words, one of which has a pseudohomophone or a homophone, we invested quite some energy in the construction of our stimulus materials. A list of 42 pairs of homophones (e.g., *rat* [*rat*] and *rad* [*wheel*]) and 42 words that could be written as pseudohomophones (e.g., *auto* [*car*], and *outo*) was selected. These 126 words (42 × 2 homophonic words + 42 pseudohomophonic words) were distributed over six lists of 21 words (so that a single list did not contain both members of a homophonic pair). Each list was scored by 40 first-year students (making a total of 240 raters), who did not participate in any of the following experiments. The students were asked to write down as quickly as possible the first association that came to mind when seeing each stimulus word.

Out of the 126 words that had been scored, two lists of 21 experimental prime trials were built. The first list consisted of the best homophonic primes, that is, those words of a pair of homophones that had the most frequent associate (one should note that only one member per homophonic pair could be selected). The mean associate-generation frequency for these words was 54.8%. Similarly, the 21 best pseudohomophonic primes were selected (mean generation frequency was 46.1%). They made up the second list.

The 21 primes of the first list (e.g., *hart* [*heart*]) were matched to their homophone (e.g., *hard* [*hard*]) and to an unrelated orthographic control word (e.g., *hars* [*resin*]) that had the same number of letters in common with the original prime and that was of roughly the same frequency as the homophone. These stimuli are listed in Appendix A. The visual similarity of the homophones and the controls to the associate primes was measured with the procedure described in Lukatela and Turvey's (1994a) study. This estimate consisted of the average of two similarity indices. The first index was obtained by dividing the number of shared letters in the same position (L1) by the number of letters in the longer letter string (L). For this index, a shared final letter was also considered to be in the same position. The second index was calculated by dividing the number of matching letters in and out of position (L2) relative to L. Consequently, for *HART* and *HARD*, L1 = 3, L2 = 3, L = 4, and the estimate of similarity was (.75 + .75) / 2 = .75; for *HART* and *HARS*, L1 = 3, L2 = 3, L = 4, and the estimate of similarity was (.75 + .75) / 2 = .75. The average index of visual similarity between associates (e.g., *HART*) and homophones (e.g., *HARD*) was .67 and that between associates (e.g., *HART*) and graphemic controls (*HARS*) was .61.

The 21 primes of the second list (e.g., *arm* [*arm*]) were matched to their pseudohomophone (e.g., *arrem*) and to an orthographic control nonword (e.g., *ars*; see Appendix B). The visual similarity between associates (e.g., *ARM*) and pseudohomophones (e.g., *ARREM*) was .70; that between associates (e.g., *ARM*) and graphemic controls (e.g., *ARS*) was also .70. All these stimuli, from both lists, were used as primes of the associates that had been generated by the students and that served as targets in the experiments below (e.g., *liefde* [*love*] was the target of the primes *hart, hard, hars*; and *hand* [*hand*] was the target of the primes *arm, arrem, ars*).

The remaining words that had been rated were used to create nonword trials for the lexical decision experiments. These trials were created exactly the same as the word trials, except that after the creation, one of the letters of the target words was changed to create either a legal nonword or a pseudohomophone (see Appendixes C–F). Therefore, after having combined the target word *vijs* [*screw*] with the primes *bout* [*bolt*], *boud* [*bold*], and *mout* [*malt*], the target was changed into the nonwords *lijs* or *veis* and presented with the same primes. We used the same criteria to create word and nonword stimuli, to make sure that no superficial relations between primes and targets would distinguish word trials from nonword trials.

In Lukatela and Turvey's (1994a) experiments, the effect of prime frequency was examined by constructing two sublists: one list with high-frequency associative primes and low-frequency homophonic primes and one list with the reverse pattern. This did not induce a systematic difference, nor did prime frequency in related research on phonological priming (Ferrand & Grainger, 1992; Lukatela, Lukatela, Carello, & Turvey, 1999; Lukatela & Turvey, 1994b). For this reason, we did not fully control the variable frequency in this study.

The experimental list for Experiment 1 with homophones of the associates is described in Appendix A, and the experimental list with pseudohomophones of the associates is described in Appendix B. Both lists were mixed and presented to the same participants.

Procedure. The main constraint of the experimental design was that a participant never saw a target word twice. This was achieved by using a Latin square design. As there were three prime types (associate, homophone or pseudohomophone of the associate, and graphemic control), each participant named only one third of the target words in each condition. Across participants, all words were presented in all conditions. Participants received a random permutation of the 42 experimental trials mixed with 42 unrelated filler trials. Before this series of trials was presented, a practice series of 28 trials was completed. Of these 28 trials, 14 prime–target pairs were associated, and 14 were not. Participants were tested individually.

A trial started with a visual warning signal (a forward mask consisting of #######) presented for 1 s, immediately followed by the presentation of the prime for 57 ms, and the target. Stimulus presentation was synchronized with the refresh cycle of the screen (70 Hz). As in Lukatela and Turvey's (1994a) study, the prime was presented in uppercase letters and the target in lowercase letters. The target word remained on the screen until the voice key registered a response. The experimenter registered online the correctness of the response and the time registration. The interstimulus interval was 2 s. Throughout the experimental session, two vertical lines were visible in the middle of the screen. These lines were presented one above the other with a gap of 1 cm between them. Participants were instructed to look at the gap between the two lines as soon as the visual warning signal appeared. Stimuli were presented so that the second letter always appeared between the lines. Previous research has shown that the second letter is the optimal viewing position for recognizing short words in Dutch (Brysbaert, Vitu, & Schroyens, 1996). Participants were instructed that a word would appear between the lines shortly after the warning signal and that they had to pronounce the word as rapidly as possible. The presence of a prime stimulus was not mentioned.

