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Prelexical phonological coding of visual words in Dutch: Automatic after all

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This paper addresses a previous claim (Brysbaert & Praet, 1992) that the use of prelexical phonology in visual word recognition is optional in the Dutch language. One backward masking experiment and two masked priming experiments are reported. The experimental task was perceptual identification. Pseudohomophones, graphemic controls, and unrelated controls of the target words were used as masks or primes. The main findings were (1) unlike previous claims, the pseudohomophone effect is not strategic in Dutch, but (2) the effect is more clearly obtained with the masked priming procedure than with the backward masking procedure.

It is becoming increasingly clear that phonology plays a substantial role in visual word recognition. Researchers no longer discuss whether phonology is involved or not, but whether the phonologically mediated route is the only one that matters in visual word recognition (e.g., Berent & Perfetti, 1995; Frost, 1998; Van Orden, Pennington, & Stone, 1990), or whether there is still enough evidence for a dual-route theory with a direct visual pathway from input to meaning (e.g., Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Jared, Levy, & Rayner, 1999; Plaut, McClelland, Seidenberg, & Patterson, 1996). The former group of researchers claim that all evidence against phonological mediation is based on null effects (i.e., the absence of phonological influences); the latter group points to the existence of patterns of results that are hard to explain within a phonology-only view.

One of the arguments given by the proponents of the dual-route theory is that the reliance on phonology in visual word processing seems to depend on the characteristics of the task. Already from the very first formulations of the dual-route theory (Coltheart, 1978), it was assumed that readers could control the weight given to one or the other pathway, and subsequently researchers have demonstrated strategic phonological effects in a whole series of word processing tasks. In lexical decision, they have shown that participants rely less on phonology when (a lot of) pseudohomophones are included in the nonword trials (e.g., McQuade, 1981; Milota, Widau, McMickell, Juola, & Simpson, 1997) or when homophones are presented in the word trials (Underwood, Roberts, & Thomason, 1988). For instance, McQuade showed that participants took longer to reject pseudohomophones (e.g., BRANE) than control nonwords (BRANT), but only when a small percentage of the nonwords were pseudohomophones. Similarly, in word naming, it has been argued that participants can be encouraged to rely more on nonlexical, assembled phonology by including many nonwords in the stimulus list and more on lexically derived, addressed phonology by including many irregular words in the stimulus list. So, Monsell, Graham, Hughes, Patterson, and Milroy (1992) reported a larger word frequency effect in the context of irregular words than in the context of nonwords, although the interpretation of this finding is strongly debated (see Zevin & Balota, 2000, for a review). Finally, Hawkins, Reicher, Rogers, and Peterson (1976) reported strategic reliance on phonology in the word identification paradigm. They gave participants forced choices concerning the identity of a tachistoscopically presented and masked word. These choices were either homophones (e.g., SENT, CENT) or orthographically matched nonhomophonic words (SOLD, COLD). Performance was impaired on trials with homophonic choice pairs, but only when a low proportion of homophones was used, not when the list contained a lot of these pairs, presumably because this discouraged the use of phonology.

Proponents of the phonology-only view have argued that the strategic effects presented in the preceding paragraph may be due to reliance on addressed phonology and say little about prelexical phonology assembly (Berent & Perfetti, 1995; Frost, 1998). Berent and Perfetti, for instance, put forward the hypothesis that, in English, lexical representations are mainly activated on the basis of consonant information. This phonological information would be computed rapidly and automatically in a first cycle, whereas the computation of the missing vowel information is slower, under strategic control, and possibly lexically mediated. Although Berent and Perfetti's distinction between consonants and vowels has been called into

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question (Lukatela & Turvey, 2000; Perry & Ziegler, in press), the basic idea that lexical access may be based on an impoverished phonological code has remained (Frost, 1998). The theory, then, is that the partial phonological code on which lexical access is based, is automatically activated and can subsequently be completed on the basis of lexical information. This view predicts automatic phonological effects in tasks that adequately measure the prelexical processes, together with strategic effects when tasks require a richer phonological code.

The most frequently used paradigms to investigate prelexical phonology assembly are the backward masking procedure and the masked priming procedure. Perfetti, Bell, and Delaney (1988) showed the existence of a pseudohomophone effect in backward masking. In this paradigm, a briefly presented target word is followed by a briefly presented nonword, the mask. The participant's task is to identify the target. The target is presented so briefly that the mask interferes with the processing of the target. However, interference depends on the relationship between target and mask: The greater the similarity among target and mask, the smaller the disruption caused by the mask. This reasoning made Perfetti et al. wonder whether a target word like "blue" would be recognized more often when it is followed by a homophonic mask (BLOO) than when it is followed by a graphemic control mask (BLOS) that shares the same number of letters with the target as the homophonic mask, but not the same number of phonemes. They indeed found such a pseudohomophone effect. Gronau and Frost (1997) reported a similar effect in Hebrew, but only when the phonological changes introduced by the graphemic control mask were large (i.e., the target word *kapit* was not recognized more often when it was followed by a homophonic mask than when it was followed by the graphemic control mask *kapiz*, but there was a difference with the graphemic control mask pronounced as *kapezet*). Gronau and Frost suggested that this was also true for Perfetti et al.'s stimuli (i.e., the phonemic difference between BLOO and BLOS is not limited to the vowel; there is an additional consonant in the graphemic control). Tan, Hoosain, and Peng (1995) replicated the homophonic effect in Chinese, but they had to use slightly longer exposure durations than they would in English. Finally, Lukatela and Turvey (1990) replicated the effect in Serbo-Croatian.

