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Automatic (Prelexical) Phonetic Activation in Silent Word Reading: Evidence from Backward Masking

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Visual access to a printed word may be accompanied by a very rapid activation of phonetic properties of the word as well as its constituent letters. We suggest that such automatic activation *during* word identification, rather than only postlexical recoding, routinely occurs in reading. To demonstrate such activation, we varied the graphemic and phonetic properties shared by a word target and a following pseudoword mask. Graphemic (MARD) and homophonic (MAYD) masks, equated for number of letters shared with a word target (*made*), both showed a masking reduction effect relative to a control mask. There was an additional effect of the homophonic mask over the graphemic mask, attributable to phonetic activation. A second experiment verified this pattern of mask reduction effects using conditions that ruled out any explanation of the effect that does not take account of the target–mask relationship. We take the results to suggest that a phonetic activation nonoptionally occurs (prelexically) during lexical access. © 1988 Academic Press, Inc.

Does visual access to a written word arouse the associated speech form of the word? This question, central to any understanding of silent reading, has usually been cast in terms of phonetic recoding, that is, whether visual access to a word's memory location is mediated by recoding its graphemic input into phonetic information. When asked this way, the consensus answer seems to be that adult readers often use unmediated routes (Baron, 1973; Davelaar, Coltheart, Besner, & Jonasson, 1978; Frederiksen & Kroll, 1976), although this consensus is challenged in recent experiments by van Orden (1987).

In our view, the question of phonetic mediation misses part of what's important in the issue of speech processes in reading. Whether "recoding" occurs may be merely a question of timing: When do phonetic codes get formed, relative to other kinds of word codes? However, a basic question for us is whether phonetic activation occurs routinely as part of lexical access. The occurrence of automatic phonetic activation allows phonetic properties of a word to be part of the immediate memory representation.

In automatic activation, phonetic information would become available very quickly as part of visual access to the lexicon. Such activation occurs because of excitatory links between graphic word forms and phonetic word forms, between letters and phonemes, and between grapheme sequences and phoneme sequences. Thus, as individual letters are visually recognized, they activate associated phonemes and letter strings activate associated phoneme sequences. Such links allow activation to occur both upward from letter and phoneme units to words and downward from words to letters and phonemes, as in the model described by Rumelhart and McClelland (1981; also Rumelhart & McClelland, 1982). Elsewhere (Perfetti & McCutchen, 1982; Perfetti, 1985) we have

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suggested how such processes could be part of a model of speech processes in reading.

What would constitute evidence for automatic activation? There is suggestive evidence from lexical decision tasks, for example the pseudohomophone effect (*brane* takes longer to reject than *brone*) and the negative priming effect of nonhomophonic spelling patterns, for example, *couch–touch* (Meyer, Schvaneveldt, & Ruddy, 1974). However, the interpretation and even the replicability of these effects are open to question (Coltheart, 1978; Davelaar et al., 1978; Hillinger, 1980). On the other hand, Humphreys, Evett, and Taylor (1982) have demonstrated phonetic priming in a word identification experiment under masking conditions that produced minimal identification of the prime itself. Although this result suggests an automatic phonetic activation process, the fact that nonword phonetic primes did not produce priming led Humphreys et al. (1982) to conclude that the effect is postlexical. Other demonstrations of phonetic effects that could be considered automatic include the results of Petrick (1981) on phonetic interference in rapidly presented sentences and the results of McCutchen and Perfetti (1982) demonstrating a visual tongue-twister effect. However, because sentences rather than words were involved in these studies, it is possible that phonetic activation did not automatically accompany lexical access, but was later induced by sentence memory and comprehension demands.

The recent experiments of van Orden (1987) could be interpreted as showing automatic phonetic activation that occurs prior to lexical access. Subjects who had to decide whether a visually presented word belonged to a prespecified semantic category made frequent errors to homophones of category instances. For example, for the category "flower" the word *rows* is homophonic to the category instance *rose*, and subjects frequently false alarmed to *rows* in the category task (relative to spelling controls, e.g., *robs*). Since there is no advantage to the subject to have the phonetic properties of words activated in this situation, these data suggest that the recognition of words is mediated automatically by their phonetic properties.