Results

Naming latencies were excluded from the analyses below when (a) the word had been pronounced incorrectly, (b) the voice key had not registered the voice-onset time correctly, or (c) reaction times (RTs) were lower than 100 ms or higher than 1,500 ms. All in all, 5.2% of the data were discarded, mostly because the response had been too weak to trigger the voice key.

Table 1 lists the naming latencies of the target words as a function of prime type. One should remember that there were two different lists, one with homophones of the associates and one with pseudohomophones of the associates. These lists were analyzed separately. Because a Latin square design was used with relatively few observations in the different cells, the group variable was included in all analyses reported below. If this were not done, the power of the design may have been deflated because of random fluctuations between the participants or between the stimuli allocated to the different cells (Brysbaert & Mitchell, 1996; Pollatsek & Well, 1995). All analyses were run over participants (F_1 analyses) and stimulus materials (F_2 analyses). The p values were smaller than .05, unless indicated otherwise.

For the list with homophones, target words were named 26 ms slower after the graphemic control primes than after the true associate primes or the homophones of the associate primes. This effect of prime type was significant, $F_1(2, 72) = 4.24$, $MSE = 2{,}077.71$; $F_2(2, 36) = 5.81$, $MSE = 897.86$, and completely due to the difference between the graphemic controls on the one hand and the associates and homophones on the other hand (Duncan's multiple range test at .05: F_1, Step 1 = 20.6, Step 2 = 21.7; F_2, Step 1 = 18.7, Step 2 = 19.7).

The same pattern was found for the list with pseudohomophones of the associate primes. The 23-ms-slower RTs after the graphemic control primes were significantly different from the RTs after the true associate primes and after the pseudohomophones of the associate primes, $F_1(2, 72) = 4.35$, $MSE = 1{,}675.88$; $F_2(2, 36) = 3.95$, $MSE = 784.11$ (Duncan's multiple range test at .05:

Table 1
Naming Latencies (in ms) in Experiment 1

Prime type	Example	Latency
Homophones		
Associate	PIJL–boog	580
Homophone	PEIL–boog	580
Visual control	PAAL–boog	606
Net associative priming		26
Net phonologically mediated priming		26
Pseudohomophones		
Associate	PALM–boom	563
Pseudohomophone	PALLEM–boom	564
Visual control	RALM–boom	587
Net associative priming		24
Net phonologically mediated priming		23

F_1, Step 1 = 18.5, Step 2 = 19.4; F_2, Step 1 = 17.5, Step 2 = 18.4).

Discussion

Experiment 1 successfully extended Lukatela and Turvey's (1994a) phonologically mediated associative-priming experiment to the Dutch language. The same priming effect was obtained with true associates and their homophones (26 ms) or with true associates and their pseudohomophones (23 ms; see Table 1). The finding that Lukatela and Turvey's (1994a) results could be replicated in Dutch adds further evidence to the claim that phonological coding of visually presented words plays a crucial role in all alphabetic languages, and it makes a good starting position for the next experiments to see whether the effect can be generalized to a lexical decision experiment.

Experiment 2

Our second question was whether phonologically mediated associative priming is confined to word naming or can be extended to lexical decision. Finding a phonological effect in the naming task is the least convincing evidence for mandatory phonological coding in visual word recognition, because naming requires the full phonological code for accurate performance and, therefore, allegedly encourages the recoding. In contrast, lexical decisions can be based on nonphonological information conveyed by the written stimulus. The lexical decision task is used in Experiments 2, 3, and 4. In all experiments, the same word stimuli were presented, so that one can directly compare the amount of priming with homophones and pseudohomophones of associate primes in the different experiments (Experiment 2: word–legal nonword decision, 57-ms prime duration; Experiment 3: word–legal nonword decision, 258-ms prime duration; Experiment 4: word–pseudohomophone decision, 57-ms prime duration). In Experiment 2, participants had to decide between words and legal nonhomophonic nonwords. Targets were preceded by the same primes as in Experiment 1.

Method

Participants. Participants were 42 first-year students at Ghent University, who participated for course credits. All were native Dutch speakers.

Procedure. The design was the same as in Experiment 1, except that now the 42 filler trials were replaced by 42 nonword trials. The nonword trials followed either the logic of the list with homophones (Appendix C) or the logic of the list with pseudohomophones (Appendix D). Before the experimental list of 84 randomly mixed trials, a practice series of 28 trials was finished. The practice series had been constructed along the same lines as the experimental list. Stimulus presentation was the same as in Experiment 1, except that participants had to indicate their word–nonword decision by pressing a button with the left or the right hand (counterbalanced across participants). External response boxes were used, connected to the game port.

Results

The results of the nonwords were not analyzed. RTs below 100 ms and above 1,500 ms were considered outliers and removed from the data analysis. This was the case for 1 out of 1,764 observations. Response latencies and percentages of errors are listed in Table 2. Because error rates were very small they are reported only when there appeared to be a difference in error rate between the conditions.

For the list with homophones, RTs were about 24 ms slower when target words were preceded by graphemic control primes than when they were preceded by associates or homophones of these associates. The effect of prime type was significant, $F_1(2, 78) = 3.93$, $MSE = 2{,}405.27$; $F_2(2, 36) = 4.10$, $MSE = 1{,}181.47$, and due to the difference between the graphemic controls on the one hand and the associates and homophones on the other hand (Duncan's multiple range test at .05: F_1, Step 1 = 21.3, Step 2 = 22.4; F_2, Step 1 = 21.5, Step 2 = 22.6).