Perfetti and Bell (1991) extended the findings of the backward masking paradigm to the masked priming paradigm. In this procedure, the homophonic or the graphemic nonword does not follow the target but precedes it. Provided the exposure duration of the prime is longer than 40 msec, a homophonic effect can be shown with this paradigm as well. Again, there is evidence that the phonological distortion introduced by the graphemic control prime must be large enough to obtain the effect. Davis, Castles, and Iakovidis (1998) failed to obtain a pseudohomophone effect in English with pairs of homophones and graphemic controls that differed in only one phoneme (usually the vowel). Grainger and Ferrand (1996) replicated the pseudohomophone effect in French. Shen and Forster (1999) replicated it in Chinese, but only when targets had to be named, not when a lexical decision had to be made.

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, some 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 phonological information), she still obtained faster decision times after homophonic primes than after graphemic control primes (indicating that prelexical phonology assembly did matter in the task).

In summary, the prevailing strong phonological theory of visual word recognition states that some form of partial phonological information is mandatory in the activation of a word's lexico-semantic information and that the use of this information can be revealed with the backward masking paradigm and the masked priming paradigm. Two studies, however, provide difficulties for this strong view. Brysbaert and Praet (1992) used the backward masking technique in Dutch and failed to obtain the pseudohomophone effect when they included filler trials so that in the majority of trials the target word was followed by an unrelated mask (i.e., a mask that did not share any letter with the target). Under these circumstances, both homophonic and graphemic masks resulted in a recognition rate of 68%. Only when the filler trials were changed so that the majority of trials consisted of a target word followed by a homophonic mask, did the pseudohomophone effect emerge (77% correct target recognition in the homophonic condition vs. 68% in the graphemic condition). On the basis of this pattern of results, Brysbaert and Praet challenged the automatic nature of phonological coding in visual word recognition and claimed that phonological information was used only when it was advantageous for the overall performance. Verstaen, Humphreys, Olson, and d'Ydewalle (1995) reported a similar strategic effect in English by using homophones as target stimuli (see Hawkins et al., 1976, discussed above). They showed that the pseudohomophone effect in backward masking is eliminated if a high proportion of the (filler) trials consists of target words that are homophones, so that reliance on phonology is detrimental for correct target identification.

Because participants in Verstaen et al.'s (1995) experiments were aware of the fact that a lot of the target words were homophones, many authors have considered this strategic effect as one that is comparable to the strategic effects in naming and lexical decision, the more so because the dependent variable (percentage correct target identification) did not allow on-line measurement of word processing (see, e.g., Xu & Perfetti, 1999).

More criticisms have been raised against Brysbaert and Praet's (1992) findings. Berent and Perfetti (1995) mentioned two problems. First, they pointed out that Brysbaert and Praet failed to replicate the normal English pseudohomophone effect in Dutch with 33% homophonic masks (maybe because of the poor quality of the stimulus materials). Second, Berent and Perfetti argued that the participants may have partly ignored the masks in the condition with a lot of unrelated masks (a criticism repeated by Ferrand, 1995). Two more criticisms were added by Xu and Perfetti (1999). First, they pointed out that the percentage of target recognition in the unrelated control condition was rather high in Brysbaert and Praet's experiments (more than 50%). In their own studies, the largest pseudohomophone effect was found for presentation durations that resulted in about 45% target identification in the unrelated control condition (see their Figure 2). Second, and most importantly, Xu and Perfetti failed to replicate Brysbaert and Praet's finding in English: They found a significant 6.7% advantage of homophonic masks over graphemic control masks in conditions that included less than 20% trials with pseudohomophone masks.

Two reasons may be given for the discrepancy between the English and Dutch data. The first is methodological and has to do with the quality of the Brysbaert and Praet (1992) stimuli. Unlike the English materials, these stimuli had not been validated in a naming and a lexical decision task and, therefore, may have been of inferior quality. The second reason is theoretical and says that, for some variable, strategic control over the phonological route is more pronounced in Dutch than in English. Zevin and Balota (2000) noted an analogous phenomenon when they reviewed the literature on word naming and saw that the more powerful demonstrations of attentional control of processing pathways in word naming have been obtained in orthographies other than English (e.g., Farsi, Korean, and Turkish). Zevin and Balota attributed this to the shallower orthography of the non-English languages (i.e., they all have more straightforward letter–sound correspondences than does English), but an alternative explanation might be that strategic reliance on prelexical phonology is more often present in small language communities, in which most inhabitants read more than one language. Very little is known about phonological coding in nonnative languages (see Brysbaert, Van Dyck, & Van de Poel, 1999), but many of these language pairs have conflicting grapheme–phoneme correspondences. So, the reason why Dutch speakers may have more control about the use of their processing pathways is that they quite often read English, French, and German texts: languages with different pronunciations of the same letters.

