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Do null phonemic masking effects reflect strategic control of phonology?

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Abstract. Verstaen, Humphreys, Olson and D'Ydewalle [(1995) *Journal of Memory and Language, 34*, 335–356] reported null phonemic masking effects with homophone targets under conditions discouraging reliance on phonology. They attributed these null effects to the absence of reliance on phonology, concluding that reliance on phonology may be strategically controlled. Two studies using Verstaen et al.'s method occasionally replicate these null phonemic masking effects, but challenge their interpretation. The emergence of null phonemic masking effects was unrelated to the strategy manipulation. Conversely, evidence for phonology emerged in homophone errors regardless of the strategy manipulation and despite null phonemic masking effects. Our findings reflect an inherent instability in the perception of homophones. We demonstrate that this instability is directly due to reliance on phonology, rather than to its control.

Key words: Homophones, Masking, Phonology, Reading

Introduction

The role of assembled phonology in skilled reading is the subject of intense debate in the reading literature. It is often assumed that reading a word entails the retrieval of its meaning from a mental lexicon. How is a word's meaning retrieved: Is it achieved solely based on *graphemic* (letter) information, or is it constrained by *phonological* information, assembled by mapping its letters into phonemes? The reading literature includes two contradictory replies to this question. According to the fast phonology hypothesis (e.g., Carello, Turvey & Lukatela, 1992; Kawamoto, 1993; Lukatela & Turvey, 1993; Perfetti, Zhang & Berent, 1992; Van Orden, Pennington & Stone, 1990; Van Orden & Goldinger, 1994) phonology is the fastest constraint on reading. Conversely, on the slow phonology view (e.g., Baron, 1973; Bower, 1970; Coltheart, 1978; Seidenberg, 1985; Seidenberg, Waters, Barnes & Tanenhaus, 1984), reading is achieved primarily by direct visual access. Assembled phonology is considered a late constraint whose contribution among skilled readers is limited to unfamiliar words. One of the principal tests for these hypotheses concerns the mandatory nature of phonology assembly. If phonology assembly is an essential component of skilled reading, then its computation may be independent of task demands. Specifically, if assembly is the optimal means for lexical access, then it may constrain word identification even under conditions that discourage its use. Indeed, mandatoriness is the defining feature of automaticity in general (Tzelgov, 1997).

There are numerous studies demonstrating the contribution of assembly under conditions that strongly discourage its use (e.g., Azuma & Van Orden, 1997; Berent, 1997; Berent & Perfetti, 1995; Bosman & DeGroot, 1996; Ferrand & Grainger, 1996; Gibbs & Van Orden, 1998; Lukatela, Savić, Urosević & Turvey, 1997; Lukatela & Turvey, 1993; Perfetti & Zhang, 1994; Peter & Turvey, 1994; Stone and Van Orden, 1993; Van Orden, 1987; Van Orden, Johnston & Hale, 1988; Ziegler & Jacobs, 1995; Ziegler, Van Orden & Jacobs, 1997b). However, a recent report by Verstaen, Humphreys, Olson and D'Ydewalle (1995) challenges this conclusion. In the crux manipulation, homophone words (e.g. *sine*) were presented briefly followed by a mask composed of letters (e.g. SYNE, SONE). Because the meaning and spelling of a homophone is unpredictable from its phonology, the use of homophones is expected to discourage participants' reliance on phonology. The contribution of phonology to the identification of these targets was examined by comparing the effects of three masks: A *pseudohomophone*, e.g. SYNE – a nonword whose pronunciation matches the target's; a *graphemic* mask, e.g., SONE – a nonword matched to the pseudohomophone in graphemic (but not phonological) similarity to the target; and a *control* mask e.g., PRAF – a nonword that shares neither phonemes nor graphemes with the target. The participants' task is simply to report the spelling of the target. If participants rely on phonology in this task, then a pseudohomophone mask (SYNE) that reinstates the target's phonology may facilitate identification compared to a graphemic control mask. The differential effect of the pseudohomophone relative to the graphemic mask on correct target identification is referred to as the *phonemic masking effect*. If participants may suppress phonology, then the phonemic masking effect may be nullified by the conspicuous presentation of homophone targets. Indeed, Verstaen et al. (1995) found that the conspicuous presentation of homophone targets results in the cancellation of the phonemic masking effect. In particular, null phonemic masking effects were observed when the experimental list consisted entirely of homophones (Verstaen et al.'s Experiments 2–3) or when homophones were conspicuously presented at the beginning of the experimental list (Verstaen et al.'s Experiment 4). Conversely, the inconspicuous presentation of homophone targets toward the end of the experiment yielded a significant phonemic masking effect (Verstaen et al.'s Experiment 4). Verstaen and colleagues thus concluded that participants can strategically control reliance on phonology. Specifically, they considered two possible loci for such control. On one view, participants may altogether disable the assembly of phonology. Conversely, participants' control may reside in the read-out of the assembly output. Either way, the reliance on phonology[1] is eliminated under conditions discouraging its use.

The experiments we next present revisit this conclusion. We do not wish to criticize the reliability of Verstaen et al.'s findings or their methodology. Our results occasionally coincide with their findings, revealing null phonemic masking effects. Our critique specifically concerns the *interpretation* of these null phonemic masking effects. We believe that these null effects do not reflect the disabling of phonology assembly or the ignoring of its output. Instead, they stem from an inherent instability in the perception of homophones. We show that the reinstatement of homophones' phonology has contradictory consequences. The nullification of the phonemic masking effect reflects a conflict that is specifically due to reliance on phonology, rather than to its strategic control.

Our manipulations closely follow Verstaen et al's Experiment 4 and employ their own homophone targets and masks. We manipulate participants' reliance on phonology by reordering two lists consisting of homophone targets and nonhomophone fillers. In the *phonology encouraging* condition, one group of participants was presented with the homophone targets after seeing nonhomophone fillers, and they were not informed of the presence of homophones. Conversely, in the *phonology discouraging* condition, participants were presented with homophones at the beginning of the experiment. Moreover, they were explicitly warned about the presence of homophones and advised to rely on spelling.

Our investigation addresses several questions. First, we wished to find out whether the null phonemic masking effect with homophones is due to participants' strategies. Recall that Verstaen and colleagues observed a significant phonemic masking effect in the phonology encouraging condition, but a null phonemic masking effect in the phonology discouraging condition. The attribution of this null effect to strategic control renders the strategy manipulation a *necessary and sufficient* condition for the nullification of the phonemic masking effect. If the strategy manipulation is necessary for this null effect, then significant phonemic masking effects should systematically emerge when the presence of phonology is encouraged. If the strategy manipulation is sufficient to eliminate the phonemic masking effect, then a null effect should emerge under the phonology discouraging conditions. A second question examined in these studies is whether the null phonemic masking effect indicates the absence of reliance on phonology assembly. Could evidence for assembly be obtained in the face of null phonemic masking effects? Finally, we wished to examine the time-course of the phonemic masking effect using distinct exposure durations for the target and mask. Experiment 1 manipulated participants' strategies using brief exposure durations for the target and mask, whereas long exposure durations are used in Experiment 2. Temporal changes in the phonemic masking effect may offer further insights regarding the source of the null effects reported by Verstaen et al. According to the slow phonology hypothesis, phonology is a late occurring constraint. Phonemic masking effects are thus more likely to occur under longer exposure durations. Conversely, if phonology is the fastest means for lexical access, then the effects of phonology should emerge even under brief durations (e.g., Lukatela et al., 1997). Specifically, according to the two cycles model (Berent & Perfetti, 1995), consonants' assembly is completed prior to vowels' and it is a mandatory constraint on word identification. The use of brief durations should thus increase the chances of tapping into consonant assembly, hence, revealing mandatory effects of phonology.

