1990

Differential effects of exposure duration on semantic priming from homophones :: evidence for Van Orden's (1987) verification model.

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DIFFERENTIAL EFFECTS OF EXPOSURE DURATION ON SEMANTIC PRIMING FROM HOMOPHONES: EVIDENCE FOR VAN ORDEN'S (1987) VERIFICATION MODEL

A Thesis Presented

by

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Submitted to the Graduate School of the
University of Massachusetts in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE

September 1990

Department of Psychology

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CHAPTER 1

INTRODUCTION

An important question in reading research is: What role does phonology play in visual word recognition? Speech recoding (the translation of a visual code into a "speech" code) is clearly involved in short-term memory processes (see Conrad, 1972, for a review of the relevant research) but a much more controversial claim is that phonology exerts an influence during lexical access--that is, that phonology "mediates" visual word recognition.

Proponents of "phonological mediation" claim that, in reading, word identification is "a process that transforms spelling to sound and then maps sound to meaning" (Van Orden, 1987, p. 181). An alternative view, "direct access," is that a word's meaning can be accessed on the basis of the orthographic/visual representation of the word without reference to the word's phonology. "Dual access" theories allow for both phonological mediation and direct access but the time course that is postulated for the two sources (visual and phonological) differs depending on the theory. In Seidenberg's (Waters & Seidenberg, 1985 and Seidenberg, Waters, Barnes, & Tanenhaus, 1984) time course model, the word recognition process begins with the extraction of visual information from the input. Based on this information, orthographic units are identified and the corresponding phonological representations are then activated. Therefore, phonological access necessarily follows visual analysis. Recognition of a word occurs when a particular node (the lexical entry corresponding to the word) reaches threshold. "If sufficient orthographic information is extracted from the input to permit recognition prior to the access of phonology, direct access results; however, if a word cannot be recognized prior to the activation of phonological information, mediated access results" (Waters & Seidenberg, 1985, p. 557). Therefore, whether phonology exerts an influence on the word recognition process depends on the time course of the extraction of visual information--phonology will only exert an influence in instances when the process is slowed down (e.g. for lower frequency words or slower readers).

A large number of studies relevant to the question of phonological mediation have been generated by two general research strategies: (1) the manipulation of spelling-to-sound regularity and (2) the manipulation of visual and phonological similarity. The first strategy is based on the assumption that, if word identification is "a process that transforms spelling to sound and then maps sound to meaning" (Van Orden, 1987, p. 181), it should be possible to find an effect of spelling-to-sound regularity on word identification -- words with consistent spelling-to-sound correspondences should be "recognized" more quickly than those with inconsistent spelling-to-sound correspondences. Before discussing the research relevant to this issue, it will first be necessary to define some terms. "Exception" words, such as HAVE, are words whose pronunciations cannot be predicted from their spelling because other words that are spelled similarly are not pronounced similarly. "Regular" words, such as MUST, are words whose pronunciations can be predicted on the basis of their spelling because all words with a similar spelling are pronounced similarly. Some researchers (e.g. Glushko, 1979) further classify "regular" words in terms of their "consistency" (the degree to which their pronunciation is "consistent" with the pronunciations of their orthographic neighbors). "Regular consistent" words are "regular" words like MUST whose orthographic neighbors (e.g. JUST, GUST) are always pronounced similarly. "Regular inconsistent" words are "regular" words like GAVE. GAVE is "regular inconsistent" in that most of its orthographic neighbors are pronounced similarly (e.g. SAVE, WAVE), but there are exceptions (e.g. HAVE).

Results of studies looking at spelling-to-sound regularity only provide mixed evidence for phonological mediation. Baron and Strawson (1976) found that regular words are named more quickly than frequency-matched exception words but Seidenberg, Waters, Barnes, and Tanenhaus (1984), who studied recognition of regular consistent (e.g. MUST), regular inconsistent (GAVE), exception (HAVE), and "strange" words (YACHT) found that an effect of word type on naming was restricted to low frequency words. The failure to find an effect of spelling-to-sound regularity for high frequency words is difficult to reconcile with the "phonological mediation" position; however, the time course model (Seidenberg et al., 1984) handles the results nicely. The explanation offered by Seidenberg et al. (1984) is that phonological information accumulates more slowly than visual/orthographic information and will only influence word recognition in instances when the process of visual information extraction is slowed down (e.g. by word frequency).

