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Can We Unmask the Phonemic Masking Effect? The Problem of Methodological Divergence

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Abstract

In studying cognition, we infer the presence of mental structures in an idealized setting from performance in various experimental settings. Although experimental settings are believed to tap the mental structure of interest, they also always reflect idiosyncratic task-specific properties. Indeed, distinct methods often diverge in their outcomes. How can we assess the presence of the mental structure in the idealized setting given divergent outcomes of distinct methods? We illustrate this problem in a specific example concerning the contribution of phonology in reading. Evidence for the role of phonology in the "idealized" reading setting is assessed by different methods. Methods of masked and unmasked display disagree in their outcomes. The contribution of phonology appears robust under masking, but limited under unmasked display. We outline two alternative explanations for the robustness of phonological effects under masking. On one view, phonemic masking effects are a true reflection of early reading stages (Berent & Perfetti, 1995). Conversely, Verstaen et al. (1995) argue (1) that masking overestimates the contribution of phonology and (2) that phonemic masking effects are eliminated by a manipulation that discourages reliance on phonology. We demonstrate that (2) is incorrect, but (1) cannot be resolved empirically.

In studying cognition, we infer the contents and structure of a cognitive architecture from observed behavior in an experimental setting. Our interest, however, is rarely limited to the specific experimental setting. Instead, we wish to describe the mental structures that pertain to some idealized general setting[1]. Our empirical data, however, provide us with only partial information for making such generalizations. Behavior observed in a given experimental setting is always at least partly due to the idiosyncratic requirements of the experimental task which may be irrelevant to the idealized setting. For instance, our own research attempts to reveal the mental structures underlying performance in an idealized "natural" reading setting. Laboratory tasks all maintain some of the characteristics of this idealized setting, but, in addition, they present some idiosyncratic demands, such as the discrimination of words from nonwords, speeded naming or identifying words when they can barely be seen due to visual masking. Indeed, distinct methods, believed to tap into a common mental structure, often diverge in their outcomes. Such divergence calls for an interpretation. Given that divergence of outcomes is partly due to methodological differences, how could one assess the generality of an inferred mental structure?

Consider, for instance, a case where two methods, M_1 and M_2 may both reflect the presence of a certain mental structure α at some idealized general setting **M**. Suppose, however, that these methods disagree in their outcomes. Method M_1 yields positive evidence for α whereas no evidence for α is detected by method M_2. One is then left with two related questions. (1)Why do the methods diverge in their outcomes? (2) Which outcome should we trust: Is the mental structure α present in the idealized setting **M**? A reply to these questions might include one of two moves[2]. One may choose to reify the outcome of method M_1 by assuming that M_1's outcome (but not M_2's) is a true marker of the structure α. On this view, structure α generally does underlie performance in the idealized setting **M**. The failure of method M_2 to reflect its presence is due to some task specific factors which reduce its sensitivity. Conversely, one may conclude that method M_1 induces an idiosyncratic bias for detecting the presence of representation α. The detection of α by method M_1 is thus due to some task specific factors that are unrepresentative of the idealized situation. Thus, method M_2 's null outcome is the true marker, and structure α generally does not underlie

[1]For the present discussion, we disregard the important question of whether such general circumstances exist by referring to an idealized, rather than real, general circumstances.

[2]Two other possible moves are (3) Rejecting the outcomes of both M_1 and M_2 on the grounds that their context-sensitivity as markers of α prevents inference regarding the idealized setting M and (4) accepting the outcome of both M_1 and M_2, assuming strategic control over α in the idealized setting. Neither of these moves escapes the induction problem. Practically all known markers of cognitive structures are context sensitive, so move 3 entails the rejection of cognitive psychology as an empirical science. Move 4 equates the study of cognition with the study of context sensitive strategic control--a rather different enterprise than the traditional pursuit of context-free structures (see Van Orden, Aitchison & Podgornik, 1996b). This move, however does not escape theory driven assumptions regarding methods M_1 and M_2 as (true) mirrors of **M**.

performance in the idealized situation **M**. Importantly, each of these moves regarding the presence of α in the idealized setting requires additional assumptions regarding methods M_1 and M_2. If these additional assumptions are derived from the same theory regarding mental structure α, then we face a problem of circularity: Theory-driven assumptions regarding method-properties predetermine the acceptability of evidence pertinent to the same theory (Van Orden, Pennington & Stone, 1996a, Van Orden et al., 1996b). The present research extends the investigation of Van Orden and colleagues to an additional example where theory-driven methodological assumptions determine the interpretation of data in reading experiments. We will not resolve these issues because there does not appear to be a simple correct answer. By reporting this example, we hope to raise specific questions regarding reading research, as well as general questions regarding the larger problem of methodological divergence.