The same pattern was obtained for the list with pseudohomophones. The 30-ms slower RTs after graphemic control primes were significantly different from the RTs after associate primes and pseudohomophones of these associate primes, $F_1(2, 78) = 7.86$, $MSE = 1{,}842.63$; $F_2(2, 36) = 10.81$, $MSE = 623.97$ (Duncan's multiple range test at .05: F_1, Step 1 = 18.6, Step 2 = 19.6; F_2, Step 1 = 15.6, Step 2 = 16.4). The difference in error rate between the nonword primes (the pseudohomophone of the associate and the graphemic control) and the associate prime was not significant, $F_1(1, 39) = 2.36$, $MSE = 0.40$, $p > .10$; $F_2(1, 18) = 2.78$, $MSE = 5.14$, $p > .10$.

Discussion

Experiment 2 successfully extended the phonological priming effect to the lexical decision task. We obtained a phonologically mediated associative-priming effect that was of the same magnitude as the priming caused by real associates. This was true for both homophones and pseudohomophones. It indicates that Lukatela and Turvey's (1994a) effect was not due to task characteristics. The naming task intrinsically requires phonology (Frost, 1998). This is not the case for lexical decision. Yet, we found the same effect, indicating the robustness of the effect.

Experiment 3

In the previous experiments, we found similar effects with homophones and pseudohomophones of associative primes. This

Table 2
Reaction Times (in ms) and Percentage Errors in Experiment 2

Prime type	Example	Reaction time	% errors
	Homophones		
Associate	PIJL–boog	565	3.4
Homophone	PEIL–boog	561	3.0
Visual control	PAAL–boog	589	5.0
Net associative priming		24	
Net phonologically mediated priming		28	
	Pseudohomophones		
Associate	PALM–boom	571	1.7
Pseudohomophone	PALLEM–boom	575	3.4
Visual control	RALM–boom	605	3.4
Net associative priming		34	
Net phonologically mediated priming		30	

was expected on the basis of the results found by Lukatela and Turvey (1994a) and Lesch and Pollatsek (1993). If prime duration is short, there is not enough time to perform a spelling check on the primes. Different results have been obtained with longer prime-exposure durations (200–250 ms). Under these conditions, phonological priming of target naming can be observed with pseudohomophones of associate primes but not with homophones (Lesch & Pollatsek, 1993; Lukatela & Turvey, 1994a). Experiment 3 was set up to find whether the same pattern of results emerges in the lexical decision task using the same procedure as in the previous experiment, with the exception of the prime-exposure time, which was set at 258 ms.

Method

Participants. Participants were 42 first-year Ghent University students, who participated for course credits. All were native Dutch speakers.

Procedure. Everything was the same as in Experiment 2, except that prime-exposure time now was 258 ms (18 refresh cycles of the screen), and the experiment was run with 4 participants (and computers) in parallel.

Results

The results of the nonwords were not analyzed. Response latencies below 100 ms and above 1,500 ms were removed. This was the case for 15 out of 1,764 observations. Table 3 lists the RTs and percentages of errors as a function of stimulus list and prime type. Because error rates were very small they are reported only when there appeared to be a difference in error rate between the conditions.

For the list with homophones, RTs were about 25 ms faster when target words were preceded by their associate than when they were preceded by a homophone of this associate or a graphemic control. The effect of prime type was significant, $F_1(2, 78) = 5.78$, $MSE = 1{,}360.22$; $F_2(2, 36) = 3.67$, $MSE = 1{,}195.51$. In contrast with the previous experiment, this time the effect was due to the difference between the associates on the one hand and the homophones and graphemic controls on the other hand (Duncan's multiple range test at .05: F_1, Step 1 = 21.6, Step 2 = 22.8; F_2, Step 1 = 16.0, Step 2 = 16.9).

The RT pattern for the list with pseudohomophones was a replica of the pattern found in Experiments 1 and 2. The 17–22-ms-slower RTs after graphemic control primes was significantly different from the RTs after associate primes and pseudohomophones of the associate primes, $F_1(2, 78) = 4.16$, $MSE = 1{,}367.32$; $F_2(2, 36) = 5.62$, $MSE = 614.60$ (Duncan's multiple range test at .05: F_1, Step 1 = 15.5, Step 2 = 16.3; F_2, Step 1 = 16.1, Step 2 = 17.0). However, the percentage of errors yielded a slightly different picture: There were more errors after a nonword prime (either pseudohomophonic or not) than after a word prime, $F_1(1, 39) = 11.85$, $MSE = 4.32$; $F_2(1, 18) = 18.95$, $MSE = 9.47$.

Table 3
Reaction Times (in ms) and Percentage Errors in Experiment 3

Prime type	Example	Reaction time	% errors
	Homophones		
Associate	PIJL–boog	516	2.7
Homophone	PEIL–boog	539	5.1
Visual control	PAAL–boog	541	5.7
Net associate priming		25	
Net phonologically mediated priming		2	
	Pseudohomophones		
Associate	PALM–boom	523	1.4
Pseudohomophone	PALLEM–boom	528	6.4
Visual control	RALM–boom	545	7.4
Net associative priming		22	
Net phonologically mediated priming		17	

Discussion

The results of Experiment 3 fully agree with the predictions derived on the basis of the results found by Lukatela and Turvey (1994a) and Lesch and Pollatsek (1993). If primes are presented long enough for the spelling check to take place, then it is no longer possible to prime a target word with a homophone of the associate, although it is still possible to prime a target word with a pseudohomophone of the associate (see Table 3). The only deviating figure is that the error rate is higher after pseudohomophonic primes (6.4%) than after associate primes (1.4%).[2] This may have to do with the fact that nonword primes more easily evoke a nonword response than do word primes. In a lexical decision task, Klinger, Burton, and Pitts (2000) found that error rates to word targets were higher when the target was preceded by a nonword prime than when it was preceded by a word prime; the reverse was true for nonword targets. Klinger et al. interpreted this finding as evidence for the claim that priming stimuli elicit response tendencies that facilitate or compete with target-based responses. When prime- and target-response tendencies are congruent, responding is more accurate than when prime- and target-response tendencies are incongruent (see also Reynvoet, Caessens, & Brysbaert, 2002).