In our experiments, we adopt a task that allows a shallower level of lexical processing. Instead of making decisions at the semantic level, which may be exactly the level at which phonetic information becomes necessary, our subjects simply identify words. The key manipulation involves backward masking. The word to be identified is followed by a mask that is a word or a letter string that varies in its graphemic and phonetic similarity to the target word. Naish (1980) reported that the disruptive effect of a backward mask was reduced when it was either visually or phonetically similar to the target word. Earlier experiments by Jacobson (1974; Jacobson & Rhinelander, 1978) also manipulated word target–mask similarity relations in the backward masking paradigm.

The logic of the experiments reported below, and of the Jacobson (1974) and Naish (1980) experiments, is as follows: Backward visual masking is affected by the relationship between the mask and the target, at least for *central masking* (Turvey, 1973) of the *structured* type (Breitmeyer & Ganz, 1976). If the target is a word and the mask is also a word, then visual similarity between the mask and the target will reduce the interruption of processing that the mask ordinarily provides. The reduction of the effect of the mask will be due to the overlapping visual letter features and specific letter shapes between the target and the mask.

Whether there should be a reduction of the masking effect with a phonetically similar mask is less obvious. Masks that are phonetically similar to targets will also be visually similar and a reduction effect can be expected on visual grounds. The question is whether there are *additional* effects due to phonetic properties of the mask. By

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our account, the basis for such an effect lies in the automatic activation of phonetic properties of words and letter sequences. As partial identification of the target word occurs prior to mask interruption, candidate phonetic values of its constituent letter strings and word candidates containing these letters are also activated. As the mask interruption occurs, the constituent letter strings of the mask also activate phonetic properties. This in turn strengthens certain word candidates consistent with the target information while weakening others.

EXPERIMENT 1

Experiment 1 tests the hypothesis that a masking effect is reduced by both the graphemic similarity and the phonemic similarity between a target and a mask. It allows the separation of two types of information in the code for a briefly presented word, a graphemic level and a phonemic level. It is a graphemic level rather than a visual one because the target is in lower case and the mask is in upper case. While this does not eliminate visual similarity, it does allow the inference that masking reduction effects occur at the level of the grapheme, not at the level of letter features. The phonetic level is inferable because the phonemic and graphemic masks are identical in their graphemic similarity to the target.

Method

Subjects. Forty-five University of Pittsburgh undergraduates participated in the experiment in partial fulfillment of course requirements. There were 15 subjects in each of three duration conditions.

Materials. Thirty-five target words were paired with each of three mask types (see Appendix I). Masks generally (three exceptions) had the same number of letters as the target. Two of the mask types, graphemic and homophonic, were pseudowords designed to share graphemic and phonemic properties of the target. A graphemic mask and a homophonic mask each shared the same number of letters with the target, as measured by their position-sensitive letter overlap with the target word. A control mask had very little overlap with the target. For example, for the target *hear,* the three masks were FODE (control), HEOR (graphemic), and HEER (homophonic). Thus a homophonic mask can be pronounced identically (or nearly so) to the target and has the same letter overlap with the target as does the graphemic mask. Note that a graphemic mask does necessarily share phonemic segments with the target, just not as many as a homophonic mask. Furthermore, some targets did not share initial letters with their homophonic and graphemic masks. For example, for the target word *phase,* the masks were COMPT (control), FARNE (graphemic), and FAYZE (homophonic).

Procedure. Stimuli were viewed on a Teleray 1060 CRT terminal (P4 phosphor) controlled by a VAX/VMS V01 operating system. Each target word and its three masks were viewed under three duration conditions, two of which were selected, on the basis of pilot work, to produce relatively low target accuracy. In one condition, the target and mask had nominal exposures of 33 and 16 ms, respectively, while in the other short duration condition the nominal durations were 30 and 25 ms for target and mask, respectively. Finally, the long duration condition exposed targets for 66 ms and masks for 33 ms. These target and mask durations are "nominal" rather than exact, because display changes could occur variably within the standard 16-ms scan rate of the CRT. Thus an actual duration of the nominally 25-ms mask could vary between 25 and 41 ms. The nominal duration values are used only to refer to the conditions and obviously are not meaningful as viewing parameters.