To further examine the issue of mandatory prelexical coding in Dutch, we made use of a validated stimulus list assembled by Verstaen, Gielen, Brysbaert, and d'Ydewalle (1993). In Experiment 1, these stimuli were presented in a backward masking experiment. In Experiments 2 and 3, the masked priming technique was used.

EXPERIMENT 1

Experiment 1 is a replication of Brysbaert and Praet (1992, Experiment 3) with better controlled stimuli to verify whether reliance on phonology in the backward masking paradigm is indeed strategic in Dutch. Target words were followed by pseudohomophone masks (e.g., *oud* [old]–AUT), graphemic control masks (*oud*–ZUM), or unrelated control masks (*oud*–ZIM). Filler trials were used to limit the number of homophonic trials to either 10/150 (6.7%), or to increase it up to 110/150 (73.3%).

Method

Participants. Participants were 80 first-year university students, who participated for course credit. All were native speakers of Dutch.

Stimulus materials. Stimulus materials were 100 target words (ranging from three to seven letters) with three masks, assembled and validated by Verstaen et al. (1993). One of these masks was a pseudohomophone, one was a graphemic control that shared the same number of letters with the target word, and one was an unrelated control mask that had no letters in common with the target word (e.g., *oud* [old]—AUT, ZUM, ZIM; or *cyclus* [cycle]—SICLUS, VACLUS, VARBEM; see Verstaen et al., 1993, for a complete list of the stimuli). Efforts were made to build graphemic controls that differed from the targets on more than one phoneme (see Davis et al., 1998, and Gronau & Frost, 1997), although this was only possible for 38 of the stimuli. Also, efforts were made to use a wide range of possible ways to create pseudohomophones (in Brysbaert & Praet, 1992, many pseudohomophones were created by changing a limited number of first or last letters). The masks were matched on bigram frequency and on Coltheart's N (i.e., the number of words that could be created by changing one letter of the nonword). In addition, the masks had been presented in a naming task with 42 participants to ensure that they were read correctly and that one type of mask did not require more processing time than the other (mean naming times were 624 msec for the pseudohomophones, 628 msec for the graphemic controls, and 637 msec for the unrelated controls).[1] Finally, the masks yielded the normal pseudohomophone effect in a lexical decision task with 42 participants (RT pseudohomophones = 866 msec; RT graphemic controls = 821 msec; RT unrelated controls = 786 msec; see Verstaen et al. for details).

A potential problem with the backward masking paradigm is that the results may be distorted because participants were able to guess the target on the basis of information they managed to extract from the mask (Brysbaert & Praet, 1992; Perfetti et al., 1988; Perry & Ziegler, in press). So, it could be that the word *oud* is reported more often when it is followed by the pseudohomophonic mask AUT than by the graphemic control mask ZUM, not because the pseudohomophonic mask interferes less with the processing of the target, but because the target has more chances of being guessed on the basis of the nonword AUT than on the basis of the nonword ZUM. Two precautions are usually taken to control for this possibility: First, participants are asked what they saw of the mask, and second, the masks are additionally paired with another word to see how much mask-related target guessing occurs under these circumstances. So, in the present experiment, the masks AUT and ZUM were paired not only with the base word *oud*, but also with the unrelated word *laf* [cowardly] to find out how often participants would report having seen the word *oud* in these conditions. The unrelated words had no letters in common with the base word and were of the same frequency and length. Because of the different types of masks and the fact that the pseudohomophonic and graphemic masks were paired with an unrelated word, there were five versions of each item, namely *oud*–AUT, *oud*–ZUM, *oud*–ZIM, *laf*–AUT, and *laf*–ZUM.

Table 1
Percentage Target Word Recognition as a Function of Mask Type and Filler Context (Phonology Encouraging or Discouraging). Data From Experiment 1

	Homophone	Grapheme Control	Unrelated Control
Base words	(*oud*–AUT)	(*oud*–ZUM)	(*oud*–ZIM)
Encouraging	73.7	71.2	53.0
Discouraging	66.5	70.0	53.2
Unrelated words	(*laf*–AUT)	(*laf*–ZUM)	
Encouraging	35.7	42.0	
Discouraging	35.2	40.0	

Each participant received 10 test items per experimental condition. This was because the five different versions of an item were distributed over participants, so that each participant saw only one version per item (according to a latin-square design). In addition, because it was difficult to manipulate the percentage of pseudohomophonic trials with the complete list of 100 items, the list had been divided into two sets of 50 test items, and each participant saw only one set in the experimental conditions. The alternate set of 50 items was used as filler material, together with 50 other filler items, so that each participant received 50 critical items among 100 filler items. Finally, 30 practice items were created that shared the same characteristics as the test and the filler items. The filler and practice items were paired with a pseudohomophonic mask in the phonology encouraging condition and with an unrelated mask in the phonology discouraging condition, so that, in the latter condition, only 10/150 target words were followed by a pseudohomophonic mask, against 110/150 in the former condition.