So far, we had found exactly the same phonologically mediated associative priming in the lexical decision task as in naming. This is interesting because there were no a priori reasons why lexical decision would require the same reliance on phonological information as does correct word naming. On the other hand, it could be argued that although the lexical decision tasks we used in Experiments 2 and 3 did not demand phonological recoding, they did not discourage it either. Because the nonwords differed from existing words both in letters and in sounds, it may have been interesting for the participants to address the phonological information, in order to speed up the decision process. As Brysbaert and Praet (1992) noted, evidence for automatic phonological coding of visually presented words can only be obtained under conditions that strongly discourage the use of phonology. This is what we looked at in the next experiment.

[2] These differences in errors between the pseudohomophone and the associate condition may complicate the interpretation of the RTs, because the RT in the pseudohomophone condition might differ from the RT in the associate condition if errors were equated in these conditions.

Experiment 4

The lexical decision task makes it possible to examine strategic effects in the use of phonology by making reliance on phonological information detrimental for good task performance. In Experiment 4 we examined to what extent the phonological priming effect found in the previous experiments is an automatic effect or can be strategically controlled by the reader. This was done by creating a condition in which the use of phonological information was detrimental for correct task performance. Two modifications were introduced to the design of Experiment 2. First, all legal nonhomophonic nonword targets were replaced by pseudohomophones, so that the word–nonword decision could no longer be based on differences in sound between both types of stimuli. In the past, strategic effects in the use of phonology have been reported with a 33% rate of pseudohomophones in the nonword trials (Ferrand & Grainger, 1996), but we wanted to make our test as strong as possible. The second change we introduced concerned the instructions given to the participants. In Experiment 4, participants were told in advance that they had to choose between words and nonwords that sounded like words, therefore they had to be very careful not to make a lot of mistakes. Because the type of nonwords and the instructions were the only aspects that changed between Experiment 2 and Experiment 4, any change in results must be due to strategic effects on the part of the participants.

Method

Participants. Participants were 42 first-year Ghent University students, who participated for course credits. All were native Dutch speakers.

Procedure. The 42 word trials were the same as in the previous experiments. The 42 nonword trials (see Appendixes E and F) were made by creating pseudohomophones of the associates given in the associate-generation study discussed in the introduction. Whenever possible, we used the most frequent associate given. However, on some occasions we had to go to the second most frequent (or in two cases the third most frequent) associate before we could find an acceptable pseudohomophone of the target word. Apart from the instructions (i.e., the warning that the nonwords sounded like real words), the procedure was exactly the same as in Experiment 2. In particular, this means that the primes were presented for 57 ms.

Results

The results of the nonwords were not analyzed. Response latencies below 100 ms and above 1,500 ms were discarded. This was the case for 5 out of 1,764 observations. Decision latencies and percentages of error as a function of stimulus list and prime type are presented in Table 4. Because error rates were very small they are reported only when there appeared to be a difference in error rates between the conditions.

For the list with homophones, there was a clear 26-ms effect of associate priming that was virtually the same as that in Experiment 2 (24 ms), giving rise to a significant effect of prime type, $F_1(2, 78) = 5.98$, $MSE = 2{,}098.14$; $F_2(2, 36) = 4.76$, $MSE = 1{,}388.36$. However, contrary to Experiment 2, the condition with homophones of the associate primes yielded the same decision latencies as the condition with control primes and differed significantly from the condition with true associate primes (Duncan's multiple range test at .05: F_1, Step 1 = 19.9, Step 2 = 20.9; F_2, Step 1 = 23.3, Step 2 = 24.5).

Table 4
Reaction Times (in ms) and Percentage Errors in Experiment 4

Prime type	Example	Reaction time	% errors
	Homophones		
Associate	PIJL–boog	576	1.4
Homophone	PEIL–boog	609	3.0
Visual control	PAAL–boog	602	2.3
Net associative priming		26	
Net phonologically mediated priming		−7	
	Pseudohomophones		
Associate	PALM–obom	569	1.4
Pseudohomophone	PALLEM–boom	574	2.4
Visual control	RALM–boom	600	1.7
Net associative priming		31	
Net phonologically mediated priming		26	

For the list with pseudohomophones, the pattern of results was an exact replica of those of Experiment 2: There was a 31-ms difference between associate primes and graphemic control primes (34 ms in Experiment 2), and there was a 26-ms difference between pseudohomophones of associate primes and graphemic controls (30 ms in Experiment 2), giving rise to a significant effect of prime type, $F_1(2, 78) = 5.42$, $MSE = 2{,}136.03$; $F_2(2, 36) = 6.26$, $MSE = 944.78$. In addition, the decision latencies after a pseudohomophone were the same as after a true associate prime and differed from those after a graphemic control prime (Duncan's multiple range test at .05: F_1, Step 1 = 20.1, Step 2 = 21.1; F_2, Step 1 = 19.2, Step 2 = 20.2).

Discussion

Experiment 4 was designed with two possible outcomes in mind. Either prelexical phonological priming was automatic, and then we would find the same pattern of results as in Experiment 2, or phonological priming was under strategic control, and then we would find no priming from homophones or pseudohomophones of the associates, because we encouraged the participants not to make use of phonological information. As it turned out, the results were a mixture of both predictions and patterned like the data of Experiment 3, in which a long prime-exposure duration was used. Phonological priming was observed with pseudohomophones but not with homophones of the associates. The implications of these findings for theories of phonological mediation in visual word recognition are discussed in the next section.