Our example concerns the role of phonology in reading, undoubtedly, one of the most controversial issues in psycholinguistics. 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 *slow* phonology hypothesis (e.g., Seidenberg, Waters, Barnes & Tanenhaus, 1984), the assembly of phonology is too slow to affect lexical access. Its computation is resource-demanding and subject to strategic control. On this view, words' meanings are retrieved primarily based on graphemic information. In contrast, the *fast* phonology hypothesis (e.g. Van Orden, Pennington & Stone, 1990) assumes that the assembly of phonology is very fast and relatively automatic. Phonology is thus believed to be a general, perhaps mandatory component of reading.

The existing, very large body of evidence pertaining to this question is highly contradictory. In a recent review paper, Berent & Perfetti (1995) suggested that the contradictions regarding the nature of phonology and its contribution to reading are systematically linked to the type of method used. Masking methods, displaying the words for a brief duration (e.g. 15 ms) followed by a masking stimulus, typically portray phonology as a fast and general constraint on reading (e.g., Perfetti & Bell, 1991). In contrast, methods in which words are not masked depict the assembly of phonology as slow, controlled and limited in its effect (e.g., Seidenberg et al., 1984). Berent & Perfetti (1995) explained that divergence within a specific theory of reading, the two cycles model. According to the two cycles model, phonology is assembled in two consecutive stages. The first consonantal cycle is fast and automatic, followed by a second, vowel cycle, which is slow and controlled. The methodological contradictions are thus addressed by assuming temporal changes in the contents of phonological representations which parallel the temporal contrast between experimental methods. Methods using clearly presented, unmasked words portray assembly as slow and controlled because they tap primarily into the late vowel cycle. In contrast, masking methods tap into the early consonantal cycle, and thus, depict phonology as a fast and general constraint. In essence, this solution to the methodological conflict assumes that both methods provide true reflections of the assembly mechanism.

From the point of view of the slow phonology hypothesis, Berent & Perfetti's (1995) account of results obtained using unmasked words is relatively uncontroversial. The idea that these findings reflect a slow and controlled vowel cycle fits well with the slow phonology hypothesis. It is the robustness of phonological effects found using masking methods that is the subject of debate. Berent and Perfetti assumed that masking procedures provide a faithful reflection of the general contribution of consonant assembly to reading. Conversely, one may question phonological effects found using masking methods by assuming that masking distorts natural reading processes. Such an explanation has been proposed by Verstaen, Humphrey, Olson, & D'Ydewalle (1995). On their view, phonological effects under masking do not reflect an inherent property of reading; they are induced by the masking technique. By contrast, graphemic information is the principal constraint on natural reading. Graphemic information, however, is disrupted by masking (see also Hawkins, 1976; Carr, Davidson & Hawkins, 1978; Carr & Pollatsek, 1985). This forces the reader to rely on phonology, which is otherwise a rather atypical method of deriving a word's meaning.

The previous view of phonology as an optional, weak constraint on reading predicts that phonology effects may be eliminated under conditions discouraging its use. Verstaen et al. (1995) supported this claim using a masking method. 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 subjects' 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 phonology nor graphemes with the target. The subjects' task is simply to report the spelling of the target. If subjects 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 is referred to as the phonemic masking effect. If subjects 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 at the beginning of the experiment results in the cancellation of the phonemic masking effect whereas the inconspicuous presentation of homophone targets toward the end of the experiment yields a significant phonemic masking effect.

The results of Verstaen et al (1995) raise questions at several levels. Concerning reading specifically, these results question Berent & Perfetti's (1995) claim that the masking method taps a mandatory component of assembly. Their findings thus challenge both the fast phonology hypothesis and the validity of the masking technique for revealing fast phonology. At a more general theoretical level, these findings illustrate the difficulty of interpreting methodological divergence. Our experiment concerns reading specifically, but we return to the wider implications in the discussion.