Procedure. Participants were divided into four groups of 20 persons each. In Groups 1 and 2, the first set of 50 items of the Verstaen et al. (1993) list was used as experimental stimuli; in Groups 3 and 4, the second set was used. Groups 1 and 3 formed the phonology encouraging condition, Groups 2 and 4 the phonology discouraging condition (see also Brysbaert & Praet, 1992, Experiment 3).

Participants were run individually. Stimuli were displayed in white against a black background. Target words were presented in lowercase, masks in uppercase. Participants were told about the presence of two stimuli presented one after the other: a word and a nonword. A row of 7 *X*s served as the fixation region. Participants were asked to fixate the second *X*, which was marked by a short vertical line above and below it. Previous research has shown that the second letter is the optimal viewing position for recognizing short words in Dutch (Brysbaert, Vitu, & Schroyens, 1996). Participants initiated a trial by pressing on the space bar; 500 msec later the row of *X*s was replaced by the target word for 50 msec and by the mask for 33 msec (without an interstimulus interval). Immediately after the mask, the row of seven *X*s appeared again. Stimulus presentation was synchronized with the vertical retrace (a VGA card with 60-Hz resolution was used). The task of the participants was to identify the first word and to type it in. They were also asked if they remembered anything about the second stimulus, the nonword, and if so, to type that in as well. To avoid confusion between both stimuli, the computer first asked "What was the first word?" and, only after the participant had entered the response, went on with the question "What was the second stimulus?" The experiment started with 30 practice trials, presented with a gradually decreasing presentation time from twice the experimental presentation duration till the intended presentation time. After the practice trials, participants received feedback about the number of words they had successfully identified (no feedback was given about the masks, because recognition was too low). Thereafter, a random permutation of the 50 test trials together with the 100 filler trials was presented, again followed by information about the total number of words recognized.

Results

Table 1 shows the percentages of words recognized as a function of mask type, word–mask relationship, and filler context (phonology encouraging vs. discouraging). The two conditions with unrelated words (i.e., *laf*–AUT and *laf*–ZUM) were analyzed first to find out to what extent the results were influenced by mask-related target guessing. Of all $80 \times 10 = 800$ trials with homophonic masks, only two occurrences of base word reporting were found (i.e., the participant typed in the target word *oud* after having seen *laf*–AUT). Two further base word reportings occurred in the 800 trials with graphemic control masks (i.e., of the type *laf*–ZUM). The mask itself was reported six times on a total of $80 \times 50 = 4{,}000$ trials. Four of these masks were graphemic control masks, two were pseudohomophonic masks. These checks ensured that any pseudohomophone effect is unlikely to be caused by deliberate guessing on the part of the participants.

Another interesting finding in the conditions with the unrelated words is that the words were identified more often when they were followed by a graphemic control mask (41%) than when they were followed by a pseudohomophonic mask (35%; see Table 1). That is, participants were more likely to identify the word *laf* in the stimulus pairing *laf*–ZUM than in the pairing *laf*–AUT [$F_1(1,78) = 6.76$, $MS_e = 179.1$; $F_2(1,99) = 7.08$, $MS_e = 427.1$; in all analyses, a conventional alpha level of .05 is used unless noted otherwise]. The filler context did not have a main effect [$F_1(1,78) < 1$, $MS_e = 410.9$; $F_2(1,99) < 1$, $MS_e = 323.5$], nor did it interact with mask type [$F_1(1,78) < 1$, $MS_e = 179.1$; $F_2(1,99) < 1$, $MS_e = 362.4$].

For the conditions with the base words, the effect of mask type was reliable [$F_1(2,156) = 52.58$, $MS_e = 151.0$; $F_2(2,198) = 30.02$, $MS_e = 661.2$]. Filler context had no main effect [$F_1(1,78) < 1$, $MS_e = 700.6$; $F_2(1,99) = 3.08$, $MS_e = 368.4$] and did not interact with mask type [$F_1(2,156) = 2.09$, $MS_e = 151.0$; $F_2(2,198) = 2.31$, $MS_e = 340.3$]. The effect of mask type was entirely due to the unrelated control condition. If the analysis is limited to the homophonic and the graphemic control conditions, there is no effect of mask type anymore [$F_1(1,78) < 1$, $MS_e = 152.9$; $F_2(1,99) < 1$, $MS_e = 545.8$]. Although there was a trend towards an interaction between mask type and filler context in this analysis, it failed to reach significance [$F_1(1,78) = 2.35$, $MS_e = 152.9$; $F_2(1,99) = 2.59$, $MS_e = 347.6$].