Targets were displayed in lower case and masks in upper case in a light on dark format. A six-letter string was approximately 1.5 × 0.5 cm. Subjects were seated

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approximately 30 cm from the screen, producing a horizontal visual angle of slightly over 2°. The screen itself was masked so that items were visible through a small 2 × 0.6-cm window.

The critical trial events, which were initiated by a subject's keyboard response, were as follows: (1) target on for specified duration (33, 30, or 66 ms), after a zero interstimulus interval, (2) pseudoword mask on for specified duration (16, 25, or 33 ms), after a zero interstimulus interval, (3) a pattern mask, consisting of a row of upper case X's, which remained in the window until the next trial. Thus, the pattern mask terminated the processing of the pseudoword mask.

Instructions to subjects included the information that the target they were to identify would always be a word and that a nonword would briefly mask it. They were also encouraged to write parts of the masking pseudoword if they could, but this was rarely done.

Subjects saw each target in each of the three masking conditions. Following warm-up trials, the 105 trials (35 targets × 3 masks) were presented. Each subject received a different randomization of the 105 trials.

Results

The basic data are the percentages of targets correctly identified. The results for the three duration conditions are shown in Figure 1.

An analysis of variance with Duration Condition between subjects and Mask Type within subjects confirmed the effect of Duration and Mask Type. The duration effect was significant both with items as random effects, $F(2,68) = 171.64$, $p < .001$, and with subjects as random effects, $F(2,42) = 29.28$, $p < .001$.

However the important results are for Mask Type. Target accuracy was significantly affected by Mask Type, both for the items analysis, $F(2,68) = 21.42$, $p < .001$, and for the subjects analysis, $F(2,84) = 31.62$, $p < .001$. However, the effect of Mask Type was less in the highly accurate 66/33 duration condition (a ceiling effect) than in the other two conditions, and the interaction of Duration Condition × Mask Type was significant, $F(4,136) = 4.31$, $p = .003$, by items, and $F(4,84) = 4.53$, $p = .002$, by subjects. This interaction was not present when the analysis included only the two shorter durations ($F < 1$).

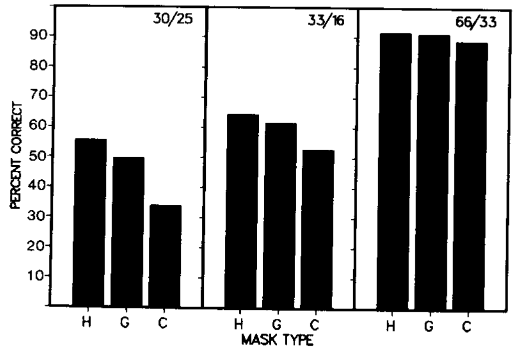

FIG. 1. Experiment 1. Percentage correct target identifications for three nominal mask types at three target–mask durations. H, homophonic; G, graphemic; C, control masks.

Of particular interest is the planned comparison of homophonic and graphemic masks for the two short duration conditions. This comparison for the two shorter durations combined showed significantly higher accuracy for homophonic masks than for graphemic masks, $F(1,56) = 5.76$, $p = .02$, by subjects, and $F(1,68) = 4.81$, $p = .03$, by items.

Discussion

There are two important results relating to masking reduction effects. First, a mask graphemically similar to a word target reduced the disruptive effect of a mask, relative to a control mask. This effect does not depend upon exact visual feature overlap because target and mask were printed in different case. The second important result is that an additional mask reduction effect occurred for masks homophonic to the target word. While the first effect is graphemic rather than simply visual, the

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second effect is phonemic rather than simply graphemic. Disregarding the 66/33 duration condition, which produced a ceiling effect, the size of the graphemic effect was 9% and the homophonic effect was 14%, relative to control masks. Critical to the explanation of the effects is that they depend on the mask reinstating information already activated during incomplete target identification. This includes information at the graphemic and phonemic levels.