The evidence supporting the suppression of phonology always rests on a failure to observe a phonology effect (Van Orden et al., 1990). Obviously, the support of hypotheses by null results is a questionable practice. The specific null effect of Verstaen et al. (1995) further disagrees with existing evidence demonstrating phonological effects under masking despite conditions that discourage reliance on phonology (e.g., Berent, 1995; Van Orden, 1987; Ziegler & Jacobs, 1995; Ziegler, Van Orden & Jacobs, in press). We begin our investigation by revisiting this null effect. We first attempt to replicate the findings of Verstaen et al. using their homophone targets. Following their design, we manipulated subjects' reliance on phonology using two lists consisting of homophone targets and nonhomophone fillers. In the phonology encouraging condition, one group of subjects was presented with the homophone targets after seeing nonhomophone fillers, and they were not informed of the presence of homophones in the list. According to Verstaen et al (1995), these conditions should encourage the reliance on phonology, yielding a significant phonemic masking effect. In contrast, subjects in the phonology discouraging condition were presented with the homophone targets at the beginning of the experiment. Moreover, they were explicitly warned about the presence of homophones and advised to rely on spelling. If phonology may be suppressed under conditions discouraging its use, then this condition should produce a null phonemic masking effect, as found by Verstaen et al. (1995).

Method

Materials

The homophone targets and their masks were 51 of the 54 homophones used by Verstaen et al. (1995)[3]. The nonhomophone fillers were the 48 simple-vowel targets used in Berent & Perfetti, (1995, Experiment 4). Following Verstaen et al., the sets of homophone and nonhomophone targets were arranged in two combinations designed to encourage or discourage the reliance on phonology. In the phonology encouraging condition, the nonhomophone targets were presented first followed by the homophone targets. In the phonology discouraging condition, the homophone targets were presented fist followed by the nonhomophone targets. Within each condition, the presentation of each target and its nonword masks was counter-balanced. Targets were presented in lower case whereas masks were presented in upper case, and they were each bounded by number signs (#) to the right and left of their outermost letters.

Procedure

At the beginning of the trial, a pattern mask (########) appeared as a fixation at the center of the monitor. Subjects 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 subject responded. The target and mask were each presented for two refresh cycles (28 ms). The order of trials for each subject within each block of trials (homophone vs. nonhomophone) was random. To reduce the visual contrast, all visual stimuli were presented in a blue color on a black background

Subjects were asked to write down the targets and masks they perceived. In the phonology discouraging condition, they were warned about the presence of homophones and advised to attend to spelling disregarding words' pronunciations. These subjects were also warmed up with homophone targets. None of the targets used in the warm up appeared in the experimental session, and they were all followed by a control mask.

Subjects

Subjects 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 subjects per condition and eliminated 6 subjects from the phonology encouraging condition and 4 subjects from the discouraging condition.

Results

Homophone Targets

Correct Identification. The ANOVA on the identification accuracy of homophone targets (2 strategy x 2 mask) revealed a significant interaction of mask by strategy ($F_1(2, 140)=3.419$, MSe=.007, p=.0355; $F_2(2, 100)=3.042$, MSe=.012 p=.0522). In the encouraging condition, the pseudohomophone ($\Delta=7.84\%$, $F_1(1, 140)=15.83$, p=.0001; $F_2(1\ 100)=13.256$, p=.0004) and graphemic mask ($\Delta=5.22\%$, $F_1(1, 140)=7.02$, p=.009; $F_2(1, 100)=5.894$, p=.017) each facilitated recognition compared to the control mask. However, the phonemic masking effect was not significant: recognition with the pseudohomophone and graphemic mask did not differ significantly ($\Delta=2.62\%$, $F_1(1, 140)=1.766$, p=.1856; $F_2(1, 100)=1.471$, p=.228). In contrast, the discouraging condition resulted in a significant phonemic masking effect. This effect, however, was inhibitory in nature: Identification accuracy in the presence of the pseudohomophone mask was significantly lower compared to the graphemic mask ($\Delta=4.91\%$, $F_1(1, 140)=6.21$, p=.0138; $F_2(1, 100)=5.155$, p=.0253). In