Filler-item recognition was 72.5% in the phonology encouraging condition (when fillers were followed by pseudohomophone masks) and 48.5% in the phonology discouraging condition (when fillers were followed by unrelated masks). These percentages did not differ significantly as a function of the stimulus set used for half of the fillers.

To test Xu and Perfetti's (1999) hypothesis that the pseudohomophone effect depends on the number of target words recognized, we split the group of participants as a function of their scores on the trials with no overlap between target and mask (i.e., the conditions *oud*–ZIM, *laf*–AUT, and *laf*–ZUM). The 8 participants with a score of 20% or less showed a pseudohomophone effect of 0.0%, the 27 participants with a score between 21% and 40% had a pseudohomophone effect of 3.7%, the 38 participants with a score between 41% and 60% had a pseudohomophone effect of −2.9%, and the 7 participants with a score above 60% showed a pseudohomophone effect of −4.3%. That is, just like Xu and Perfetti, we found some evidence that the pseudohomophone effect in the masked priming paradigm is largest when in the unrelated conditions some 20% to 40% of the target words are recognized, although the pattern in the present experiment must be regarded with considerable caution [interaction mask type × score: $F_1(3,76) < 1$, $MS_e = 156.5$].

To test Gronau and Frost's (1997) suggestion that the pseudohomophone effect in the backward masking paradigm can only be obtained when the phonemic representations of the target and the graphemic mask differ in more than a single phoneme, we divided the items into a set of 62 items with one mismatching phoneme and a set of 38 items with two mismatching phonemes. The pseudohomophone effect was −3.7% for the former set (68.1% vs. 71.8% target identification in the homophonic and the graphemic control condition) versus 4.7% for the latter set (73.4% vs. 68.7% target identification). The interaction between item set and mask type approached significance [$F_2(1,98) = 2.99$, $MS_e = 535.1$, $p < .09$].[2]

Discussion

The main finding of Experiment 1 was that even though a carefully designed list of 100 stimuli was used, it was not possible to obtain a pseudohomophonic effect with the backward masking paradigm in Dutch. The construction of better controlled stimuli with more variation in the way pseudohomophones were created did not result in a stronger effect than the one reported by Brysbaert and Praet (1992), but in the disappearance of the single reliable effect Brysbaert and Praet found. Even when the majority of the masks were pseudohomophones, the pseudohomophone effect was absent. Needless to say, the absence of an effect in the most felicitous condition makes it pointless to look for context effects due to the characteristics of the filler trials.

It may be tempting to interpret the absence of a pseudohomophone effect as evidence against the existence of prelexical phonology assembly in Dutch, as was done by Brysbaert and Praet (1992). However, before accepting this null hypothesis, it may be interesting to look at what has since been discovered about the power of the backward masking paradigm to reveal the pseudohomophonic effect. For a start, the effect in English is rather modest and usually hinges around 5% (Perfetti & Bell, 1991; Perfetti et al., 1988; Xu & Perfetti, 1999), despite the fact that the difference in phonemic representation between the pseudohomophonic masks and the graphemic control masks can be made larger than in Dutch (Gronau & Frost, 1997) and the fact that stimulus presentation durations have been optimized (Xu & Perfetti, 1999). On the basis of the post-hoc analyses of the data of Experiment 1, it looks like one may find an equivalent effect in Dutch under similar optimized conditions. In addition, there is the (ironic) finding that pseudohomophonic masks interfered more with the processing of unrelated target words than did the graphemic control masks (see Table 1).

A dilemma at this point is that it may not be a good idea to limit the Dutch pseudohomophonic masks to those instances that allow for the change of a double phoneme, as these are very limited in number. They mainly involve the diphthongs *ei/ij* and *ou/au* (*kei*–KIJ–KIG, *fout*–FAUT–FEUT), the letter *x* (*taxi*–TAKSI–TANNI), the ending *-ch* (*zich*–ZIG–ZIRF), the ending *-tie* (*optie*–OBSIE–OKRIE), and loan words from other languages (*chef*–SJEF–VLEF). The main reason for this limited choice is that the grapheme–phoneme correspondences are more straightforward in Dutch than in English or Hebrew (see Van den Bosch, Content, Daelemans, & De Gelder, 1994, for a quantitative estimate of the orthographic depth in English and Dutch).

Therefore, rather than trying to improve the backward masking design, we decided to turn to the masked priming paradigm, which on the basis of the current literature looked like a slightly more powerful technique to reveal prelexical phonological coding. Perfetti and Bell (1991) reported a maximal priming effect of 10% with this technique, against a maximal backward masking effect of 5% with the same stimuli. Grainger and Ferrand (1996) even obtained a phonological priming effect of 17% with French four-letter words of which the graphemic prime differed in all phonemes except for the first (see also Brysbaert et al., 1999, Experiment 2). In addition, the priming procedure may be more interesting than the backward masking procedure, because it allows more freedom of presentation (e.g., in some studies, a backward pattern mask is inserted between the prime and the target, so that the prime is presented for a short period of time, but still has a longer time to build up its influence; also, the experimental task can be lexical decision or naming instead of perceptual identification). For these reasons, in the next two experiments, the backward masking paradigm was replaced by the masked priming paradigm.