Experiment 1

Experiment 1 examines the strategy manipulation using brief exposure durations for the target and mask. If the strategy manipulation is necessary to produce null phonemic masking effects, then significant phonemic masking effects are expected in the phonology encouraging condition. If the manipulation is sufficient for disabling reliance on phonology, then no evidence for phonology should emerge in the phonology discouraging condition.

Method

Participants

Participants were Arizona State University undergraduates who were native English speakers with normal or corrected to normal vision. To eliminate floor and ceiling performances, a cut off procedure was adopted. The level of acceptable performance was set to 10–90% overall accuracy across target types. This cut off yielded 36 participants per condition and eliminated 6 participants from the phonology encouraging condition and 4 participants from the discouraging condition.

Apparatus

The experiment was conducted using a personal computer with a 25×80 color VGA monitor and the Micro Experimental Lab software. Precise brief displays of the target and mask were achieved by locking the electron gun to the top of the screen and specifying their duration as multiples of full refresh cycles (14.21 ms).

Materials

The homophone targets and their masks were 51 of the 54 homophones used by Verstaen et al. (1995). One target (*court*) was excluded because its "pseudohomophone" (COUGHT) does not match its pronunciation in American English. Two other targets (*know*, *chute*) were excluded for the purpose of counterbalancing. The nonhomophone fillers were the 48 simple-vowel targets used in Berent and Perfetti (1995, Experiment 4). Each nonhomophone target (e.g., tank) was masked by either a mask that reinstated its consonants (e.g., TINK), a mask reinstating its vowel (e.g., TAFK), or a control mask (e.g., MELF), as described in Berent and Perfetti (1995, Experiment 4).

Following Verstaen et al. (1995, Experiment 4), the sets of homophone targets and nonhomophone fillers were arranged in two combinations designed to encourage or discourage the reliance on phonology. In the phonology encouraging condition, the nonhomophone fillers were presented first followed by the homophone targets. In the phonology discouraging condition, the homophone targets were presented first followed by the nonhomophone fillers. Targets were presented in lower case whereas masks were presented in upper case. To control for the visual salience of letters at word external position, targets and nonword masks were presented with pound signs (#) immediately to their left and right.

Warm up materials. Two additional sets of 30 targets and masks were used in warm up trials. In the phonology encouraging condition, targets were all nonhomophones, whereas in the phonology discouraging condition, the targets were homophones. These warm-up items did not overlap with the set of targets used in the experimental blocks. Each target was followed by a control mask. Targets were all presented in lower case whereas masks were presented in upper case.

Design. Mask type (3: pseudohomophone, graphemic, control) was manipulated within participants and items whereas strategy (2: phonology encouraging vs. phonology discouraging) was manipulated between participants. Within each condition, the presentation of each target and its nonword masks was counter-balanced in a Latin Square design. Each target was presented only once and each participant saw the same number of targets with each of the three masks. Across participants, a target was presented the same number of times with each of the three masks.

Procedure

The instructions in each of the strategy levels informed participants of the presence of a target and a mask. The instructions at the two strategy levels contrasted in the extent to which participants were alerted to the presence of homophones and required to attend to their spelling. The instructions for the phonology encouraging condition did not mention the presence of homophones. Conversely, participants in the phonology discouraging condition were explicitly informed of the presence of homophones: "... Many of the words you are about to see have more than one possible spelling (e.g., *sun, son*). You should therefore pay close attention to their spelling and ignore their sound". The instructions were followed by a warm up session. To accustom participants to the brief duration of the display, target duration in the warm up trials was set initially to 84 ms and gradually reduced to two refresh cycles (28 ms). In the warm up, participants reported the identity of targets and masks aloud. In the phonology discouraging condition, they were also required to indicate which of the two meanings or spellings of the homophone were seen, thereby emphasizing the presence of homophones, and the need to rely on spelling. At the end of the warm up trials, participants were given an opportunity to ask questions regarding the procedure. They were then presented with the experimental session, consisting of two consecutive blocks of homophone and nonhomophone targets. Participants were not informed of the division of the experimental session into two blocks. No participant correctly identified a mask in any of the trials.

At the beginning of the trial, a pattern mask (XXXXXXX) appeared as a fixation at the center of the monitor. Participants initiated a trial by pressing the space bar. Each trial contained three successive events: A target word, a nonword mask and a pattern mask. The target was followed immediately by the nonword mask and a pattern mask which remained on the screen until the participant responded. The target and mask were each presented for two refresh cycles (28 ms). The order of trials for each participant within each block of trials (homophone vs. non homophone) was random. The stimuli were presented at the center of the screen at a distance of approximately 18 inches. To reduce the visual contrast, all visual stimuli were presented in a blue color on a black background. At the end of each experimental trial, participants were asked to write down the targets and masks they perceived.

Results

Our principal interest concerns the presence of phonology, in general, and the phonemic masking effect, in particular, in each of the strategy conditions. Before addressing this question, we wished to examine the effectiveness of the strategy manipulation. The effect of strategy on correct target identification was assessed by ANOVA's (2 strategy $\times$ 3 mask) by participants and items. The main effect of strategy was not significant [$F_1(1,70) < 1$; MSE = 0.053; $F_2(1,50) = 1.956$, MSE = 0.012, $P = 0.1681$]. However, the interaction of strategy by mask was significant by participants and items [$F_1(2,140) = 3.419$, MSE = 0.007, $P = 0.0355$; $F_2(2,100) = 3.042$, MSE = 0.012, $P = 0.0522$].

Table 1. Target identification accuracy (% correct) and homophone errors (% homophone errors per participant and homophone target) as a function of mask type in the phonology encouraging condition in Experiment 1.

	Target correct identification	Homophone errors
Pseudohomophone	26.63	2.78
Graphemic	24.01	1.31
Control	18.79	0.98

Evidence for phonology in the phonology encouraging condition

Correct target identification. Given the general efficacy of the strategy manipulation, we now turn to examine reliance on phonology separately in each of its levels. If the strategy manipulation is necessary to produce null phonemic masking effects with homophones, then significant phonemic masking effects are expected in the phonology encouraging condition. A one way ANOVA conducted on correct target reports in the encouraging condition revealed a significant main effect of mask type [$F_1(2,70) = 8.169$, MSE = 0.007, $P = 0.0006$; $F_2(2,100) = 5.696$, MSE = 0.014, $P = 0.0045$]. Target identification accuracy as a function of mask type is presented in Table 1. The pseudohomophone improved target identification compared to the control mask [$\Delta = 7.84\%$; $F_1(1,70) = 15.76$, $P = 0.002$; $F_2(1,100) = 10.97$, $P = 0.0013$]. However, the phonemic masking effect was not significant [$\Delta = 2.61\%$; $F_1(1,70) = 1.751$, $P = 0.19$; $F_2(1,100) = 1.219$, $P = 0.27$].

Homophone errors. Thirty one of the responses given in the phonology encouraging condition were homophone errors (e.g., the report of *sign* to the target *sine*). Mean homophone errors as a function of mask type is presented in Table 1. A one way ANOVA conducted over the homophone errors revealed a significant main effect of mask [$F_1(2,70) = 3.322$, MSE = 0.001, $P = 0.0419$; $F_2(2,100) = 4.22$, MSE = 0.001, $P = 0.0174$]. There was a significant increase in homophone errors when the target was masked by the pseudohomophone compared to the control mask [$\Delta = 1.8\%$; $F_1(1,70) = 5.855$, $P = 0.0181$; $F_2(1,100) = 7.438$, $P = 0.0075$]. Importantly, the pseudohomophone resulted in a significant increase in homophone errors compared to its graphemic mask [$\Delta = 1.47\%$; $F_1(1,70) = 3.917$, $P = 0.0517$; $F_2(1,100) = 4.976$, $P = 0.0279$]. Thus, the emergence of homophone errors is specifically related to the reinstatement of targets' phonology.