There are, however, some problems with the interpretation of this experiment. The first problem is that the phonetic masks and word targets occasionally shared additional letters out of position. For example, for the target word *steak*, both the phonetic mask STAIK and the visual mask STEEB shared three letter positions with the target, *s, t,* and *k* for STAIK and *s, t,* and *e* for STEEB. However, STAIK shared an additional letter, *a*, with *steak* "out of position." Thus, although the method of control counted only in-position overlap, 11 of the targets showed an additional out-of-position letter with the phonetic mask. We compared these 11 items with those whose letter matches were identical regardless of position and found no difference in the magnitude of the phonetic mask reduction. Nevertheless, we decided that this problem should be addressed by experimental control rather than ad hoc comparisons.

A second problem concerns the possibility that subjects developed homophonic strategies in identifying words. Since on one-third of the trials a target word was followed by a pseudohomophone mask, the subjects might have developed a homophonic strategy. In such a case, it would be possible to "identify" the word not by the word itself but by decoding the mask and searching for a real word that is homophonic to it. For example, a subject might not "see" the word *steak* at all, but generate it after seeing the mask STAIK. Notice there would be no such benefit for visual masks, since they were not homophonic to the targets. We think this possibility is fairly unlikely. It requires that on some trials the mask, itself not a word, is more identifiable than the target, a real word. Since the mask itself had a shorter duration than the target and was masked by a pattern mask, this is a rather unlikely possibility. Nevertheless, it is a possibility and along with the out-of-position overlap problem noted above motivated a new experiment that would be free of both problems.

EXPERIMENT 2

Although the logic of Experiment 2 was the same as that of Experiment 1, there were changes in method that would solve the potential problems of interpretation. First, the homophonic masks and the graphemic mask for a given target always shared the same number of letters with the target, both "in-position" and "out-of-position." Second, in order to assess effects of response bias, we did two things. First, we added a re-pairing condition to the experiment. Target words were re-paired with the masks for other target words. If the masks themselves, rather than the combination of target and mask, are responsible for the effects, then re-pairing the masks could be expected to mimic the mask reduction effect. As a second control for intrinsic mask effects, we also introduced intermittent blank trials. On these trials, unknown to the subject, no target word appeared. However, a "mask" did appear as in regular trials. If the subject could use information in the mask to infer or guess the identity of words in regular trials, then this should be reflected in performance on the blank trials mimicking performance on normal trials. Specifically, given a nonword homophonic mask, subjects should sometimes "identify" the homophonically related but nonoccuring target word.

Finally there was an instrumentation change in Experiment 2. As we observed in describing Experiment 1, computer presentation of brief visual displays faces well-known timing problems owing to scan rate limitations. To gain better control over stimulus presentation, we used tachistoscopic displays in Experiment 2.

Method

Materials. A new set of materials having little overlap with that of Experiment 1 was constructed. The word targets were 36 English words, mean length 4.1 letters and a mean standardized frequency of 54.72 (roughly 30 per million) (Carroll, Davies, & Richman, 1971). The three nonword mask types were the homophonic, graphemic, and control masks, defined as in Experiment 1, except that the graphemic and homophonic masks shared the same number of letters with the target in terms of both exact letter positions and total number of letters. The complete set of targets and masks is in Appendix II.

The targets and masks were formed into three basic experimental lists of 108 target–mask pairs. Within each list, each target occurred with each of its masks. The order of the masks for each target was counterbalanced across the three lists, such that a given target had its first occurrence paired with a control mask on List 1, a graphemic mask on List 2, and a homophonic mask on List 3, whereas the next target was paired with its graphemic mask on List 1, its homophonic mask on List 2, and its control mask on List 3, etc, across the 36 targets. Within each list, all targets occurred before any were repeated. This in effect allows a between-groups comparison of masking effects based solely on first-occurrence trials.

Blank trials were assigned to 9 of the 36 targets on each list, creating four versions of each basic list in order to produce blank trials for each of 36 targets. On blank trials, a control mask, a graphemic mask, or a homophonic mask occurred without a preceding target. For example, for one version of List 1, the target word *made* never occurred, but a blank trial included the homophonic mask MAYD. On some other version of List 1, the graphemic mask for *made* (MARD) occurred, etc., for all targets. This procedure meant that 1 out of 4 trials within any list were blank trials. These trials were interspersed throughout the list in a quasirandom manner.