EXPERIMENT 2

In Experiment 2, the stimuli of Experiment 1 were used in a masked priming task. Perfetti and Bell (1991) were the first to report a pseudohomophone effect with nonword primes on the basis of this paradigm. They also showed that the prime must be presented for at least 40 msec in order to obtain a phonemic effect. Ferrand and Grainger (1993; see also Grainger & Ferrand, 1996) replicated the effect in French: They did not find a reliable pseudohomophone effect with a prime exposure duration of 33 msec, but did find one with prime exposure durations of 50 and 67 msec. In this experiment, we compared prime presentation times of 29 and 43 msec. We predicted that we would not find a pseudohomophone effect at 29 msec, but would at 43 msec.

Table 2
Percentage Target Word Recognition as a Function of Prime Type and Prime Duration (in Milliseconds). Data From Experiment 2

	Homophone (*aut*–OUD)	Grapheme Control (*zum*–OUD)	Unrelated Control (*zim*–OUD)
29 msec	47.8	47.5	23.6
43 msec	47.2	39.6	8.1

Method

Participants. Participants were 54 first-year students, who participated for course credits. Half of them were assigned to the condition with the short prime duration and half to the condition with the long prime duration. Assignment to one or the other condition was random. All participants were native Dutch speakers.

Procedure. The procedure was based on Grainger and Ferrand (1996). The beginning of a trial was marked by the appearance of two vertically aligned lines in the middle of the computer screen. Between the lines, there was a gap (of one line of text) where the participants were supposed to fixate. Five hundred milliseconds after the participant pressed the space bar, a row of seven hash-marks (#######) appeared with the second mark between the vertical lines. The forward mask was presented for 500 msec, immediately followed by the prime in lowercase, the target in uppercase, and a new line of seven hash marks. The latter remained on the screen while the observer typed in the word he/she had seen, and, if possible, the nonword he/she had perceived. Prime and target were presented in such a way that the participant fixated the second letter, irrespective of the length of the prime and the target. Prime duration was 29 or 43 msec (between-subjects variable). Target duration always was 29 msec. Timing was synchronized with the vertical retrace (using a graphics card of 70 Hz).

The 99 stimuli were taken from the Verstaen et al. (1993) list (the only missing target word was *squash*). These stimuli were divided over three lists as a function of prime type (homophonic, graphemic control, and unrelated control). The primes were no longer combined with unrelated target words, because guessing on the basis of the nonword is assumed to be less of a problem in masked priming than in backward masking and because we failed to find mask-related target guessing in the previous experiment (also see Brysbaert & Praet, 1992). Stimuli were distributed across participants according to a latin-square design, so that each target word was presented only once per person. Each participant saw a different permutation of the stimulus list, and the experimental trials were preceded by 18 practice trials (which had the same composition as the test trials). Participants received feedback about their performance on the word stimuli after the practice trials and after the experimental trials. No filler items were used in this study, so that one-third of the target words were preceded by a pseudohomophonic prime, one-third by a graphemic control prime, and one-third by an unrelated control prime.

Results

The percentages of target recognition as a function of prime duration and prime type are listed in Table 2. On the basis of the English and the French data, we expected an advantage of the pseudohomophone primes over the graphemic control primes in the 43-msec prime duration condition but not in the 29-msec condition. This is indeed what we found. In the analyses of variance (ANOVAs) there was a main effect of prime duration [$F_1(1,52) = 5.13$, $MS_e = 510.0$; $F_2(1,98) = 28.94$, $MS_e = 324.8$], a main effect of prime type [$F_1(2,104) = 212.79$, $MS_e = 76.2$; $F_2(2,196) = 87.66$, $MS_e = 676.3$], and a significant interaction [$F_1(2,104) = 9.29$, $MS_e = 76.2$; $F_2(2,196) = 12.25$, $MS_e = 215.0$].

In the 29-msec condition, target identification was the same after a pseudohomophone prime (48%) as after a graphemic control prime (48%) [$F_1(1,26) < 1$, $MS_e = 52$; $F_2(1,98) < 1$, $MS_e = 335$], and both prime types yielded higher recognition rates than the unrelated control primes (24%) [$F_1(1,26) = 81.6$, $MS_e = 100$; $F_2(1,98) = 69.0$, $MS_e = 429$, for homophonic primes; and $F_1(1,26) = 103.3$, $MS_e = 76$; $F_2(1,98) = 64.2$, $MS_e = 444$, for graphemic primes].

In the 43-msec condition, target identification was significantly better after pseudohomophone primes (47%) than after graphemic control primes (40%) [$F_1(1,26) = 18.9$, $MS_e = 41$; $F_2(1,98) = 6.1$, $MS_e = 449$], and both types of primes led to significantly higher recognition rates than the unrelated control primes (8%) [$F_1(1,26) = 185.1$, $MS_e = 111$; $F_2(1,98) = 165.6$, $MS_e = 456$, for homophonic primes; and $F_1(1,26) = 176.3$, $MS_e = 76$; $F_2(1,98) = 88.2$, $MS_e = 560$, for graphemic primes]. As in Perfetti and Bell (1991), the difference between the 29-msec and the 43-msec conditions was not due to an enhanced facilitation of the pseudohomophone primes in the longer prime duration condition, but to an increased inhibitory effect of the nonhomophonic primes.