[3]One target was excluded because its pseudohomophone failed to match the target's pronunciation in American English. Two additional targets were excluded for the purpose of counterbalancing.

addition, the graphemic mask (Δ=8.66%, $F_1(1, 140)=19.32$, p=.0000; $F_2(1, 100)=16.11$, p=.0001), but not the pseudohomophone (Δ=3.75%, $F_1(1, 140)=3.62$, p=.059; $F_2(1, 100)=3.039$, p=.0844) improved recognition accuracy compared to the control mask

	Encouraging	Discouraging
Pseudohomophone	26.63	24.50
Graphemic	24.01	29.41
Control	18.79	20.75

Table 1: Target identification accuracy (% correct) as a function of mask type in the phonology encouraging and phonology discouraging condition

Homophone Errors. Of the 1836 trials involving homophone targets, 31 of the responses given in the phonology encouraging condition and 36 of the responses in the phonology discouraging condition were incorrect reports of the target's homophone (e.g., *sign* reported to the target *sine*). The ANOVA on homophone errors (2 strategy x 2 mask) revealed a significant main effect of mask type ($F_1(2, 140)=5.017$, MSe=.001, p=.0079; $F_2(2, 100)=9.216$, MSe=.001, p=.0002). Interestingly, homophone errors reflected a phonology effect. Across strategy conditions, the pseudohomophone mask resulted in a marginally significant increase in homophone errors compared to the graphemic mask (Δ=.0098, $F_1(1, 140)=2.72$, p=.1012; $F_2(1, 100)=5.005$, p=.0275) and the control mask (Δ=.0188, $F_1(1, 140)=10.028$, p=.0019; $F_2(1, 100)=18.47$, p=.0000). The graphemic mask also produced a marginally significant increase in homophone errors compared to the control mask (Δ=.009, $F_1(1, 140)=2.39$, p=.13; $F_2(1, 100)=4.225$, p=.04). An inspection of the cell means, however, revealed that the phonology effect is mainly due to the phonology encouraging condition. In the phonology encouraging condition, the pseudohomophone mask resulted in a significant increase in homophone errors compared to the graphemic mask (Δ=.0147, $F_1(1, 140)=3.95$, p=.049; $F_2(1, 100)=4.664$, p=.0332). In contrast, no such difference in homophone errors was found in the phonology discouraging condition (Δ=.0048, $F_1(1, 140)<1$, $F_2(1, 100)<1$).

	Encouraging	Discouraging	All
Pseudohomophone	.0278	.0278	.0278
Graphemic	.0131	.0229	.0180
Control	.0098	.0082	.0090

Table 2: The mean number of homophone errors produced by a subject per homophone target in the phonology encouraging and phonology discouraging conditions.

Discussion

The present experiment was designed to assess the claim of Verstaen et al (1995) that reliance on phonology may be eliminated by phonology discouraging conditions. In support of their claim, Verstaen and colleagues presented a null effect of phonemic masking obtained when subjects were confronted with homophone targets. The results of the present experiment contradict the attribution of this null effect to the absence of phonology. Although the pseudohomophone mask increased homophone errors compared to the graphemic mask, no phonemic masking effect was obtained in correct target identification. Thus, the strategy manipulation is not *necessary* to produce a null phonemic masking effect. Moreover, the results of the phonology discouraging condition suggest that their strategy manipulation is not *sufficient* to eliminate phonology either[4]. A strong inhibitory phonemic masking effect was obtained under conditions designed to discourage reliance upon phonology. The topology of effects in our data is identical to theirs; A similar nonsignificant inhibitory trend was observed also in each of the studies of Verstaen et al. (1995). Because the pseudohomophone and graphemic mask differ only in their phonological similarity to the target, any difference in their effect must indicate the presence of phonology. What is the reason for this inhibitory effect? Why did it emerge in the discouraging condition?