Finally, there was a Re-pairing Condition added to the basic experiment. In the re-pairing lists, targets were never paired with either their homophonic or graphemic masks. Instead, they were paired with the graphemic and homophonic masks that were paired with some other target in the experimental lists. For example, in the Re-pairing Condition, the target word *made* was paired with the graphemic and homophonic masks that had been paired with *ache* in the experimental lists. Thus the three masks for *made* were AIKE, ARSE, and COND, all essentially control masks.

Subjects and procedure. Data collected from 24 subjects filled the design of the experiment, 12 in the Experimental Condition and 12 in the Re-pairing Condition. However an additional 37 subjects failed to achieve the minimal performance criterion established for the experiment (see below).

Stimuli, which were typed on a standard IBM typewriter, were displayed by three slide projectors fitted with tachistoscopic shutters that were under computer control. The first projected targets, the second, nonword masks, and the third, pattern masks. Each slide was rear projected onto a 10 × 5-cm screen in the center of a 23 × 33-cm blackboard. The size of the projected stimuli was 2.5 × 0.6 cm. Subjects sat approximately 2 ft (60 cm) from the viewing screen creating an approximately 2° horizontal visual angle.

The pattern mask served as a fixation region. Subjects started each trial by pressing a button that initiated a sequence of three slides with zero ISI. The target and mask durations were set at values that produced between 20 and 80% accuracy in most subjects tested in pilot work. These values were 45 ms for the word target and 30 ms for the nonword mask. The experimental session began with 35 practice trials during

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which the exposure duration was gradually decreased from 120 ms (target) and 80 ms (mask) to the values of the experiment, 45 and 30 ms. Subjects were instructed that each trial would contain either one or two "words" and that these "words" could be either real words or nonwords. They were instructed to report as many words (or nonwords) as possible, even if their confidence was low.

Results

The main results are the percentages of correct identification for the three masking conditions. These are shown in Figure 2.

In the Experimental Condition, there were two clear and statistically reliable effects. First, words were identified more often when followed by a graphemic mask (45.5%) and by a phonemic mask (54.0%) than when followed by a neutral control mask (31.6%). The mask main effect was $F(2,48) = 23.39, p < .001$, by subjects, and $F(2,70) = 8.01, p < .001$, by items. Most important, words were identified more often when followed by a homophonic mask (54.0%) than when followed by a graphemic mask (45.5%), $F(1,12) = 11.50, p = .005$, by subjects, and $F(1,35) = 5.29, p = .027$, by items. Figure 2b shows the data for the Re-pairing Condition. There was no effect of mask type. Thus the effect of masking in the Experimental Condition must be attributed to target–mask combinations rather than to the masks themselves.

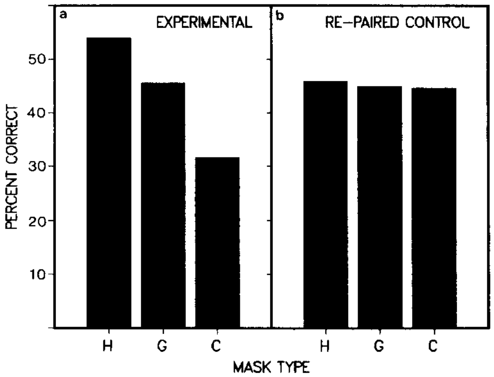

FIG. 2. Experiment 2. (a) Percentage correct target identifications for homophonic, graphemic, and control masks. Target duration was 45 ms and mask duration was 30 ms. (b) Data for re-paired condition in which masks were reassigned to different word targets.

Consistent with this conclusion are the results for blank trials. The blank trials gave 1266 total opportunities for a false identification of a target word. There was a total of five such false identifications, four with a homophonic mask and one with a graphemic mask.