The second research strategy, the manipulation of visual and phonological similarity, has provided stronger evidence for phonological mediation. While most of this research relies on the existence of homophones (pairs of words in the language that are spelled differently but that sound alike) some research has focused on nonwords that sound like words --pseudohomophones. Indeed, until recently, the finding of a "pseudohomophone effect" was the best evidence for phonological mediation. Using a lexical decision task, Coltheart, Davelaar, and Jonasson (1977) found that subjects take longer to correctly reject pseudohomophones (e.g. BRANE) than to reject controls. This finding suggests that the phonological representation of the pseudoword BRANE activates the lexical entry for BRAIN making the classification of BRANE as a nonword more difficult.

A finding similar to the pseudohomophone effect is that, when using a categorization task, subjects take more time to correctly reject words homophonic with category exemplars (Meyer & Gutschera, 1975 in Van Orden, 1987). The explanation suggested is, given a category such as A FRUIT, the phonological representation of the target PAIR activates the lexical entry for PEAR thereby making rejection of PAIR more difficult.

There are several problems in interpeting the results of the above two studies as evidence for phonological mediation. Results of studies using nonwords as stimuli may not have much relevance to how real words are read. Secondly, as Coltheart et al. (1977) and Van Orden (1987) point out, because the pseudohomophone effect is observed on "no" trials, and "no" trials are generally slower than "yes" trials, "the nonword DYME's effect in the lexical decison task may arise after the time has elapsed that is usually required for word identification in normal reading" (Van Orden, 1987, p. 182). This criticism also applies to the Meyer and Gutschera study (1975 in Van Orden, 1987). The results of Coltheart et al. (1977) and Meyer and Gutschera (1975 in Van Orden, 1987) are readily interpretable within Seidenberg's (1985) time-course framework--effects of homophony are only seen on slower ("no") responses--responses that allow sufficient time for phonological sources of activation to accrue.

In a series of experiments, Van Orden (1987) found a homophone effect on "yes" responses in a categorization task. In Experiments 1 and 2, subjects were not only required to judge whether a target word is an exemplar of a preceding category, but also to name (identify) the word. Therefore, given the category A FLOWER, and the stimulus ROWS, the appropriate response would be /NO, ROZ/. The added requirement of naming the stimulus allowed for the discrimination of two possible accounts of high false positive response rates: (1) false word identification (supporting phonological mediation) or (2) a yes-bias artifact hypothesis which suggests that "phonology's errant activation of meanings could merely increase the subjects' bias toward responding 'yes' in the categorization task, without actually causing false word identification" (Van Orden, 1987, p. 183). Van Orden (1987) argued that, given the category A FLOWER, false word identification would be indicated when subjects respond "Yes, Rows" while a yes-bias artifact would be indicated by the occurrence of responses such as "Yes, I mean, no, Rows".

In Experiment 1, the category name and fixation point (a "+" below the category name indicating the location of the forthcoming target) remained visible for 1500 msec and then were replaced by the target word which remained visible for 500 msec before being replaced by a pattern mask. Subjects produced larger false positive error rates to stimulus foils that were homophonic to category exemplars (e.g. ROWS for ROSE given the category A FLOWER) than to spelling control foils (e.g. ROBS). Also, subjects produced larger false positive error rates to more similarly spelled homophone foils (e.g. MEET vs. MEAT) than to less similarly spelled homophone foils (e.g. ROWS vs. ROSE). Because subjects were required to categorize and to identify the target, it is possible to infer that the locus of the false positive errors is in the word identification process and is not merely due to a yes-bias artifact.

The procedure in Experiment 2 was the same as that used in Experiment 1 except that a pattern mask was used at an SOA "at which the subjects could still report a large percentage of the practice target words that were exemplars of their preceding category but could no longer report any practice target words that were not exemplars of their preceding category" (Van Orden, 1987, p. 185). As in Experiment 1, there was a homophone effect on rate of false positive responses but, unlike Experiment 1, there was no difference between more and less similarly spelled homophone foils. According to Van Orden (1987), "the pattern masking conditions of Experiment 2 provided a situation in which word identification was best served by its most rapidly available sources of activation. Under those conditions, the effects of orthographic similarity disappeared, but the effect of homophony remained relatively unperturbed" (p. 186). These results suggest that phonology is an early source of information in visual word identification.