Table 2. Target identification accuracy (% correct) and homophone errors (% homophone errors per participant and homophone target) as a function of mask type in the phonology discouraging condition in Experiment 1.

	Target correct identification	Homophone errors
Pseudohomophone	24.50	2.78
Graphemic	29.41	2.29
Control	20.75	0.82

Evidence for phonology in the phonology discouraging condition

Correct target identification. To assess the sufficiency of the strategy manipulation for disabling reliance on phonology, we submitted correct target reports to a 1 way ANOVA. The main effect of mask type was significant [$F_1(2,70) = 8.552$, MSE = 0.008, $P = 0.0005$; $F_2(2,100) = 7.141$, MSE = 0.013, $P = 0.0013$]. Importantly, the phonemic masking effect was significant by participants and items [$\Delta = 4.9\%$; $F_1(1,70) = 5.443$, $P = 0.0225$; $F_2(1,100) = 4.557$, $P = 0.0352$]. Its direction, however, was inhibitory: the pseudohomophone resulted in a decrease in correct target reports relative to the graphemic mask (see Table 2). In contrast, the graphemic mask resulted in greater accuracy compared to the control mask [$\Delta = 8.66\%$; $F_1(1,70) = 16.988$, $P = 0.0001$; $F_2(1,100) = 14.222$, $P = 0.0003$].

Homophone errors. Thirty six of the responses in the phonology discouraging condition were homophone errors (see Table 2). A one way ANOVA conducted on these responses revealed a marginally significant main effect of mask type [$F_1(2,70) = 2.433$, MSE = 0.002, $P = 0.0952$; $F_2(2,100) = 5.044$, MSE = 0.001, $P = 0.0082$]. The pseudohomophone resulted in a significant increase in homophone errors compared to the control mask [$\Delta = 1.96\%$; $F_1(1,70) = 4.492$, $P = 0.0376$; $F_2(1,100) = 9.304$, $P = 0.0029$]. There was also a numerical, but nonsignificant increase in homophone errors in the presence of the pseudohomophone relative to the graphemic mask [$\Delta = 0.49\%$; F_1, $F_2 < 1$).

Discussion

Verstaen et al. (1995) observed null phonemic masking effects under phonology-discouraging conditions. Experiment 1 examined two questions: (1) Is the null phonemic masking effect with homophones due to the strategy manipulation (2) Does this null phonemic masking effect stem from readers' ability to avoid reliance on phonology.

With regard to the first question, our results suggest that the null phonemic masking effect observed with homophones is not directly related to the strategy manipulation. The strategy manipulation may not be necessary to cause a null phonemic masking effect, as such a null effect emerges even under conditions believed to encourage reliance on phonology. Conversely, the strategy manipulation is not sufficient to produce a null phonemic masking effect either. We observe a significant phonemic masking effect despite conditions designed to discourage reliance on phonology. It is unlikely that this phonemic effect stems from the ineffectiveness of the strategy manipulation, as the interaction of mask by strategy was significant. Instead, it appears that the strategy manipulation is neither necessary nor sufficient for obtaining null phonemic masking effects with homophone targets.

Does a null phonemic masking effect indicate the absence of phonology? The inference of mental structures from performance in experimental tasks is never transparent, and this problem is especially acute when it comes to the interpretation of null effects (G. Van Orden, C. Aitchison & M. Podgornik, unpublished manuscript [1996]; Van Orden, Pennington & Stone, 2001). Thus, the attribution of a null phonemic masking effect to the absence of reliance on phonology is never certain. The homophone error data provide some specific evidence against this inference. Our findings, as well as the results reported by Verstaen et al. (1995), manifest homophone errors in each of the strategy levels. Such homophone errors may, in principle, reflect the activation of phonology. Because the homophone-competitor (e.g., *sign*) is indistinguishable from the target (e.g., *sine*) on the phonological dimension, an activation of the target's phonology in the lexicon is bound to activate also its homophone, resulting in homophone errors. If homophone errors stem from reliance on phonology, then reinstating the target's phonology should increase homophone errors. The findings of Experiment 1 support this prediction. The reinstatement of the target's phonology by the pseudohomophone resulted in a significant increase in homophone errors compared to its graphemic control in the phonology encouraging condition. This increase in homophone errors explains the absence of the phonemic masking effect in correct target identification, as the two responses (e.g., *sign* vs. *sine*) are mutually exclusive. The sensitivity of homophone errors to the phonological contents of the mask demonstrates the presence of phonology assembly despite null phonemic masking effects. These findings thus suggest that null phonemic masking effects with homophones may not indicate the absence of reliance on phonology.

Interestingly, our findings also reveal a deleterious effect of the pseudohomophone mask on the identification of homophone targets. This inhibition may be traced to the combined effect of two forces. One force concerns the strategy manipulation. Participants in the phonology discouraging condition were required to pay special attention to the target's spelling. These instructions could have caused them to be especially vigilant to the activation of the target's letters. Indeed, the reinstatement of the target's letters by the graphemic mask improved target identification in the phonology discouraging (M = 29.41%) relative to the phonology encouraging condition (M = 24.01%). Surprisingly, however, the increased in vigilance did not produce a similar increase in target identification with the pseudohomophone mask, even though the pseudohomophone and graphemic mask share with the target the same number of letters. If graphemic similarity enhances correct target identification in the presence of the graphemic mask, then why doesn't the same spelling similarity improve performance in the presence of its yoked pseudohomophone?

This puzzle points towards a second force that constrains the identification of masked homophone – a force that is intimately linked to the mask's phonology. Despite the equation of the graphemic and pseudohomophone masks on the spelling dimension, they clearly differ in their phonological similarity to the target. The phonological similarity of the pseudohomophone to the target may have countered the effect of spelling similarity. Indeed, the reinstatement of the phonology of homophones by a pseudohomophone mask comes at a cost: the activation of multiple competing spellings associated with a single phonology. The reinstatement of the target's phonology (e.g., *sine*) activates the spelling of its homophone competitor (e.g., *sign*). In addition, the pseudohomophone also introduces an incorrect spelling of its own (e.g., *syne*). Thus, the masking of the target by a pseudohomophone activates multiple competing spellings associated with a single phonological representation. The resulting ambiguity concerning the target's spelling decreases its activation. Indeed, inconsistency in the mapping of phonology back to spelling is known to impair word identification (Stone, Vanhoy & Van Orden, 1997; Ziegler, Montant & Jacobs, 1997a). The deleterious effect of spelling competition is further magnified by the increased vigilance under the phonology discouraging condition: If vigilance enhances target identification by the detection of its correct spelling, then it should also decrease its identification when incorrect, competing spellings are detected. The overall level of target identification thus depends on the combined effect of two conflicting forces: the vigilance for correct spelling, and the activation of incorrect spelling by phonology. Because the graphemic mask reinstates some of the target's letters, but does not result in significant activation of competitors, the increased vigilance improves target identification with the graphemic mask. Conversely, an increased vigilance will decrease target identification with the pseudohomophone mask due to the detection of competing spellings activated by phonology. The combined effect of selective benefits with the graphemic mask (due to vigilance), but not the pseudohomophone mask (due to spelling ambiguity), thus results in an inhibitory effect of phonemic masking.