The design of the stimulus lists allowed the effects of masking to be assessed between groups separately for the first occurrence of each target word. The first occurrence analysis confirmed the overall analysis in all respects. In the Experimental Condition, the percentages of correct identifications were 56.9, 41.2, and 31.0 for homophonic, graphemic, and control masks, respectively. For the Re-pairing Condition, the corresponding mean percentages were 46.3, 41.7, and 43.1. As in the overall analysis, homophonic masks in the Experimental Condition provided a significant boost in identification relative to graphemic masks, $F(1,4) = 32.11, p = .004$, by subjects, and $F(1,35) = 7.30, p = .011$, by items.

A peripheral result, apparent from Figure 2, is that the Re-pairing Condition produced higher base-rate identification accuracy than did the Experimental Condition, as reflected in the identification of control masks. This difference is also present in the first-occurrence data. The reason for the overall advantage of the re-pairing group lies in group differences resulting from the performance criterion. The Re-pairing Condition, by hypothesis, was more difficult because it presented no advantageous target–mask pairings. Thus, given that a subject was going to fail our 20% accuracy criterion, he was more likely to be in the Re-pairing Control Condition. Of the 37 subjects who failed to achieve the 20% criterion, 31 were in the Re-pairing

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Condition. Because low performing subjects were eliminated, subjects surviving the criterion to remain in this condition tended to be higher performing subjects.[1]

Discussion

Experiment 2 showed the same pattern of results as Experiment 1 under control conditions that tend to rule out any explanation that doesn't take account of target–mask relationships. In the overall analysis, the graphemic effect was 14% relative to the control mask and the phonemic effect was 22.5% relative to the control mask (8.5% relative to the graphemic mask). In the first-occurrence analysis, the size of the phonemic effect is actually larger, 15.7% relative to the graphemic mask and 26% relative to the control mask. By either measure, both the graphemic and phonemic reduction effects were larger than those in Experiment 1.

Finally, it is interesting to note that the phonemic effect was fairly general across items. In a post hoc examination of 11 target and homophonic mask pairs having the lowest overlap in the spelling of their shared phonemes, for example, *file*–*PHIAL*, the homophonic mask reduction effect was found to be comparable relative to the graphemic mask reduction effect, although smaller relative to the control mask. Thus, for target–mask pairs with low letter overlap, the mask reduction effects were generally smaller, but the homophonic mask produced further reduction effects beyond those of the graphemic mask, just as it did for target–mask pairs having more letter overlap.

GENERAL DISCUSSION

These results can be taken to demonstrate that two different levels of information rapidly become available early (prior to lexical access) in word identification. First, the graphemic effect reflects the contribution of particular *abstract* letter information. Because the letters of the mask were upper case, the lower case visual features of target word letters were not preserved. Word identification is enhanced; that is, the disruptive effect of a backward mask is reduced, because the letters of the target word are reinstated by the mask, even as it interrupts processing at the visual level. This abstract letter code, which can be considered a level of representation indifferent to visual forms, also has been identified in other research, for example, Rayner, McConkie, and Zola (1980) and Coltheart (1981).

The second type of information includes the phonetic values of the graphemes and of the word itself. The mask reduction effect for a homophone mask reflects the reinstatement of phonetic codes already activated by the incomplete identification of the target.

One account of how this occurs is provided by the class of interactive models described by Rumelhart and McClelland (1981). The general shape of this account has been suggested by Perfetti and McCutchen (1982) and a more specific interactive model of phonetic effects in word recognition has been discussed by Seidenberg, Waters, Barnes, and Tanenhaus (1984). Essentially, in these accounts, activated letter level units activate both word candidates and phonemic codes that are consistent with these units (and hence connected with them). The letter units include frequent multiletter strings and the phonemic units include multiphoneme sequences, as Seidenberg et al. (1984) also argue. Furthermore, activated word candidates strengthen certain phonetic values over others just as they strengthen certain letters over others. Thus, the word receiving enough activation to be the one "recognized" has a considerable amount of phonetic activation accompanying its recognition even before the process is com-

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[1] Obviously, in retrospect, to avoid this sampling problem it would have been better to individualize target and mask SOAs. Pilot work indicated the SOA values used would produce criterial performance from most subjects, but it was based exclusively on subjects tested in the experimental condition.