Van Orden (1987) also found evidence that homophony causes both a "yes" bias and a "no" bias, as illustrated by the following types of responses: (1) "Yes, I mean, no ROWS" and (2) "No, I mean, yes ROSE." These types of responses are suggestive in that they may reflect "successive, inconsistent outcomes of an iterative verification process" (Van Orden, 1987, p. 188). Indeed, Van Orden develops a verification model to account for his results.

In the verification model developed by Van Orden (1987), candidate lexical entries are activated exclusively by a phonological representation. Before one entry can be selected, it must pass a verification test/spelling check. The verification procedure is repeated (using the next most active candidate entry) until a match occurs. Presumably, pattern masking interrupts the word identification process prior to verification (see Paap, Newsome, McDonald, & Schvaneveldt, 1982). Results from a third experiment further support the verification hypothesis.

In Experiment 3, the special definition of false positive categorization errors was dropped because the results of Experiments 1 and 2 failed to provide exclusive support for a yes-bias artifact hypothesis--there was evidence that homophone foils induce both a positive and a negative response bias. In this experiment, Van Orden found that false positives are least likely when corresponding category exemplars (e.g. ROSE given the category A FLOWER) are very high in frequency. The explanation that the verification hypothesis provides goes as follows: "If exemplar ROSE is a high frequency word, readers are more likely to have complete knowledge of its spelling and are thus more likely to detect the stimulus imposter ROWS. Consequently, the likelihood that ROWS will be miscategorized as A FLOWER is reduced when ROSE is a high frequency word" (Van Orden, 1987, p. 187).

Van Orden's verification model also explains the finding that a spelling-to-sound regularity effect is restricted to lower frequency words--a finding that previous models of "phonological mediation" had difficulty accounting for. Van Orden (1987) suggests that the mechanism by which associations between orthographic features and phonological features are acquired is sensitive to the covariance of these features across words. A consistent covariance across many words results in faster performance. Van Orden further assumes that overlearning "can compensate for the disadvantage resulting from inconsistency. Thus phonological codes of very familiar words, whether they be consistent or inconsistent, are all computed with equal efficiency" (Van Orden, 1987, p. 193). Therefore, explanation of the spelling-to-sound regularity data does not require a "dual access" model in which the phonological route plays a secondary role in the word recognition process.

The Van Orden (1987) results have recently been extended to nonword stimuli. Van Orden, Johnston, and Hale (1988) found higher false positive response rates to nonword homophone foils (e.g. SUTE for AN ARTICLE OF CLOTHING) than to nonword nonhomophonic spelling controls and further found that matched word and nonword homophones produced virtually identical error rates. Viewing nonwords as extremely unfamiliar words,the Van Orden et al. (1988) results indicate a failure to find an effect of stimulus familiarity (no difference between error rates for nonword and word stimuli). This result suggests that phonological coding plays a role in the identification of all printed words. The Van Orden (1987) and Van Orden et al. (1988) studies also argue that the activation of phonological information during word identification is automatic since, in these studies, the activation of phonological information could only serve to hinder subjects' performance if access of word meanings could be achieved efficiently without it.

The Van Orden studies (1987; Van Orden, Johnston, & Hale, 1988) go a long way towards eliminating the problems that have been associated with the finding of a pseudohomophone effect. But, one potential problem remains: the possibility of priming from the category name to the target. The category name A FLOWER may activate the lexical entry ROSE, the phonological representation of which then activates ROWS. Indeed, in Experiment 2, thresholds were set at a duration at which "the subjects could still report a large percentage of the practice target words that were exemplars of their preceding category but could no longer report any practice target words that were not exemplars of their preceding category" (Van Orden, 1987, p.185). This suggests that sound coding may only enter into the word recognition process when there is "top-down" priming.

Perfetti, Bell, and Delaney (1988) have also found evidence that suggests that phonology is an automatic (prelexical) source of information in visual word recognition. They varied the graphemic and phonemic properties shared by a word target and a following pseudoword mask. The dependent measure used was percent correct identification of the target word. Graphemic (MARD) and homophonic (MAYD) masks were equated for number of letters shared with a word target (MADE). Both types of mask showed a masking reduction effect relative to a control mask. That is, subjects identified MADE correctly more often when the mask shared graphemic or phonemic characteristics with the target word than when the mask did not share any characteristics with the target word. There was an additional effect of the homophonic mask over the graphemic mask, attributable to phonetic activation (Perfetti et al., 1988). Perfetti et al. (1988) suggest that the homophonic masks reinstate information activated during incomplete target identification resulting in a higher correct report rate for targets.