General Discussion

In recent years, a strong phonological model of visual word recognition has been promoted, according to which the orthographic stimulus is first translated into a partial phonological code that makes access to stored word information. Once the stored representation has been activated, additional information about the exact pronunciation and spelling becomes available. In such a view, prelexical phonological coding is mandatory, but the use of lexically supported phonology may be under strategic control (e.g., Berent, 1997; Berent & Perfetti, 1995; Frost, 1998; Gibbs & Van Orden, 1998; Xu & Perfetti, 1999).

Some of the evidence that word processing may be different in the very first, prelexical, stages than in the later, postlexical, stages comes from Lukatela and Turvey's (1994a) study. These authors reported priming with both homophones and pseudohomophones of associate primes at a prime-exposure time of 50 ms. However, at a prime-exposure duration of 250 ms, priming with homophones was no longer observed, even though it was still possible to prime target words with pseudohomophones of the associates. Lukatela and Turvey (1994a) explained this finding by assuming (a) automatic prelexical activation of phonology and (b) the existence of a lexically based spelling-verification process that could clean up ambiguities raised by the phonological code (Van Orden, 1987).

The present experiments were set up as a further test of the strong phonological model of visual word recognition. If prelexical phonology is mandatory, then it should be observed for all alphabetic languages (even those languages that frequently co-occur with knowledge of other languages that have conflicting letter-sound mappings) and for tasks other than word naming. In addition, if the recoding is not under strategic control, then traces of it must be found under conditions that strongly discourage the use of phonological information. By and large, all three predictions were confirmed. Lukatela and Turvey's (1994a) findings could be generalized to the Dutch language and to the lexical decision task, and priming with the pseudohomophone of an associate prime (i.e., the Dutch equivalent of *TODE–frog*) was observed in a word–pseudohomophone-decision task that strongly discouraged the reliance on phonology. The only result that deviated was the observation that we could not prime a word by a homophone of an associate in the word–pseudohomophone-decision task, even though prime-presentation time was limited to 57 ms (i.e., it was no longer possible to prime *frog* with *TOWED*, or more correctly, *boog* with *PEIL*; see Table 4).

To understand the significance of this finding, one must keep in mind that the absence of a phonological priming effect with homophones cannot be due to an absence of phonological mediation in visual word processing. The fact that we always found a priming effect with pseudohomophones of associates indicates (a) that in all our experiments phonological information was activated and (b) that the phonological code was assembled prelexically (cf. the pseudohomophone test of Humphreys et al., 1982). What seems to happen, however, is that an ambiguous phonological code (i.e., a code that is shared by more than one word) can rapidly be disambiguated on the basis of its spelling. This was already known for SOAs above 200 ms (Lesch & Pollatsek, 1993; Lukatela & Turvey, 1994a; Van Orden, 1987; see also Experiment 3 in the present study). Now, it has been shown for an SOA of 57 ms, at least when the task encourages the participants to pay particular attention to the orthographic information (see Experiment 4).

Our findings are in line with Lukatela and Turvey's (1994a) activation-verification model, which sees the phonological activation as an automatic, ballistic process followed by a lexically mediated verification stage in case more than one spelling corresponds to the activated phonological representation. Our findings raise, however, the questions of why the time course of the spelling check is not constant but seems to depend on the task at hand, and—maybe more important—what the default value of this time course is in normal reading. As for the first question, it is true that the pattern of results described in Table 4 surprised us at first. We had expected Table 4 to be more like Table 2 than like Table 3 (i.e., reliable phonologically mediated associative priming for both homophones and pseudohomophones). However, post hoc, the finding that a lexically mediated spelling check is under strategic control should not have amazed us that much. After all, strategic reliance on phonology because of characteristics of the words or the nonwords has been reported many times in the lexical decision task before (see Berent & Perfetti, 1995, for a review), even with masked priming. Ferrand and Grainger (1996) presented French target words preceded by form-related (instead of associatively related) masked primes (prime duration of 57 ms). The primes were either pseudohomophones of the targets (e.g., *foit–FOIE*), homophones (e.g., *fois–FOIE*), or unrelated control primes (e.g., *avec–FOIE*). Separate groups of participants saw the words presented in a list with illegal nonwords, legal nonwords, or pseudohomophones. Whereas the pseudohomophonic primes always had a facilitative effect, the effect of the homophonic primes depended on the nonwords in the list. It varied from being facilitative in the presence of orthographically legal nonwords, inhibitory in the presence of pseudohomophones, and null in the presence of illegal nonwords. Thus, just like in our study, Ferrand and Grainger's (1996) findings indicated that phonological information is always generated from a pronounceable string of letters, independent of list context, but that the ambiguity of this information can be rapidly canceled when the phonological code is shared by two known words.

The fact that participants can adapt their response criteria as a function of task demands and list context raises the question of what the default value of the spelling check is in normal reading: the value suggested by the 57-ms SOA in Experiment 4 or the 200-ms SOA from the naming task and the lexical decision with nonhomophonic nonwords. For various reasons, we are inclined to defend the former. The first reason is that it agrees with Lee et al.'s (1999) findings with the fast priming technique in text reading (see the introduction). With this technique, Lee et al. found facilitation effects of homophones for prime durations up to 35 ms but not longer. The second reason is that 35–57 ms seems a better estimate of the speed with which readers can extract orthographic information from homophones in reading. Brysbaert, Grondelaers, and Ratinckx (2000), for instance, started from the observation that in Dutch, morphological information about the tense of a verb is sometimes revealed by pairs of homophones (e.g., *zij verwachten* [*they expect*] vs. *zij verwachtten* [*they expected*][3]). They examined how readers deal with this kind of information and discovered that it only takes a few milliseconds longer to extract tense information from homophonic verb forms than from heterophonic control forms. They hypothesized that this could be due to a direct visual route from print to meaning or to the existence of a very rapid spelling check for these particular words (see also Daneman, Reingold, & Davidson, 1995; Jared, Levy, & Rayner, 1999). The present results provide evidence for the existence of such fast spelling verification for pairs of homophones. A final reason why the time course of 200 ms for the spelling check may not be the