By definition, the pseudohomophone provides subjects with the target's correct phonology at the price of incorrect spelling. If phonology feeds back activation to spelling (Stone, Vanhoy & Van Orden, in press), then the pseudohomophone phonology may activate the spelling of the target's homophone competitor (e.g. *sign*), introducing additional competition. The activation of multiple spellings may result in a competition which ultimately reduces the activation of the target's correct spelling (Ziegler & Jacobs, 1995; Ziegler et al., in press). Thus, in the presence of homophone targets, the pseudohomophone may not only increase the availability of incorrect spelling information (expressed in homophone errors in the encouraging condition) but also decrease the activation of the target's correct spelling (expressed in failures of target recognition in the discouraging condition). Phonemic masking thus increases the uncertainty regarding targets' spelling. Given the emphasis on correct spelling in the discouraging condition, subjects may adapt to the spelling uncertainty by means of two strategies. They may adopt a cautious report strategy in cases of spelling uncertainty. In addition, subjects may increase their tolerance of incorrect phonemic information associated with non-homophone masks. These two strategies would lead to a decrease in target report with the pseudohomophone and perhaps an increase in the presence of the graphemic mask. The inhibitory phonemic masking effect in the phonology discouraging condition may reflect the combined effect of these two strategies. Interestingly, an inhibitory phonemic masking effect has also been found in the absence of such an explicit strategy manipulation in Hebrew, a language manifesting pervasive homophony (Berent & Frost, in press). An inhibition of inconsistent correspondences between phonemes and graphemes may be necessary to ensure correct spelling in this language. Importantly, however, inhibitory effects of

[4]Proponents of the slow phonology hypothesis may still argue that phonology assembly may be eliminated by some other still stronger discouraging manipulation. This pursuit of null phonology effect would seem to carry the burden of proof.

phonemic masking are strong evidence for the contribution of phonology. Thus, in contrast to the conclusion of Verstaen et al. (1995), the present results suggest that reliance on phonology persists under conditions designed to suppress its contribution.

What are the general implications of our findings for the debate regarding the contribution of phonology in reading? We began this discussion with a stalemate. One of the strongest sources evidence supporting the fast phonology hypothesis is the robustness of phonology effects under masking conditions. These findings contrast with outcomes of methods of unmasked display. We outlined two competing accounts for this methodological divergence. Specifically, these accounts concern the phonemic masking effects. Berent & Perfetti (1995) attributed the robustness of phonemic masking effects to the inherent properties of consonant assembly, tapped by the masking procedure. Conversely, Verstaen et al. (1995) argued that masking effects artificially encourage phonology by selectively degrading graphemic information. Our present findings demonstrate that subjects rely on phonology under phonology discouraging masking conditions. Unfortunately, however, these findings do not resolve the stalemate with respect to the role of phonology in reading. The resolution of this stalemate requires a priori, objective knowledge of the masking procedure. The falsification of Verstaen et al.'s (1995) claim that assembly may be suppressed under masking does not discredit their general contention that the masking procedure overestimates the contribution of phonology.

It seems difficult, perhaps impossible, to determine whether evidence for phonology from masking studies reflects the idealized reading setting or artifacts of the masking procedure. Evidence for a mental structure in an experimental setting increases our certainty that this structure is present in the experimental setting, but it does not necessarily increase certainty about its presence in the idealized setting. The tighter the construction of the experimental setting, the greater the difficulty in generalizing its outcomes to the idealized setting. This uncertainty is particularly salient when outcomes of distinct methods diverge. These problems are clearly not limited to any particular experimental method, but they are especially grave with respect to masking. If Berent & Perfetti (1995) are right to claim that the contents of phonology change along the time dimension, then properties of early reading stages are fully confounded with the masking paradigm. Only masking methods may reveal the unique properties of early reading stages. If so, then divergence between the outcomes of masked and unmasked settings is virtually guaranteed.

A methodological divergence invites the labeling of empirical methods as biased mirrors of an idealized setting. Given inherent uncertainty as to how idiosyncratic tasks affect the outcomes of experiments, the resolution of methodological divergence cannot be achieved in a theory-independent fashion. We offer no solution for these problems. However, recognizing the role of theory driven assumptions in such interpretations may reduce the risk of unacknowledged circularity. The illusion that methodological divergence can be resolved based on theory independent inferences is dangerous, since it inevitably licenses theories to ignore conflicting data by stigmatizing methods used in their collection (Van Orden et al., 1996b). Recognizing the role of theory in the evaluation of empirical outcomes could protect against unfounded dismissals of conflicting data. Pluralism may well be our best means for progress.

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