Inhibitory phonemic effects have been documented in both the masking (Berent & Frost, 1997; Tan & Perfetti, 1996) and primed lexical decision tasks (Berent,1997; Ferrand & Grainger, 1996). Common to these tasks is the strong emphasis on correct spelling. The precise circumstances leading to the emergence of inhibitory effects of phonology require further research. For the present purposes, however, suffice it to note that, regardless of its direction, any difference between the pseudohomophone and graphemic mask indicates the activation of phonology. The observation of such a significant effect in the phonology discouraging condition questions the sufficiency of the strategy manipulation for the elimination of reliance on phonology, in general, and the phonemic masking effect, in particular.

Experiment 2

Experiment 1 suggests that the strategy manipulation is neither necessary nor sufficient for the emergence of null phonemic masking effects. Such null effects, however, do not indicate the absence of reliance on phonology, as phonology effects were reflected by homophone errors despite a null phonemic masking effect. Experiment 2 has two goals. One is to replicate these findings using a longer exposure duration for the target and mask. The second goal is to examine the effect of exposure duration on participants' reliance on phonology. According to the slow phonology hypothesis, phonology is a slow constraint on reading. On this view, the absence of phonemic masking effects in the brief duration reflects the absence of phonology due to its slow computation. The increase in exposure duration should thus increase the chances of obtaining significant phonemic masking effects. These phonemic effects should further interact with the strategy manipulation: Significant phonemic masking effects are expected in the phonology encouraging, but not the phonology discouraging manipulation. Conversely, the fast phonology hypothesis views phonology as the principal constraint on reading. The absence of phonemic masking effects in the brief duration is attributed to the competition between the spellings associated with the target's phonology. The precise dynamics of this competition is not entirely clear apriori. The increase in exposure duration may enhance the activation of the target's correct spelling. Conversely, it should also increase the activation of its competitor homophone and the pseudohomophone's own incorrect spelling. It is thus conceivable that the longer duration may increase spelling competition. Consequently, the reinstatement of the target's phonology by the pseudohomophone may not facilitate its correct identification relative to the graphemic mask. Importantly, if the null phonemic masking effect associated with homophones reflects spelling competition, rather than the absence of phonology, then evidence for phonology may still be detected by homophone errors.

Method

The materials, equipment, design, and procedure were identical to Experiment 1, with the only change in the exposure duration of the target and mask, which were now set to 42 ms and 56 ms, respectively. Participants were Arizona State University undergraduates who were native English speakers. As in Experiment 1, the level of acceptable performance was set to 10–90% overall accuracy across target types. This cut off yielded 24 participants per condition and excluded 4 participants in the encouraging condition and 2 participants in the discouraging condition. There were 2 correct reports of the mask in each condition, all occurring in the presence of the pseudohomophone mask.

Results

The effectiveness of the strategy manipulation in the longer duration was evaluated by means of 2 way ANOVA's (2 strategy $\times$ 3 Mask) by participants and items. The ANOVA's performed on correct target identification did not reveal a significant main effect of strategy [$F_1(1{,}46) < 1$, MSE = 0.052; $F_2(1{,}50) < 1$, MSE = 0.022] nor a significant interaction of mask $\times$ strategy [$F_1(2{,}92) = 1.05$ MSE = 0.009, $P = 0.3540$; $F_2(2{,}100) = 1.087$, MSE = 0.019, $P = 0.3413$]. There were 32 homophone errors in the encouraging condition and 44 in the discouraging condition. The main effect of strategy [$F_1(1{,}46) < 1$, MSE = 0.004; $F_2(1{,}50) = 1.619$, MSE = 0.005, $P = 0.2019$] and its interaction with mask type [$F_1(2{,}92) < 1$, MSE = 0.002; $F_2(2{,}100) < 1$, MSE = 0.003] were not significant in the analysis of homophone error. We thus proceeded to examine the effect of mask type across the two levels of strategy.

Correct target identification. Correct target identification as a function of strategy and mask type is described in Table 3. The main effect of mask type was significant [$F_1(2{,}92) = 61.842$, MSE = 0.009, $P = 0.0000$; $F_2(2{,}100) = 26.682$, MSE = 0.045, $P = 0.0000$]. The pseudohomophone [$\Delta = 20.22\%$, $F_1(1{,}92) = 107.986$, $P = 0.0000$; $F_2(1{,}100) = 46.587$, $P = 0.0000$] and graphemic control [$\Delta = 16.78\%$, $F_1(1{,}92) = 74.426$, $P = 0.0000$; $F_2(1{,}100) = 32.117$, $P = 0.0000$] each improved target identification compared to the control mask. However, the phonemic masking effect did not reach signifi-

Table 3. Target identification accuracy (% correct) as a function of mask type and strategy level in Experiment 2.

	Encouraging	Discouraging	Mean
Pseudohomophone	30.39	34.80	32.60
Graphemic	28.43	29.90	29.16
Control	12.99	11.76	12.38

Table 4. The rate of homophone errors (% homophone errors per participant and homophone target) as a function of mask type and strategy level in Experiment 2.

	Encouraging	Discouraging	Mean
Pseudohomophone	5.65	6.63	6.14
Graphemic	1.72	2.95	2.33
Control	0.49	1.23	0.86

cance [Δ = 3.44%, $F_1(1,92) = 3.114$, $P = 0.081$; $F_2(1,100) = 1.342$, $P = 0.2495$].

Homophone errors. The rate of homophone errors as a function of mask type is presented in Table 4. The main effect of mask type was significant in the analyses of homophone error [$F_1(2,92) = 15.912$, MSE = 0.002, $P = 0.0000$; $F_2(2,100) = 14.053$, MSE = 0.005, $P = 0.0000$]. The pseudohomophone resulted in an increase in the report of the target's homophone relative to the control mask [Δ = 5.21%, $F_1(1,92) = 29.876$, $P = 0.0000$; $F_2(1,100) = 26.389$, $P = 0.0000$]. A similar, albeit nonsignificant, trend was observed with the graphemic mask [Δ = 1.47%, $F_1(1,92) = 2.324$, $P = 0.1308$; $F_2(1,100) = 2.055$, $P = 0.1548$]. Importantly, homophone errors were specifically sensitive to the phonological similarity of the mask and the target. The report of the target's homophone increased when it was masked by the pseudohomophone relative to the graphemic control [Δ = 3.81%, $F_1(1,92) = 15.532$, $P = 0.0002$; $F_2(1,100) = 13.716$, $P = 0.0003$].

Discussion

The results at the longer duration replicate the principal conclusions of the brief duration. The emergence of null phonemic masking effects was independent of the strategy manipulation. To assure that the absence of a significant phonemic masking effect in the encouraging condition is not due to a lack of statistical power in discriminating between the two strategy levels, we specifically tested for the phonemic masking effect in the encouraging condition separately. The phonemic masking effect did not approach significance [$\Delta = 3.65\%$, $F_1(1{,}46) < 1$; $F_2(1{,}100) < 1$]. Thus, the strategy manipulation is not necessary to produce a null phonemic masking effect. As in Experiment 1, however, significant effects of phonology emerged in the homophone error data. The report of the target's homophone increased by reinstating the target's phonology. To confirm the presence of phonology in the discouraging condition, we tested the error data separately in the phonology discouraging condition. Homophone errors significantly increased in the presence of the pseudohomophone compared to the graphemic mask [$\Delta = 3.68\%$, $F_1(1{,}46) = 4.686$, $P = 0.0356$; $F_2(1{,}100) = 7.261$, $P = 0.0038$]. Thus, the strategy manipulation is not sufficient to eliminate reliance on phonology. Specifically, the phonology discouraging condition reflects significant evidence for phonology despite the presence of a null phonemic masking effect in correct target identification. These findings indicate that null phonemic masking effects with homophones are not necessarily due to strategic control on phonology, nor do they indicate the absence of reliance on phonology.