[3] A similar phenomenon exists in French: *il joue* [*he plays*] versus *ils jouent* [*they play*].

default value in reading is that this value has been found in tasks in which the ambiguity of the phonological code did not have an adverse effect. Both in word naming and in lexical decision with nonhomophonic nonwords, the effects of phonology can be entirely facilitative, because the phonological information conveyed by the prime does not impede correct performance in the task but is supportive, even when it is ambiguous. In these tasks there are good reasons not to suppress activation that has begun on a phonological basis.

Therefore, what our results tell us is not that there is strategic control over the prelexical activation of phonology but that there may be some control over the rapidity to disambiguate this information. To explain why the disambiguation does not happen within 250 ms for pseudohomophones, Lukatela and Turvey (1994a) hypothesized that the spelling check only occurs when multiple spellings are activated by a phonological access code in the lexicon (see above). This is the explanation we have used as a working hypothesis, too. However, it may be good to keep in mind that other models of word recognition can also account for the different effects of pseudohomophones and homophones. This would be the case for models that postulate the existence of an orthographic input lexicon that interacts with the phonological lexicon (Ferrand & Grainger, 1996), or models that posit direct connections between orthographic codes and semantic features for known words (e.g., Farrar, Van Orden, & Hamouz, 2001; Gottlob, Goldinger, Stone, & Van Orden, 1999; Seidenberg & McClelland, 1989).

In summary, our findings are in line with a model of visual word processing that considers the first stages as automatic, ballistic processes, but accepts strategic influences after the input code makes contact to stored lexicosemantic information (see Brysbaert, Van Dyck, & Van de Poel, 1999, for converging evidence from bilingual word processing). Our data add further support to the strong phonological theory of visual word recognition, which claims that the stored lexicosemantic information requires a phonological access code. Finally, we provide evidence suggesting that previous studies on phonologically mediated associative priming may have overestimated the time required to disambiguate the phonological code of homophones, because these studies used tasks for which the ambiguity of the phonological code had no implications.

References

Baayen, R. H., Piepenbrock, R., & van Rijn. H. (1993). *The CELEX lexical database* (CD-ROM). Philadelphia, PA: Linguistic Data Consortium, University of Pennsylvania.

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

Berent, I., & Perfetti, C. A. (1995). A ROSE is a REEZ: The 2-cycles model of phonology assembly in reading English. *Psychological Review, 102,* 146–184.

Besner, D., Dennis, I., & Davelaar, E. (1985). Reading without phonology? *The Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 37*(A), 477–491.

Brysbaert, M. (2001). Prelexical phonological coding of visual words in Dutch: Automatic after all. *Memory & Cognition, 29,* 765–773.

Brysbaert, M. (in press). Bilingual visual word recognition: Evidence from masked phonological priming. In S. Kinoshita & S. J. Lupker (Eds.), *Masked priming: State-of-the-art*. Hove, UK: Psychology Press.

Brysbaert, M., Grondelaers, S., & Ratinckx, E. (2000). Sentence reading: Do we make use of orthographic cues in homophones? *Acta Psychologica, 105,* 35–56.

Brysbaert, M., & Mitchell, D. C. (1996). Modifier attachment in sentence parsing: Evidence from Dutch. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 49*(A), 664–695.

Brysbaert, M., & Praet, C. (1992). Reading isolated words: No evidence for automatic incorporation of the phonetic code. *Psychological Research, 54,* 91–102.

Brysbaert, M., Van Dyck, G., & Van de Poel, M. (1999). Visual word recognition in bilinguals: Evidence from masked phonological priming. *Journal of Experimental Psychology: Human Perception and Performance, 25,* 137–148.

Brysbaert, M., Vitu, F., & Schroyens, W. (1996). The right visual field advantage and the optimal viewing position effect: On the relation between foveal and parafoveal word recognition. *Neuropsychology, 10,* 385–395.

Coltheart, M. (1978). Lexical access in simple reading tasks. In G. Underwood (Ed.), *Strategies of information processing* (pp. 151–216). San Diego, CA: Academic Press.

Coltheart, M., Curtis, B., Atkins, P., & Haller, M. (1993). Models of reading aloud: Dual-route and parallel-distributed-processing approaches. *Psychological Review, 100,* 589–608.

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

Daneman, M., Reingold, E. M., & Davidson, M. (1995). Time course of phonological activation during reading: Evidence from eye fixations. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 884–898.

Farrar, W. T., IV, Van Orden, G. C., & Hamouz, V. (2001). When SOFA primes TOUCH: Interdependence of spelling, sound, and meaning in "semantically mediated" phonological priming. *Memory & Cognition, 29,* 530–539.

Ferrand, L., & Grainger, J. (1992). Phonology and orthography in visual word recognition: Evidence from masked non-word priming. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 45*(A), 353–372.

Ferrand, L., & Grainger, J. (1996). List context effects on masked phonological priming in the lexical decision task. *Psychonomic Bulletin & Review, 3,* 515–519.

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

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

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

Humphreys, G. W., & Evett, L. J. (1985). Are there independent lexical and nonlexical routes in word processing? An evaluation of the dual-route theory of reading. *Behavioral and Brain Sciences, 8,* 689–740.