The magnitude of the pseudohomophone effect in the 29-msec condition to some extent depended on the number of different phonemes between the pseudohomophonic and graphemic primes. There was a trend toward a positive effect for the items with two mismatches [44.7% target recognition after a homophonic prime vs. 38.4% after a graphemic control prime; $F_2(1,36) = 1.55$, $MS_e = 470$], whereas there was an opposite trend for the items with one mismatch (50.0% vs. 53.1%) [$F_2(1,61) = 1.21$, $MS_e = 241$], giving rise to a nearly significant interaction between number of phoneme mismatches and prime type [$F_2(1,97) = 3.11$, $MS_e = 328$, $p < .09$]. In contrast, in the 43-msec condition, there was no bias for a larger pseudohomophone effect with double mismatching primes than with single mismatching primes (2 phonemes: 39.3% vs. 32.4%; 1 phoneme: 52.0% vs. 44.3%; interaction presentation duration × prime type) [$F_2(1,97) < 1$, $MS_e = 454$].

Discussion

Although there may be further optimizations of the backward masking procedure (e.g., by reducing the visibility of the target words), the results of Experiment 2 suggest that the masked priming procedure is a more interesting technique to examine reliance on early phonological codes in Dutch. At least, we were able to replicate findings previously reported in the literature using the same presentation conditions.[3] As in English and in French, we obtained a reliable pseudohomophone effect with prime durations longer than 40 msec but not with prime durations shorter than 30 msec. In this respect, it should be mentioned that Lukatela, Frost, and Turvey (1998) and Lukatela and Turvey (2000) have recently ob-

Table 3
Percentage Target Word Recognition as a Function of Prime Type and Context (Phonology Encouraging or Discouraging). Data From Experiment 3

	Homophone	Grapheme Control	Unrelated Control
Encouraging	50.6	41.7	9.6
Discouraging	51.8	42.6	11.3

tained phonological priming effects for shorter prime presentation times when the forward mask was changed (e.g., by replacing the hash marks with underscores), so that the optimal presentation duration might be procedure specific. Also, the onset of the effect may depend to some extent on the number of mismatching phonemes between the homophonic and graphemic primes.

The fact that we were able to replicate the basic English finding with the masked priming procedure puts us in a better position to address the issue of strategic reliance on nonlexical phonology in Dutch. This issue is examined in the next experiment.

EXPERIMENT 3

As indicated in the beginning, four criticisms have been formulated against Brysbaert and Praet's (1992) finding of strategic use of prelexical phonological information in visual word recognition: (1) the poor quality of the stimuli, (2) the possibility that participants may have ignored the masks, (3) the question of whether in Dutch it is possible to find a pseudohomophone effect with backward masking, and (4) the fact that the strategic effect has not been replicated in English. Experiments 1 and 2 addressed the first and third criticisms and showed that part of the problem with Dutch is indeed the difficulty to obtain a normal pseudohomophone effect with the backward masking paradigm and that more reliable information may be obtained with the masked priming technique. The present experiment mainly addressed the second and fourth criticisms.

However, the experiment was not a mere replication of Brysbaert and Praet (1992, Experiment 3), because of Xu & Perfetti's (1999) failure to repeat the finding. It occurred to us that having target words preceded by unrelated primes might not be the best way to discourage reliance on nonlexical phonology, partly because it may induce participants to disregard the prime and partly because an unrelated prime may not bring about a very big interference with the target word; the reason being is that such primes do not have a large phonological overlap with existing words.

Because of these problems, we decided to use a different manipulation in the phonology discouraging condition. Instead of combining filler words with unrelated nonwords (e.g., *mondap*–ZESTIG [sixty]), we combined filler words with the pseudohomophonic prime of another filler word (e.g., *ocapi*–ZESTIG [sixty]; *ocapi* is a pseudohomophone of *okapi* [okapi]). In this way, the nonwords used in the encouraging and the discouraging conditions were exactly the same; and the primes of the filler items in the discouraging condition strongly pointed to another word than to the word that had to be identified. As suggested by the conditions with the unrelated words in Experiment 1, it can be assumed that the pairing of a word with an unrelated pseudohomophone creates a stronger interference with the processing of the target word, so that we had more chances of observing a strategic effect as a function of context.

Method

Participants. Participants were 72 first-year university students, who participated for course credit. All were native Dutch speakers, and none had participated in any of the preceding experiments. Participants were divided randomly into two groups, depending on whether they would receive the phonology encouraging context or the phonology discouraging context.