Although the long duration did not reveal a significant effect of strategy, it is unlikely that the divergence between our conclusions and those of Verstaen et al. (1995) is due to the weakness of our strategy manipulation in the phonology discouraging condition. First, our design and procedure closely follow that described in Verstaen et al. (1995), who also employed long durations for the target and mask (approximately 45 and 30 ms, respectively). Second, as in the present study, the main effect and interaction involving the strategy factor were only marginally significant in Verstaen et al. (1995, Experiment 4). Third, the use of the same manipulation under brief exposure durations in Experiment 1 revealed a significant interaction of strategy with mask. Finally, and most importantly, the attribution of the divergence between our findings and Verstaen's et al. to our failure to discourage reliance on phonology cannot account for the null phonemic masking effect we observe in the phonology encouraging condition. If the phonology discouraging manipulation is too weak to eliminate reliance on phonology, then, surely, a phonology encouraging manipulation could not achieve such an outcome. Indeed, we believe that neither the null phonemic masking effect observed by Verstaen et al. in their phonology discouraging conditions, nor the ones we report in our phonology encouraging conditions are due to the avoidance of reliance on phonology. Instead, they reflect its conflicting consequences on the perception of homophones.

The results of Experiment 2 converge with the findings of Experiment 1 in suggesting that reliance on phonology is maintained regardless of the strategy manipulation. However, the two experiments differ with regards to the specific manifestations of phonology. The reinstatement of the target's phonology at the longer duration had no significant effect on its correct identification. The nullification of the phonemic masking effect at the long duration cannot be explained by the slow phonology hypothesis, as significant phonemic masking effects were obtained in the brief duration. Furthermore, the presence of phonology in the long duration was clearly evident in the homophone errors. The greater sensitivity of homophone errors to the mask's phonology may reflect temporal increase in the activation of the target's homophone competitor. To examine the temporal changes in the identification of masked homophones, we next assess the effect of exposure duration on each of the strategy levels.

A meta-analysis of the effect of duration

The effect of duration at the encouraging condition

Correct target identification. The effect of duration was assessed by two way ANOVA's (2 duration $\times$ 3 mask) by participants and items. For the sake of simplicity, in this and all subsequent analyses we focus on the effects involving the duration factor. The main effect of duration was not significant [$F_1(1,58) < 1$, MSE = 449.75; $F_2(1,50) < 1$, MSE = 288.557]. However, duration modulated the effect of mask type, resulting in a significant interaction [$F_1(2,116) = 5.725$, MSE = 82.321, $P = 0.0043$; $F_2(2,100) = 4.410$, MSE = 188.695, $P = 0.0146$]. The increase in duration resulted in a numerical improvement in target identification in the presence of the pseudohomophone and graphemic mask (see Figure 1). However, this trend did not reach significance by simple effects[2] (With the pseudohomophone mask: $F_1(1,101) < 1$; $F_2(1,50) = 1.577$, $P = 0.215$; With the graphemic mask: $F_1(1,101) = 1.377$, MSE = 204.797, $P = 0.243$; $F_2(1,50) = 1.882$, $P = 0.176$). In contrast, for the control mask there was a marginal decrease in identification at the longer duration ($F_1(1,101) = 2.365$, MSE = 204.797, $P = 0.127$; $F_2(1,50) = 4.942$, $P = 0.031$).

Homophone errors. The ANOVA's (2 duration $\times$ 3 mask) on homophone errors revealed a marginally significant main effect of duration [$F_1(1,58) = 3.358$, MSE = 0.001, $P = 0.0720$; $F_2(1,50) = 1.839$, MSE = 0.004, $P = 0.1812$]. Across mask type, there was a trend of increasing homophone errors with the increase in duration. However, the significance of the interaction [$F_1(2,116) = 4.361$, MSE = 0.001, $P = 0.0149$; $F_2(2,100) = 3.147$, MSE = 0.002, $P = 0.0473$] suggests that this increase was modulated by mask prop-

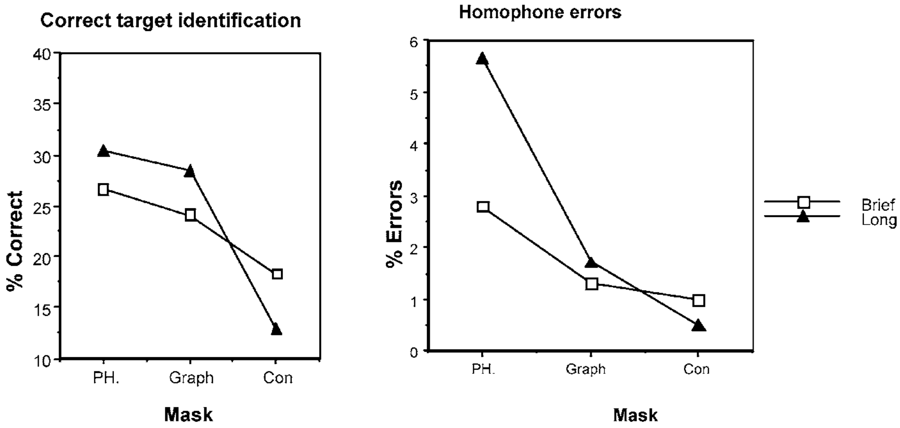

Figure 1. The effect of exposure duration and mask type on target identification accuracy (% correct) and homophone errors (% homophone errors per participant and homophone target) in the phonology encouraging conditions.

erties. Simple main effects indicated that the increase in homophone errors occurred only in the presence of the pseudohomophone mask [$F_1(1,174) = 11.439$, MSE = 0.001, $P = 0.001$; $F_2(1,50) = 3.794$, $P = 0.057$]. No significant increase was detected with either the graphemic or the control mask (all $F < 1$). Thus, the increase in homophone errors at the longer durations is due to the reinstatement of the target's phonology.

The effect of duration at the phonology discouraging condition

Correct target identification. The ANOVA's (2 duration × 3 mask) on correct target identification did not yield a significant main effect of duration [$F_1(1,58) < 1$, MSE = 0.061; $F_2(1,50) < 1$, MSE = 0.107]. However, the interaction of mask × duration was significant [$F_1(2,116) = 16.727$, MSE = 0.008, $P = 0.0000$; $F_2(2,100) = 17.421$, MSE = 0.014, $P = 0.0000$]. Simple main effects revealed that the increase in duration improved identification in the presence of the pseudohomophone [$F_1(1,90) = 5.978$, MSE = 0.026, $P = 0.016$; $F_2(1,50) = 11.579$, $P = 0.001$] but not the graphemic mask (all $F < 1$). Thus, the benefit of longer duration depends on the phonological similarity between the target and the mask (see Figure 2). A radical dissimilarity between the target and mask, in the case of the control mask, resulted in a significant decrease in target identification [$F_1(1,90) = 4.543$, MSE = 0.026, $P = 0.036$; $F_2(1,50) = 21.848$, $P = 0.000$].