Humphreys, G. W., Evett, L. J., & Taylor, D. E. (1982). Automatic phonological priming in visual word recognition. *Memory & Cognition, 10,* 576–590.

Jared, D., Levy, B. A., & Rayner, K. (1999). The role of phonology in the activation of word meanings during reading: Evidence from proofreading and eye movements. *Journal of Experimental Psychology: General, 128,* 219–264.

Klinger, M. R., Burton, P. C., & Pitts, G. S. (2000). Mechanisms of unconscious priming: I. Response competition, not spreading activation. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26,* 441–455.

Lee, H. M., Rayner, K., & Pollatsek, A. (1999). The time course of phonological, semantic, and orthographic coding in reading: Evidence from the fast-priming technique. *Psychonomic Bulletin & Review, 6,* 624–634.

Lesch, M. F., & Pollatsek, A. (1993). Automatic access of semantic information by phonological codes in visual word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19,* 285–294.

Lukatela, G., Lukatela, K., Carello, C., & Turvey, M. T. (1999). Effects of frequency and phonological ambiguity on naming Serbo-Croatian words. *European Journal of Cognitive Psychology, 11,* 1–16.

Lukatela, G., & Turvey, M. T. (1994a). Visual access is initially phonological: 1. Evidence from associative priming by words, homophones, and pseudohomophones. *Journal of Experimental Psychology: General, 123,* 107–128.

Lukatela, G., & Turvey, M. T. (1994b). Visual access is initially phonological: 2. Evidence from phonological priming by homophones and pseudohomophones. *Journal of Experimental Psychology: General, 123,* 331–353.

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

Perfetti, C. A., Bell, L., & Delaney, S. (1988). Automatic phonetic activation in silent word reading: Evidence from backward masking. *Journal of Memory and Language, 27,* 59–70.

Pollatsek, A., Lesch, M., Morris, R. K., & Rayner, K. (1992). Phonological codes are used in integrating information across saccades in word identification and reading. *Journal of Experimental Psychology: Human Perception and Performance, 18,* 148–162.

Pollatsek, A., & Well, A. D. (1995). On the use of counterbalanced designs in cognitive research: A suggestion for a better and more powerful analysis. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 785–794.

Reynvoet, B., Caessens, B., & Brysbaert, M. (2002). Automatic stimulus-response associations may be semantically mediated. *Psychonomic Bulletin & Review, 9,* 107–112.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review, 96,* 523–568.

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

Xu, B., & Perfetti, C. A. (1999). Nonstrategic subjective threshold effects in phonemic masking. *Memory & Cognition, 27,* 26–36.

Appendix A

Word Stimuli Used in Experiments 1–4 to Examine Homophonic Priming

Target	Target's associate	Homophone of the associate	Graphemic control word
liefde (170)	HART (190)	HARD (230)	HARS (5)
boog (46)	PIJL (16)	PEIL (13)	PAAL (17)
riool (3)	RAT (23)	RAD (8)	RAS (25)
vlees (81)	RAUW (21)	ROUW (6)	BOUW (21)
zee (143)	KRAB (3)	KRAP (5)	KRAT (4)
berg (55)	STEIL (23)	STIJL (49)	STIJF (39)
stof (6)	LAP (13)	LAB (3)	LAF (10)
jas (49)	BONT (16)	BOND (20)	BONS (0)
muziek (115)	NOOT (19)	NOOD (31)	POOT (0)
drugs (13)	HIGH (5)	HAAI (3)	HOME (4)
koud (137)	IJS (28)	EIS (81)	LES (32)
brood (70)	RIJZEN (38)	REIZEN (37)	REIKEN (36)
been (178)	BOT (19)	BOD (9)	BOM (23)
onderbroek (8)	SLIP (4)	SLIB (1)	SLOP (2)
vis (73)	GRAAT (2)	GRAAD (31)	GRAAN (12)
baby (79)	SLAB (0)	SLAP (27)	SLAK (5)
rechts (41)	LINKS (91)	LYNX (1)	LANS (5)
boek (387)	LEZER (67)	LASER (1)	LEVER (13)
zacht (195)	MILD (21)	MILT (2)	MIME (0)
gras (62)	WEI (11)	WIJ (1,115)	WAS (0)
pijn (153)	LIJDER (3)	LEIDER (71)	LADDER (14)

Note. Values in parentheses are frequencies per million (Baayen, Piepenbrock, & van Rijn, 1993).

Appendix B

Word Stimuli Used in Experiments 1–4 to Examine Pseudohomophonic Priming

Target	Target's associate	Pseudohomophone of the associate	Graphemic control nonword
hand (1,028)	ARM (187)	ARREM	ARS
sneeuw (39)	BERG (55)	BERCH	BERS
warm (158)	JAS (49)	IAS	VAS
nacht (266)	DAG (935)	DACH	DAP
goed (1,877)	SLECHT (188)	SLEGT	SLEPT
meisje (357)	DOCHTER (120)	DOGTER	DOPTER
kerk (205)	PAUS (27)	POUS	PEUS
naald (16)	DRAAD (28)	DRAAT	DRAAS
boom (137)	PALM (14)	PALLEM	RALM
man (1,196)	VROUW (900)	VRAUW	VREUW
bord (64)	KRIJT (6)	KREIT	KRAAT
druk (97)	STAD (323)	STAT	STAS
strand (51)	ZAND (56)	ZANT	ZANK
peper (16)	ZOUT (11)	ZAUT	ZUUT
plakken (23)	LIJM (7)	LEIM	LAAM
kind (961)	STOUT (8)	STAUT	STUUT
rook (37)	PIJP (25)	PEIP	POUP
appel (17)	VRUCHT (39)	WRUCHT	KRUCHT
recht (232)	LIJN (104)	LEIN	LOEN
wind (111)	STORM (23)	STORREM	STORS
wit (306)	TAND (89)	TANT	TANS

Note. Values in parentheses are frequencies per million (Baayen, Piepenbrock, & van Rijn, 1993).