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pleted. What masking does is to interrupt processing before it is complete by overwriting the visual feature information being extracted from the target word. However, the letter identification process begun on the target, although interrupted by the mask, has already activated word candidates. To the extent that the mask contains the *letters* of activated words, even in different shapes, the interruption of visual information extraction will be compensated to some degree by reactivation of these same letters, thus strengthening the activation of the target word. If, in addition to graphemic information, the mask shares phonetic information with the target word, it will further compensate for processing interruptions by continuing the activation of the phonetic values initiated by target letters and word candidates consistent with them.

Of course an interactive model is not the only model consistent with these data, and indeed a full network of excitatory and inhibitory interconnections among graphemic units, phonetic units, and words would be rather too powerful without some constraining assumptions. However, the general account suggested by such a model is particularly appropriate for word identification if the key processing event is the rapid access to levels of information that constitute a word's lexical entry. It allows "lexical access" to be considered less of a magical moment and more of a continuum of many moments, any one of which produces various configurations of graphemic, phonemic, and even symbolic (categorical) information. Whether phonetic "recoding" is prelexical or postlexical becomes a matter of timing and definition. Graphemic information is always quickly activated because visual word identification is initiated by visual processes. Phonetic information is also quickly activated and assists word identification in general. However, the extent to which it assists identification depends on the timing of activation patterns. The timing of activation may depend on a word's frequency, as Seidenberg et al. (1984) also have suggested, and on the consistency or regularity of its spelling pattern. Thus, more phonetic activation may build up prior to access for a low frequency word and for a word with a consistent spelling pattern.

The most general suggestion we make here is that some phonetic activation occurs *nonoptionally during* word identification. The "nonoptionally" part of this claim has received support from other experimental paradigms (Humphreys, Evett, & Taylor, 1982; Navon & Shimron, 1981), as well as from the present masking results. If correct, this claim is of some practical significance for actual reading. It would mean that the speech "recoding" that plays a "downstream" role in memory and comprehension has already occurred concurrently with identification. Theories that assume this recoding occurs only in response to difficult texts would be partly incorrect.

The "during word identification" part of the claim rests on the backward masking data. The backwards effect of the mask, we assume, is on an identification process not yet completed at the onset of the mask. It is phonetic information activated during this incomplete process that is affected by the mask. Thus, in the usual way of thinking about lexical access, it is a prelexical effect. Of course, in other paradigms there is considerable evidence that is usually taken to demonstrate that much phonetic coding is postlexical (see Humphreys & Evett, 1985; McCusker, Gough, & Bias, 1981; Perfetti & McCutchen, 1982). It is also possible that there are distinctive prelexical and postlexical codes, having little or no direct connection between them.

In fact it is difficult to distinguish between an account that assumes a single phonetic activation process concurrent with lexical access and an alternative account that assumes distinct prelexical and postlexical codes, each subject to its own activation process. Just and Carpenter (1987), for example, assume that prelexical phonetic codes are routinely activated con-

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currently with lexical access but typically fail to reach threshold prior to lexical access, which usually occurs by the visual route. The phonetic codes that aid comprehension and memory, by this account, are generated from pronunciations stored with words and available only after lexical access. Since postlexical phonology is required in any model in order, for example, to assign syllabic stress, produce vowel reduction, etc., all theories have to be dual code theories in the sense of assuming that some phonetic information is stored with lexical entries. This lexical code presumably serves comprehension and memory as well as speech production. The possibility that it is generated without any direct influence of the early occurring (prelexical) phonetic processes is certainly not contradicted by our results.

Whatever their fate for postlexical processes, our conclusion is that prelexical codes are activated to an appreciable degree on a routine basis. Indeed, van Orden's (1987) experiments might be taken to demonstrate very strong prelexical phonetic mediation of word identification. Our claim is only slightly weaker. A high degree of phonetic activation always occurs during lexical access, never being wholly delayed until some "moment of access" and never being omitted.