Results of a recent study by Brysbaert, Praet, & d'Ydewalle (1990) suggest an alternative interpretation of the Perfetti et al. (1988) results. Brysbaert et al. (1990), in an attempt to replicate the Perfetti et al. (1988) results, found that an advantage of a homophonic mask over a graphemic mask was dependent on the proportion of homophonic masks in the stimulus set -- there was no advantage when few (less than 10%) of the masks were homophonic. One important difference between the Brysbaert et al. (1990) and the Perfetti et al. (1988) studies that should be noted is that Brysbaert et al. (1990) used Dutch stimuli while Perfetti et al. (1988) used English stimuli. Brysbaert et al. (1990) suggested that the more restricted and straightforward grapheme-to-phoneme correspondence rules characteristic of Dutch should result in the greater reliance of Dutch subjects on the phonological recoding route. Brysbaert et al. (1990) suggest that the phonological route is an optional route that may be consulted in the word recognition process in contexts in which it is useful to do so. For example, in the Brysbaert et al. (1990) experiments, the use of the phonological route in conditions in which there were a large proportion of homophonic masks would result in the identification of a large number of targets. The Brysbaert et al. (1990) results are also consistent with a sophisticated guessing explanation of the Perfetti et al. (1988) results. Subjects may have performed better in the "homophone" condition merely because it was easier to guess the identity of the target in this condition.

In another experiment concerned with the activation of phonological information, Rayner and Posnansky (1978) used a modification of the Stroop (1935) word-color interference task to examine stages of processing in word identification. In the typical Stroop task, subjects are presented with color names printed in colored ink and are required to name the color of the ink. Subjects take longer to name the color of the ink when the meaning of the word conflicts with the ink color (e.g. RED printed in GREEN ink) than when it is congruent (RED printed in RED ink) or neutral (CHAIR printed in RED ink). This interference is taken as evidence that the meaning of the printed word is processed automatically. In the Rayner and Posnansky (1978) task, pictures with superimposed print were pattern-masked at varying exposure durations: Threshold (to identify the picture) + 20, Threshold + 40, Threshold + 80, and

Threshold + 160. Mean Threshold ranged between 15 and 20 msec. Subjects were required to name the picture as fast as possible. In a series of experiments, Rayner and Posnansky (1978) varied the visual and phonological similarity of nonwords to the actual picture label. It was found that nonwords that preserved visual or phonological features resulted in faster naming times than nonwords that preserved few visual or phonological features. The visual similarity effect appeared at a very early stage in the visual word recognition process--at an exposure duration of Threshold + 20 msec--but faded quickly (by Threshold + 40 msec). The phonological similarity effect appeared at an exposure duration of threshold + 40 msec and was relatively long-lasting (at least through Threshold + 160 msec). These data were taken as evidence for phonological mediation although Rayner and Posnansky (1978) suggest that their task is limited in its generality because the processing of the superimposed print was an incidental task. It should be noted that the finding of a visual similarity effect at threshold + 20 msec seems to be in conflict with the lack of a visual similarity effect at the short exposure duration in the Van Orden (1987) task.

Much of the previous research on phonological mediation has involved the manipulation of visual and phonological similarity. Perfetti, Bell, and Delaney (1988) and Brysbaert, Praet, & d'Ydewalle (1990) varied the graphemic and phonemic properties shared by a word target and a following pseudoword mask. Rayner and Posnansky (1978) varied the visual and phonological similarity of nonword labels to the actual picture label in a picture-word interference task. While all three of these studies provide evidence that phonological information is activated early in the word recognition process, none directly implicates the use of a phonological representation in the accessing of meaning. The purpose of the present experiment is to further test the verification model proposed by Van Orden (1987) using a task in which an explicit tie between the activation of phonological information and its use in lexical access can be established.