Appendix C

Nonword Trials Used in Experiments 2 and 3 Based on Homophonic Base Stimuli

Target (and original word)	Target's associate	Homophone of the associate	Graphemic control word
lijs (vijs)	BOUT	BOUD	MOUT
laby (baby)	DOOP	DOPE	DOOF
brus (brug)	PONT	POND	PAND
hons (hond)	PUP	PUB	PUL
oten (eten)	KOOK	COKE	KOER
lout (fout)	MIS	MISS	MIME
tagel (nagel)	VIJL	VEIL	VETO
nater (water)	POEL	POULE	DOEL
zwaak (zwaar)	LOOD	LOOT	LOOM
kanan (kanon)	KRUIT	KRUID	KRUIS
grak (gras)	WEIDEN	WIJDEN	WANDEN
hoom (hooi)	MIJT	MEID	MAAT
bif (bij)	RAAT	RAAD	RAAM
pout (post)	MAIL	MEEL	MUIL
kokker (kikker)	PAD	PAT	PAK
lamaai (lawaai)	LUID	LUIT	LUIS
wos (bos)	EIK	IJK	PAK
dif (dik)	KONT	KOND	KOOI
il (ik)	MIJ	MEI	MOS
eilang (eiland)	WAD	WAT	WAL
kos (koe)	WEIDE	WIJDE	WOEDE

Appendix D

Nonword Trials Used in Experiments 2 and 3 Based on Pseudohomophonic Base Stimuli

Target (and original word)	Target's associate	Pseudohomophone of the associate	Graphemic control nonword
bielen (wielen)	AUTO	OUTO	EUTO
roning (honing)	BIJ	BEI	BOG
nak (dak)	HUIS	HUYS	HURS
petter (letter)	CIJFER	SIJFER	PIJVER
mistruik (misbruik)	MACHT	MAGT	MART
goel (geel)	KAAS	CAAS	TAAS
knoos (knoop)	HEMD	HEMT	HEMP
belukkig (gelukkig)	BLIJ	BLEI	BLAS
vuik (buik)	DARM	DARREM	DARP
diek (dier)	HOND	HONT	HONS
zeek (zeep)	SOP	SOB	KOB
paten (pater)	PIJ	PEI	POE
zol (zon)	KUST	KUSD	KUSP
teeuw (leeuw)	TIJGER	TEIGER	TROGER
krui (trui)	MOUW	MAUW	MEUW
staas (staal)	IJZER	EIZER	BEZER
trakken (trekken)	TOUW	TAUW	TEUW
moos (roos)	ZALM	ZALLEM	ZALK
voem (voet)	KOUS	KAUS	ROUS
baam (baan)	WEG	WECH	WER
oken (oren)	KONIJN	KONEIN	KONKEN

Appendix E

Pseudohomophonic Nonword Trials Used in Experiment 4 Based on Homophonic Base Stimuli

Target (and original word)	Target's associate	Homophone of the associate	Graphemic control word
veis (vijs)	BOUT	BOUD	MOUT
babie (baby)	DOOP	DOPE	DOOF
bruch (brug)	PONT	POND	PAND
hont (hond)	PUP	PUB	PUL
eeten (eten)	KOOK	COKE	KOER
faut (fout)	MIS	MISS	MIME
nachel (nagel)	VIJL	VEIL	VETO
watur (water)	POEL	POULE	DOEL
zwaer (zwaar)	LOOD	LOOT	LOOM
kannon (kanon)	KRUIT	KRUID	KRUIS
chras (gras)	WEIDEN	WIJDEN	WANDEN
hooj (hooi)	MIJT	MEID	MAAT
bei (bij)	RAAT	RAAD	RAAM
posd (post)	MAIL	MEEL	MUIL
kicker (kikker)	PAD	PAT	PAK
lawaaj (lawaai)	LUID	LUIT	LUIS
blat (blad)	EIK	IJK	PAK
gad (gat)	KONT	KOND	KOOI
zelv (zelf)	MIJ	MEI	MOS
eilant (eiland)	WAD	WAT	WAL
coe (koe)	WEIDE	WIJDE	WOEDE

Appendix F

Pseudohomophonic Nonword Trials Used in Experiment 4 Based on Pseudohomophonic Base Stimuli

Target (and original word)	Target's associate	Pseudohomophone of the associate	Graphemic control nonword
reiden (rijden)	AUTO	OUTO	EUTO
hooning (honing)	BIJ	BEI	BOG
dack (dak)	HUIS	HUYS	HURS
lettur (letter)	CIJFER	SIJFER	PIJVER
misbruyk (misbruik)	MACHT	MAGT	MART
cheel (geel)	KAAS	CAAS	TAAS
knoob (knoop)	HEMD	HEMT	HEMP
gelukkich (gelukkig)	BLIJ	BLEI	BLAS
buyk (buik)	DARM	DARREM	DARP
kad (kat)	HOND	HONT	HONS
zeeb (zeep)	SOP	SOB	KOB
patur (pater)	PIJ	PEI	POE
zant (zand)	KUST	KUSD	KUSP
leew (leeuw)	TIJGER	TEIGER	TROGER
truy (trui)	MOUW	MAUW	MEUW
stael (staal)	IJZER	EIZER	BEZER
trecken (trekken)	TOUW	TAUW	TEUW
lekkur (lekker)	ZALM	ZALLEM	ZALK
sgoen (schoen)	KOUS	KAUS	ROUS
straad (straat)	WEG	WECH	WER
ooren (oren)	KONIJN	KONEIN	KONKEN

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