APPENDIX 1

Target	Homophonic	Graphemic	Control
bear	BAIR	BOIR	FLEN
blue	BLOO	BLOS	CAFT
break	BRAIK	BROLK	SCRON
choir	KWIER	KNARR	SLAGH
floor	FLORE	FLOME	GRENT
flu	FLOO	FLEO	NADE
goat	GOTE	GOPS	STEL
great	GRAIT	GRALT	MERSE
grows	GROZE	GROME	FLASE
group	GRUPE	GRUST	BOSER
hear	HEER	HEOR	FODE
hole	HOAL	HORL	PLIS
made	MAYD	MAGO	STOR
mail	MAYL	MARL	THON
main	MAYN	MARN	CRUB
moan	MONE	MOCE	DROK
none	NUNN	NANO	CIRT
one	WUN	WEN	BEC
phase	FAYZE	FARNE	COMPT
piece	PEESE	PIOSE	DROAT
pores	PORZE	PORFE	FEDIR
quote	KWOAT	KWORN	MELST
sole	SOAL	SOAD	JECK
stalk	STAWK	STASK	CHUNT
steak	STAIK	STEEB	NARTH
style	STIAL	STIRT	GROST
suit	SUTE	SULE	MAGE
tax	TAKS	TAFS	RILB
toad	TODE	TIDD	LERT
wade	WAID	WALB	DRIL
waist	WAYST	WAPST	DEILK
wait	WATE	WAFO	HOND
war	WOAR	WYAR	BOKE
wear	WAIR	WOIR	BRES

APPENDIX 2

Target	Homophonic	Graphemic	Re-paired homophonic	Re-paired graphemic	Control
ache	AIKE	ARSE	MAYD	MARD	FOST
bake	BAIK	BAWK	YURE	YURM	CRUB
bite	BIGHT	BISHT	SAWK	SENK	DROK
blame	BLAIM	BLARM	TRUPE	TRAPE	CROSH
boat	BOTE	BOTS	RUME	RIME	CIRE
brain	BRANE	BRANT	KRAIT	KRAST	FLEST
chair	CHARE	CHARK	TRANE	TRANK	SLUGE
claim	KLAME	KLAMB	STAIK	STREK	ROUNT
code	KOAD	KOID	PAYN	PAMN	SNAL
cog	KAWG	KENG	WAIR	WIER	BAX
crate	KRAIT	KRAST	BRANE	BRANT	SKOND
doll	DAWL	DEWL	RADE	RADS	JICK
door	DORE	DODE	NUNE	NANE	NADE

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APPENDIX 2—*Continued*

Target	Homophonic	Graphemic	Re-paired homophonic	Re-paired graphemic	Control
drop	DRAWP	DREAP	KIGHT	KIRST	FLIN
fame	PHAIM	PHAFT	ROAL	RELL	CRON
file	PHIAL	PHIFT	GAWN	GURN	BORT
food	PHUDE	PHIDE	WATE	WATS	YINK
glue	GLOO	GLAM	HOAM	HOSH	TRIN
gone	GAWN	GURN	PHIAL	PHIFT	HAST
home	HOAM	HOSH	GLOO	GLAM	TING
kite	KIGHT	KIRST	DRAWP	DREAP	MANG
log	LAWG	LERG	TUNN	TANN	RES
made	MAYD	MARD	AIKE	ARSE	COND
noon	NUNE	NANE	DORE	DODE	LERB
pain	PAYN	PAMN	KOAD	KOID	SHEG
raid	RADE	RADS	DAWL	DEWL	KETS
roll	ROAL	RELL	PHAIM	PHAFT	CAFT
room	RUME	RIME	BOTE	BOTS	SINT
sock	SAWK	SENK	BIGHT	BISHT	FERM
steak	STAIK	STREK	KLAME	KLAMB	CHOIT
ton	TUNN	TANN	LAWG	LERG	HAP
train	TRANE	TRANK	CHARE	CHARK	GLOUM
troop	TRUPE	TRAPE	BLAIM	BLARM	MALSH
wait	WATE	WATS	PHUDE	PHIDE	PRES
wear	WAIR	WIER	KAWG	KENG	MOND
your	YURE	YURM	BAIK	BAWK	VIST

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