According to the verification model, candidate lexical entries are activated exclusively by a phonological representation and are then subjected to a verification test/spelling check. Therefore, given a word that is a homophone, both meanings associated with the sound representation of the homophone should initially be activated. Later, as a result of the verification process, one meaning is selected. The present experiment is designed to test this hypothesis using a priming paradigm in which the primes (members of homophone pairs, e.g. BEECH, BEACH) are masked at two different exposure durations and time to name the target word (associates of each of the members of the homophone pair) is measured. As in the Rayner and

Posnansky (1978) and the Van Orden (1987) studies, using different exposure durations should allow for an examination of the time course of the activation of visual and phonological information in visual word recognition. But, unlike the Rayner and Posnansky (1978), the Perfetti et al. (1988), and the Brysbaert et al. (1990) studies, the present experiment is concerned with semantic priming from words visually or homophonically related to an "appropriate" prime (e.g. priming of TREE from BEACH or BENCH) rather than with strictly visual or homophonic priming (e.g. priming to MAID from MAYD or MARD).

CHAPTER 2

EXPERIMENT 1

The experimental design included the following prime-target conditions: (1) "appropriate" -- a member of a homophone pair followed by an appropriate associate (e.g. BEECH followed by TREE), (2) "homophone" -- the other member of the homophone pair followed by an associate of the first member of the pair (e.g. BEACH followed by TREE), (3) "visually similar" -- a word as visually similar to the "appropriate" word as the other member of the homophone pair is followed by the associate of the "appropriate" homophone (e.g. BENCH followed by TREE), and (4) "different" -- a word visually and semantically unrelated to the homophone followed by the homophone's associate (e.g. FLUID followed by TREE). The "visually similar" condition allowed for the differentiation of an effect of phonology from an effect of visual similarity. The control condition allowed for the determination that there is in fact a standard priming effect in the appropriate condition. Exposure duration was a between subjects factor.

Priming words were pattern-masked at two different exposure durations (50 and 200 msec) in order to distinguish between pre- and post-verification stages. The reasoning behind the use of pattern-masking is the same as that used by Van Orden (1987): A pattern mask is assumed to terminate processing of a word, such that under brief pattern masking conditions only the most rapidly activated codes are available. If a sound representation is such a code, the onset of the pattern mask in the short exposure duration condition should terminate processing prior to the completion of the verification procedure while the longer exposure duration should allow ample time for completion of the verification procedure before onset of the pattern mask.

If a phonological code is first activated, and the short exposure duration condition is successful in preventing verification from occurring, then one would expect that both the "appropriate" and the "homophone" primes would facilitate naming of the target word. If the longer exposure duration allows sufficient time for verification to occur, then one would expect facilitation only from the "appropriate" prime. Whether there should be an effect of visual similarity is unclear as the Van Orden (1987) and Rayner and Posnansky (1978) studies provide conflicting results regarding the effects of visual similarity in visual word recognition. Van Orden (1987) found an effect of visual similarity that was restricted to the longer exposure duration (500 msec) in his experiments while Rayner and Posnansky (1978) found an effect of visual similarity at their shortest exposure duration (approximately 40 msec). If there is an effect of visual similarity, it should be smaller than the effect of homophony but larger than the effect of the "different" prime--naming latencies for "visually similar" trials should be longer than naming latencies for "homophone" trials but shorter than naming latencies for "different" trials.

Van Orden's (1987) verification model further suggests that there may be an effect of the frequency of the homophone. According to the model, the lower frequency member of the homophone pair is more likely than the higher frequency member to prime the other homophone's associate (e.g., BEECH is more likely to prime SAND than BEACH is to prime TREE). This prediction follows from the assumption that the reader is less likely to have complete knowledge of the low frequency member's spelling than he is to have complete knowledge of the high frequency member's spelling.

Another issue relevant to the present experiment is whether the activation of a phonological code during word recognition is the result of automatic or strategic processes. In one attempt to distinguish between conscious predictive and automatic priming effects, Neely (1977) used a lexical decision task in which the primes were category names and the targets were category exemplars. Some category names (e.g., BIRD) were followed consistently by members of another category (e.g. exemplars of the category BODY PARTS). Neely (1977) suggested that, if the category name BIRD were to prime an exemplar of birds, this would be indicative of the operation of automatic/associative priming since the occurrence of the category BIRD would predict the occurrence of an exemplar of the category BODY PARTS. On the other hand, if BIRD were to prime an exemplar of the category BODY PARTS, this would be indicative of the operation of conscious/predictive priming.