Homophone errors. The ANOVA (2 duration × 3 mask) by items revealed a significant main effect of duration [$F_2(1,50) = 4.960$, MSE = 0.004, $P = 0.0351$] and a significant interaction of duration by strategy [$F_2(2,100)$

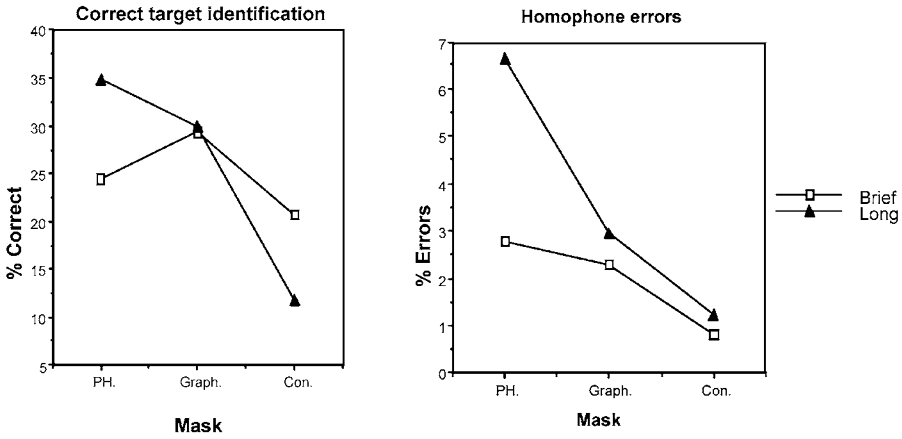

Figure 2. The effect of exposure duration and mask type on target identification accuracy (% correct) and homophone errors (% homophone errors per participant and homophone target) in the phonology discouraging conditions.

= 3.341, MSE = 0.003, P = 0.0394]. Similar, albeit nonsignificant, trends emerged in the analyses by participants. [The main effect of duration: $F_1(1,58) = 3.505$, MSE = 0.003, P = 0.0662; the interaction: $F_1(2,116)$ = 2.292, MSE = 0.002, P = 0.1056]. Across mask types, the increase in duration resulted in an increase in homophone errors. Simple main effects indicated that the pseudohomophone [$F_1(1,168) = 8.068$, MSE = 0.003, P = 0.005; $F_2(1,50) = 6.251$, P = 0.016], but not its graphemic control (all $F < 1$), resulted in a significant increase in homophone errors at the longer duration. Thus, the increase in homophone errors at the longer duration occurred only when the mask fully reinstated the target's phonology.

Discussion

The meta-analysis of Experiments 1–2 assessed the effect of duration on target identification and the magnitude of homophone errors. The increase in duration generally had little effect on target identification accuracy. Specifically, increasing the duration of the target did not improve identification in the encouraging condition. In the discouraging condition, the increase in duration improved identification only in the presence of the pseudohomophone mask. The modest effect of duration on correct target identification may be explained by the increase in homophone errors at the longer duration, as these responses are mutually exclusive. Importantly, however, the effect of duration was modulated by mask type. The increase in duration was associated with an elevation in homophone errors specifically in the presence of the pseudohomophone mask, but not its graphemic control. Thus, the increase in duration strengthened the activation of the homophone competitor only when its phonology was fully reinstated. This finding suggests that the homophone competitor is activated by phonology. Homophone errors are thus specifically related to reliance on phonology assembly.

General discussion

The role of phonology in the identification of homophones

Verstaen et al. (1995) reported null phonemic masking effects with homophone targets under conditions discouraging reliance on phonology. They attributed these null effects to the absence of reliance on phonology, concluding that reliance on phonology may be strategically controlled. Our findings converge with Verstaen et al. (1995), reflecting null phonemic masking effects in the correct identification of homophone targets. However, our results question the interpretation offered by Verstaen and colleagues for these null effects. In particular, the logic of Verstaen et al. (1995) assumes that (a) the strategy manipulation is sufficient to cause the nullification of the phonemic masking effect, and (b); null phonemic masking effects reflect the absence of reliance on phonology.

Our findings challenge each of these assumptions. With regards to the first assumption, our results do not exhibit a causal link between the strategy manipulation and the phonemic masking effect. The phonology encouraging condition failed to reveal significant phonemic masking effects in either the brief or the long duration. Conversely, the phonology discouraging condition yielded a significant inhibitory phonemic masking effect at the brief duration. We thus conclude that the strategy manipulation is neither necessary nor sufficient for the emergence of null phonemic masking effects. The attribution of null phonemic masking effects with homophones to strategic control over phonology is thus uncertain.

Our results also challenge the attribution of null phonemic masking effects to the absence of reliance on phonology. To gauge for the presence of phonology, we compared two phonological markers: the phonemic masking effect in correct target identification and homophonic errors. The two markers often diverge in their conclusions. In particular, the marker of homophonic errors reveals strong evidence for phonology despite null phonemic masking effects in correct target identification. Two pieces of evidence link homophonic errors to phonology. First, homophonic errors increase when the target is followed by the pseudohomophone mask compared to its graphemic control.[3] Second, the increase in exposure duration elevates homophonic errors only if the mask fully reinstates the target's phonology, i.e., in the presence of the pseudohomophone, but not the graphemic mask. The emergence of evidence for phonology by the marker of homophonic errors suggests that the absence of phonemic masking effects in the correct identification of homophone targets is not due to the elimination of reliance on phonology, its computation or its consideration.

The source of null phonemic masking effects with homophones

Why do homophones yield null phonemic masking effects? Our findings reflect an instability inherent in the perception of masked homophones. We have demonstrated that masked homophones may yield both positive and null phonemic masking effects in either correct target identification or homophone errors. We attribute these divergent manifestations to the activation of the homophone mates via a shared phonology. The reinstatement of the target's phonology by the pseudohomophone accentuates this competition: The pseudohomophone activates the target's competitors and it introduces an additional competing spelling of its own. Consequently, reliance on the phonology of the target and mask may not necessarily improve target identification. Participants' interpretation of the outcome of this rich dynamics may be further modulated by their strategies. For instance, we noted that the brief exposure duration in Experiment 1 may result in increased vigilance in the phonology discouraging condition. This strategic adjustment enhances target identification when its spelling is certain (with the graphemic mask), but decreases target identification when multiple contradictory spelling are activated (with the pseudohomophone mask), resulting in an inhibitory effect of phonemic masking in the discouraging condition of Experiment 1. The increase in exposure duration for the target and mask in Experiment 2 may have reduced the need for such additional vigilance. The increased duration, however, also allowed for the competition between the homophone's mate to further develop. The coupling of increased competition and lesser vigilance might have led to the elevation in homophone errors in Experiment 2.

Our account attributes the various outcomes of masked homophone identification to a competition between multiple spellings that share a common phonology. The competition may be captured within a dynamical framework including bidirectional connections between spelling and phonology (e.g., Stone et al., 1997; Van Orden & Goldinger, 1994). The outcomes of the competition depend on three factors. The first factor concerns the interconnectivity between the target, mask and homophone mates, which, in turn, depends on the relative frequency of the homophone mates, and their orthographic and phonological similarity to the mask. The second factor is the strength of the visual input, which, in turn, depends on the exposure durations of the target and mask in the visual display. The third factor is participants' response strategies, which modulate the interpretation of activation in generating a response. The precise outcomes of this competition for any given target, mask, exposure duration or strategy level are difficult to predict. In fact, given the inherent nonlinearity of the three field masking paradigm (Michaels & Turvey, 1979), and homophone identification, in particular, these outcomes may not be fully predictable. For our present discussion, however, the existence of this competition is far more important than its outcomes. If the assembly of homophone's phonology triggers a competition whose consequences include null phonemic masking effects, then greater caution is required in the interpretation of null effects with homophones. Such null phonemic masking effects may not necessarily reflect the absence of reliance on phonology.