Procedure. A representative sample of 42 test stimuli was drawn from the list of 99 stimuli used in Experiment 2.[4] The remaining 57 stimuli served as filler items and were either preceded by their homophonic prime (e.g., *ieb*–IEP [elm] and *gad*–GAT [hole]) or by the homophonic prime of an unrelated word (e.g., *gad*–IEP and *ieb*–GAT). The same manipulation was made in the 18 practice trials. For the rest, the procedure was exactly the same as that in Experiment 2, except that prime duration was always 43 msec (target duration was 29 msec). Due to the presence of filler items, the phonology encouraging condition contained 42/3 + 57 = 71 trials with target words preceded by their pseudohomophone (i.e., 72%), whereas the phonology discouraging condition contained only 42/3 = 14 trials, in which the target words were preceded by their pseudohomophone (i.e., 14%).

Results

Targets of the filler items were recognized in 47.3% of the cases when they were preceded by their pseudohomophone and in 11.2% of the cases when they were preceded by the pseudohomophone of another word. The effects of stimulus context and prime type on the experimental materials can be found in Table 3.

ANOVAs limited to the conditions with homophonic and graphemic control primes revealed a significant pseudohomophone effect of 9.1% [$F_1(1,70) = 14.2$, $MS_e = 207$; $F_2(1,41) = 6.32$, $MS_e = 592$] and no main effect of context [$F_1(1,70) < 1$, $MS_e = 358$; $F_2(1,41) < 1$, $MS_e = 124$] nor an interaction between prime type and context [$F_1(1,70) < 1$, $MS_e = 207$; $F_2(1,41) < 1$, $MS_e = 132$].

Discussion

The results of Experiment 3 clearly show that the magnitude of the pseudohomophone effect was not modulated by the context created with the filler items. There was no difference when, in the majority of trials, phonological coding of the prime was detrimental for target recognition or when, in the majority of trials, phonological coding of the prime was helpful for target recognition. This strongly suggests that prelexical phonological assembly in Dutch is an automatic process that cannot be strategically controlled with attention. This result agrees with Xu and Perfetti's (1999) position and contradicts previous conclusions drawn by Brysbaert and Praet (1992).

GENERAL DISCUSSION

Three experiments were reported that re-examined the issue of strategic prelexical phonology assembly in Dutch. The issue regained interest after Xu and Perfetti (1999) failed to replicate the effect in English. On the basis of new evidence and a review of recent literature, it can be concluded (1) that unlike previous accounts, prelexical phonological recoding in visual word recognition proves to be as mandatory in Dutch as in English, but (2) that a number of methodological caveats are in order when one tries to obtain empirical evidence of the recoding (i.e., the pseudohomophone effect).

The first finding is important because it underscores the cross-linguistic validity of current models of word recognition, largely built on English findings. There were a priori reasons to believe that Dutch would differ from English (e.g., because of the orthographic depth of the language or the widespread multilingualism among native Dutch students), and, as long as Brysbaert and Praet (1992) was the only reference for this language, it was not clear to what extent the strong phonological models of visual word recognition were language specific.

The second finding is valuable as well, because it is our understanding that quite a bit of work has been done with the backward masking paradigm (and the masked priming paradigm) that has resulted in null effects. On the basis of the data presented here, three methodological concerns seem to be important. First, we believe that evidence for phonological coding is more difficult to obtain with the backward masking paradigm than with the masked priming paradigm (although more parametric studies may be needed to really establish this conviction). With backward masking, the phonological effect rarely exceeds 5–7%, whereas effects up to 17% have been reported with masked priming. Second, the magnitude of the phonological effect depends on the overall accuracy of target recognition. In general, accuracy should be rather low. Finally, there is evidence that the phonological code, which is used for lexical access, is not fully specified (Frost, 1998). This means that small differences between the phonological codes of the homophonic primes/masks and the graphemic primes/masks may not be picked up in the initial stages of word processing. This may also imply that the issue of prelexical phonology cannot be investigated in languages that tolerate only very small phonological differences between the two types of nonwords.

The issue of which differences between homophonic and graphemic control primes/masks influence target word recognition is likely to become an important research topic in the coming years, not only for methodological reasons but also for theoretical reasons. Now that the existence of mandatory prelexical phonology assembly has been demonstrated, the logical next question is what this code looks like. Some authors have suggested that it may mainly consist of consonant information (Berent & Perfetti, 1995), at least in English. Others point to the reading direction and hypothesize a larger role for the word beginning than for the word ending (Perry & Ziegler, in press). Probably, these are but two instances of a larger array of possibilities.

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NOTES

1. When the analysis was limited to the pseudohomophones and the graphemic controls that started with the same grapheme/phoneme, there was a significant 9-msec advantage for the pseudohomophones. See Verstaen et al. (1993) for details.

2. The F_1 analysis could not be calculated because the stimuli were not eMemory & Cognitionvenly distributed over the different lists of 10 items.

3. The target and mask durations of Experiment 1 were based on Perfetti et al. (1988) and Perfetti and Bell (1991).

4. Of these items, 18 had two different phonemes between the homophonic and the graphemic primes.

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