At present, our main piece of evidence for the competition between the homophone target and its mates is the modulation of homophone errors by the mask's phonology. We now turn to examine additional predictions of our competition account. If the pseudohomophone triggers a competition between the target and its competitors, then the emergence of the phonemic masking effect should depend on the target's likelihood of winning the competition. The competition between the homophone's mates is likely to be won by the most frequent competitor. Consequently, strongly dominant homophones are expected to benefit from the reinstatement of their phonology. In contrast, because subordinate homophones are likely to lose the competition, the reinstatement of their phonology should not benefit their identification. The findings of a recent investigation by Berent and Van Orden (2000) support this prediction. Berent and Van Orden (2000) compared the effect of phonemic masking of dominant homophones and their subordinate mates under a phonology discouraging manipulation. The results of four experiments revealed consistent null phonemic masking effects for subordinate homophones. Conversely, significant phonemic masking effects were observed for dominant homophones.

The effect of homophone dominance may also be assessed in our present findings. The homophones used in our experiments were taken from the list of stimuli of Verstaen et al. (1995). These materials were not designed to test for dominance effects, but they nevertheless included a relatively even mix of 25 dominant homophones and 26 subordinate homophones. If our dominance account is correct, then it should be possible to unveil stronger evidence for phonology within each of our markers by considering target dominance. Our Experiment 2 was designed to maximize the competition between the homophone mates by using relatively long durations for the target and mask. Indeed, Experiment 2 yielded an increase in homophone errors coupled with a null phonemic masking effect. Given such strong evidence for the

Table 5. Homophonic errors (% errors) in Experiment 2 as a function of target dominance, mask type and the strategy manipulation.

	Mask type		
	Pseudo-homophone	Graphemic	Control
Dominant homophone targets			
Encouraging	2.5	0.0	0.0
Discouraging	5.0	3.0	0.5
Subordinate homophone targets			
Encouraging	8.7	3.4	1.0
Discouraging	8.2	2.9	1.9

presence of competition, these data permit evaluating the role of homophone dominance in each of these markers of phonology. The following analyses[4] first examine the effect of target dominance on homophonic errors and the phonemic masking effect in Experiment 2. We next assess the effect of the orthographic similarity of the pseudohomophone to the target's competitor on the emergence of the phonemic masking effect.

The modulation of homophonic errors by dominance. If homophonic errors reflect the activation of the homophone's competitor, then subordinate homophones should be more likely to result in homophonic errors compared to dominant homophones. Furthermore, if the activation of competitors is constrained by phonology, then homophonic errors for subordinate homophones should increase by the reinstatement of the target's phonology.

Table 5 lists the percentage of homophonic errors as a function of mask type, target dominance and the strategy manipulation. We first tested for the main effect of dominance by means of a 3 way ANOVA (2 dominance $\times$ 2 strategy $\times$ 3 mask) on homophonic errors[5] As expected, homophonic errors were significantly more frequent for subordinate targets [$F(1,49) = 4.80$, MSe = 0.010]. We next evaluated the effects of mask type within each of the dominance levels by means of separate 2 way ANOVA's (2 strategy $\times$ 3 mask). The mask type modulated the identification of both dominant [$F(2,48) = 4.68$, MSe = 0.003] and subordinate targets [$F(2,50) = 9.63$, MSe = 0.007]. However, planned comparisons revealed some marked difference in the effect of the mask's phonology within the two dominance levels. For subordinate targets, homophonic errors were significantly more frequent in the presence of the pseudohomophone relative to the graphemic mask [$F(1,50) = 7.48$; $F(1,48) = 7.48$; at the phonology encouraging and phonology discouraging

Table 6. Target identification accuracy (% correct) in Experiment 2 as a function of target dominance, mask type and the strategy manipulation.

	Mask type		
	Pseudo-homophone	Graphemic	Control
Dominant homophone targets			
Encouraging	43.5	35.5	19.0
Discouraging	43.5	35.5	17.5
Subordinate homophone targets			
Encouraging	17.8	21.6	7.2
Discouraging	26.4	24.5	6.2

conditions, respectively]. In contrast, the effect of phonemic masking was much weaker with dominant targets. The pseudohomophone did not significantly increase homophone errors relative to the graphemic mask in the phonology discouraging condition [$F(1,48) = 2.57$, $P = 0.1177$], and only marginally so in the phonology encouraging condition [$F(1,48) = 3.96$, $P = 0.052$]. These findings support the view of homophone errors as the outcome of a competition mediated by phonology and reaffirm their view as a marker of phonology.

The modulation of the phonemic masking effect by dominance. We now consider the effect of dominance on correct target identification. If dominant homophones are more likely to win the competition between the homophone identities, then dominant homophones should be more accurately identified than subordinate homophones. Furthermore, the reinstatement of phonology should be more likely to enhance the identification of dominant compared to subordinate targets.

Table 6 lists the percentage of correct target identification as a function of mask type, target dominance and the strategy manipulation. We first tested for the main effect of dominance on correct target identification[6] by means of a 3 way ANOVA (2 dominance × 2 strategy × 3 mask). As expected, dominant targets were identified more accurately than subordinate targets [$F(1,39) = 10.28$, MSe = 0.170]. We next evaluated the effects of mask type in each of the dominance levels.

Recall that the results of Experiment 2 did not yield an overall significant effect of phonemic masking in either the phonology encouraging or phonology discouraging conditions. However, when the same data were broken by dominance, the results were dramatically different. The ANOVA's (2 strategy × 3 mask) conducted over the 25 dominant targets yielded a significant main effect of mask type [$F(2,48) = 14.25$, MSe = 0.058]. Planned comparisons indicated equal size, phonemic masking effects in both the phonology encouraging [$F(1,48) = 3.73$, $P = 0.0593$] as well as phonology discouraging [$F(1,48) = 3.73$, $P = 0.0593$] condition. A significant main effect of mask type was detected also for subordinate targets [$F(2,50) = 14.38$ MSe = 0.030]. However, the phonemic masking effect did not approach significance for subordinate targets (all $F < 1$). These findings replicate the results of Berent and Van Orden (2000) in demonstrating a modulation of the phonemic masking effect by target dominance: Dominant homophones show phonemic masking effects, subordinate homophones do not. The consideration of the relative strength of the homophone competitors is thus critical for unmasking the phonemic masking effect with homophones.

The effect of the orthographic similarity of the pseudohomophones to competitors on the identification of dominant homophones. Our analysis so far has considered only the constraints related to the dominance of the homophone mates. We now turn to consider the constraints provided by the pseudohomophone mask, namely, its phonology and spelling. By definition, the phonology of the pseudohomophone contributes equally to both mates. However, the spelling of the pseudohomophone mask may not provide equal constraints for both homophone spellings. For instance, the pseudohomophone RYTE bears closer similarity to the subordinate target (WRITE) than the dominant target (RIGHT). Thus, the reinstatement of the phonology of a dominant target, RIGHT, by RYTE should create a counter force in favor of the subordinate competitor. Given strongly dominant targets, this counter-force may be insufficient for the subordinate mate to win the competition. However, the spelling similarity of the pseudohomophone to the subordinate mate may nevertheless impair the identification of the dominant target.

To examine this prediction, we calculated the orthographic similarity between the pseudohomophone of dominant targets and their subordinate competitor using OS – our index of orthographic similarity. As expected, there was a significant negative correlation between the correct identification of dominant homophones and the orthographic similarity of the pseudohomophone mask to its subordinate competitor in both the phonology encouraging ($pr = -0.36$) and phonology discouraging (Spearman $r = -0.45$) conditions.[7] Please note that this very specific effect of spelling similarity cannot be reduced to a purely orthographic effect. Instead, the effect of spelling similarity appears to depend on the *phonological* identity of the pseudohomophone mask and the competitor homophone. Two findings support this conclusion. First, a similar analysis on the graphemic control mask revealed no effect of its orthographic similarity to the subordinate mate on target identification (Spearman $r = 0.02$ for the encouraging condition; $r = 0.05$, for the discouraging conditions). Thus, the cost of activating the homophone's mate by an orthographically similar mask is found only when the mask shares phonology with the target. Second, the presence of orthographically similar neighbors that do not share phonology with the target and mask does not have a similar effect on target identification. Specifically, an analysis of Coltheart N (the number of words that can be constructed from each mask by changing one letter) found no evidence for a decrease in the identification of dominant targets due to the similarity of any of the mask types to orthographic competitors.[8] These results suggest that the similarity of the mask to word competitors impairs the identification of dominant targets only when the target, mask, and competitors are phonologically identical.[9]

Conclusion

Our findings demonstrate that the phonemic masking of homophones entails a competition mediated by phonology. This competition often prevents homophone targets from benefiting from the reinstatement of their phonology, resulting in null phonemic masking effect. We view such null phonemic masking effects as a direct consequence of reliance on phonology, rather than its absence.

We began this article by noting the general prediction of the hypothesis that phonology is mandatory for skilled reading. If phonology is mandatory, then phonology should always constrain word identification, even under conditions that discouraged its use. The conditions of our experiments actively discouraged reliance on phonology for word identification. Homophones are conspicuously presented, and homophones' ambiguous phonology penalized performance overall. Clearly there was a cost for participants to rely on phonology in the present experiments. Nevertheless, target and mask phonology interacted to modulate performance in all conditions.

The implications of our findings are both methodological and theoretical. Our analyses underscore the importance of comparing various phonology marker effects (e.g., the effect of phonemic masking on correct target identification and homophone errors) in order to establish the role of phonology in reading. Perhaps it may pay to reexamine other reported null phonology effects in this fashion. Our results further demonstrate that the computation of phonology persists despite the presence of conditions that strongly discourage its use. These results are consistent with the findings of numerous studies demonstrating the contribution of phonology under circumstances in which its computation is contrary to task demands (e.g., Azuma & Van Orden, 1997; Berent, 1997; Berent & Perfetti, 1995; Berent & Van Orden, 2000; Bosman & DeGroot, 1996; Ferrand & Grainger, 1996; Gibbs & Van Orden, 1998; Lukatela et al., 1997; Lukatela & Turvey, 1993; Perfetti & Bell, 1991; Perfetti & Zhang, 1994; Peter & Turvey, 1994; Stone & Van Orden, 1993;

Van Orden, 1987; Van Orden et al., 1988; Ziegler & Jacobs, 1995; Ziegler et al., 1997a). These findings suggest that phonology is an early constraint on word identification whose contribution to skilled reading may be mandatory.

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Notes

1. We use the term "reliance on phonology" generically, to refer to either the computation of phonology or its consideration.
2. Following Winer (1971: 530), the error term for testing the between participant factor was computed using a pooled error term. The degrees of freedom were calculated using Satterthwaite's approximation.
3. Verstaen et al.'s (1995) findings reflect a numerically higher rate of homophone errors in the presence of the pseudohomophone mask in Experiments 2-4. However, they did not provide a statistical analysis of the effect of mask.
4. Because our experiments did not counterbalance dominance across participants, the contrast between dominant and subordinate homophones may be adequately evaluated only in the item analysis.
5. The very brief duration in Experiment 1 allowed for only a very small number of homophonic errors. We nevertheless assessed the effect of dominance on these errors. Homophonic errors were overall more frequent for subordinate than for dominant targets [$F(1,49) = 8.47$, MSe = 0.007]. Homophonic errors for dominant targets were not modulated by mask's phonology (all $F < 1$). In contrast, homophonic errors for subordinate targets were more numerous in the presence of the pseudohomophone mask relative to its graphemic control, and this difference was significant in the phonology encouraging condition [$F(1,50) = 5.46$].
6. In view of the brief duration of Experiment 1, we did not expect strong modulation of the effect of mask type by dominance. Correct target identification was higher for dominant targets than for subordinate targets [$F(1,49) = 7.861$, MSe = 0.203]. In accord with Experiment 2, there was no evidence for a phonemic masking effect for subordinate targets (all $F < 1$). Likewise, the phonemic masking effect was not significant for dominant targets in the phonology encouraging condition [$F(1,48) = 1.23$, $P = 0.2729$ n.s]. Interestingly, the analysis of dominance demonstrated that the inhibitory effect of phonemic masking observed in the discouraging condition was entirely due to dominant targets [$F(1,48) = 5.86$]. We discuss this finding in note 9.
7. Correct identification of dominant homophones (*right*) in the phonology encouraging condition was positively correlated with spelling similarity between pseudohomophone masks and targets ($pr = 0.39$), and the two respective indices of similarity are negatively

correlated ($r = -0.47$). In view of these significant correlations, we assessed the orthographic similarity of the pseudohomophone and the homophone competitor by means of partial correlations. The correlation between OS (calculated between the pseudohomophone and target spellings) and correct target identification was not reliable in any other condition in Experiments 2 or 1, so partials were not necessary in those conditions.

8. Coltheart N for the respective masks was distributed as follows: pseudohomophone masks (M = 3.0, SD = 2.98); graphemic control masks (M = 3.58, SD = 3.56); baseline control masks (M = 3.54, SD = 3.37). Coltheart N does not reliably predict correct identification to dominant targets with either baseline control masks (encouraging: $r = 0.19$; discouraging: $r = 0.04$) or graphemic control masks (encouraging: $r = 0.19$; discouraging: $r = 0.15$). However, Coltheart N for pseudohomophone masks is reliably and positively (not negatively!) correlated with correct identification in the encouraging condition ($r = 0.48$), but not the discouraging condition ($r = 0.32$, $P > 0.13$). This positive correlation may derive from a statistically reliable but spurious negative correlation between OS, computed between pseudohomophone masks [RYTE] and homophone competitors [WRITE]), and pseudohomophone masks Coltheart N [$r = -0.43$]. Partial correlation analyses better preserved the reliable negative correlation of OS (between RYTE and WRITE, for example) and correct identification of right ($pr = -0.40$), than the correlation with Coltheart N ($pr = 0.33$).
9. Given the brief duration of the target and mask in Experiment 1, we did not observe strong evidence for competition between the homophone mates in the form of homophonic errors. Recall, however, that the findings of the discouraging condition reveled an unusual decrease in target identification relative to the graphemic mask, a decrease we attributed to heightened vigilance in the phonology discouraging condition. If dominant homophones are more strongly activated, they may also have a greater potential to benefit from vigilance given the very brief SOA in Experiment 1. The increased vigilance, however, may impair the identification of targets due to the activation of competitors by the pseudohomophone. Accordingly, the identification of dominant target should be impaired by pseudohomophones whose orthography resembles the subordinate competitor. In accord with this expectation, the correct identification of dominant targets correlated significantly with the orthographic similarity of the pseudohomophone mask to the subordinate competitor (Spearman $r = -0.62$, $r = -0.48$, for the encouraging and discouraging condition, respectively). In contrast, there was no such effects in the presence of the graphemic mask (Spearman $r = -0.27$, $P > 0.21$, for the encouraging condition; $r = -0.31$, $P > 0.13$, for the discouraging conditions), nor did the presence of orthographic neighbors (Coltheart N) decrease target identification . Thus, replicating the findings of Experiment 2, the activation of orthographically similar competitors by the mask impairs the identification of dominant targets only when the target, mask, and the competitor share a common phonology. The existence of this competition accounts for both the null phonemic masking effect and the inhibitory effect observed in the phonology encouraging and discouraging conditions of Experiment 1, respectively.

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