In order to examine the time course of these two types of priming, Neely (1977) varied the stimulus onset asynchrony (SOA) between the prime and the target from 250 to 2000 msec. At the shortest SOA Neely (1977) found associative priming, which is assumed to be automatic, while at longer delay intervals there was priming attributable to conscious prediction. Neely (1977), using cost-benefit analysis (Posner & Snyder, 1975), also determined that there was a benefit, but no cost, associated with associative priming at short intervals. An approximately equivalent cost and benefit was associated with predictive priming at the longer intervals.

In the present experiment, SOA will be 250 msec for the two masking conditions in order to minimize the influence of conscious prediction. The Neely (1977) results suggest that 250 msec is insufficient time for the development and use of a conscious prediction.

Method

Subjects

96 subjects, who were members of the University of Massachusetts community, received money or experimental credit for their participation. All were native English speakers and had normal or corrected-to-normal vision.

Materials

15 individuals were given typed lists of 49 homophone pairs. They were asked, for each word on the list, to take the noun reading of that word and to write down the first word that came to mind that was also a noun. They were told that if they could not think of a word immediately, they should skip the item. From this list, 32 pairs were chosen that satisfied the following constraints: (1) the highest associate for each word was given by at least 20% of the subjects and (2) the "no response" rate for each word did not exceed 15%.

The highest associates for these 32 pairs of words served as the targets. "Level of association" was taken to be the percentage of times the item appeared as a response. Mean level of association was 48.06 (SD = 20.37). Each member of the 32 pairs served both as an "appropriate" and "homophone" prime. 32 "visually similar" primes were designed to be as visually similar to both members of the homophone pairs as possible ("visually similar" is defined such that a "visually similar" word contains the same letters, in the same positions, as the two members of the homophone pair share). A visual similarity rating system (see Appendix A) was devised in which visual similarity ranges from 0 to 1, where 1 indicates an exact match. Mean visual similarity within homophone pairs (BEACH-BEECH) was .62 and mean visual similarity between the homophones and their "visually similar" controls (BEACH or BEECH paired with BENCH) was .64. "Different" primes were constructed so as to be unrelated visually and semantically to the homophones. "Visually similar" and "different" primes were equated in terms of word length (Mean = 4.31 and SD = .82) and approximately equated in terms of frequency (Francis & Kucera, 1982). "Visually similar" primes had a mean frequency of 48.56 and standard deviation of 81.64 while "different" primes had a mean frequency of 52.47 and standard deviation of 112.92.

A set of filler stimuli was constructed so as to be comparable to the experimental stimuli except that 32 pairs of "visually similar" words (COUCH-COACH) were used instead of homophone pairs. Words judged as being associated with these words served as targets (SOFA, TEAM). See Appendix B for the stimulus materials.

<u>Procedure and Design</u>

Subjects were seated before a Megatek Whizzard CRT display which has P-31 phosphor and temporal resolution within 2 msec. The subject was asked to rest his/her chin in a chin rest in order to maintain a constant distance of 63.5 cm between the subject and the screen throughout the experiment. At this distance, three characters subtended 1 degree of visual angle. Presentation of stimuli was controlled by a Vax 11/730 computer. All stimuli were printed in lower case. The mask was printed in upper case.

A trial was initiated by the appearance of a "+" that served as a warning and fixation point. After a fixed delay, a prime word appeared in the same location as the "+" and was masked after 50 or 200 msec by a pattern of overlapping X's and O's. The mask extended beyond the beginning and ending of the word. In order to hold SOA constant, the mask durations were 200 and 50 msec for the 50 and 200 msec exposure durations respectively. The target word immediately followed the pattern mask and was flanked by "#" signs. See Figure 1.

Subjects were instructed to attend to the prime word and to name the target word as quickly and as accurately as possible. The experimenter recorded pronunciation errors and failures to set off the voice key. 32 practice trials were followed by 128 trials in the experimental session. Of these 128 trials, there were 64 experimental trials (2 trials per homophone pair) and 64 filler trials and each subject only saw one homophone from each pair. For each homophone pair, one of the homophones appeared as a prime for a given subject and either the visually similar or different prime was used instead of the other homophone. Thus no prime or target was repeated for a subject. The experimental conditions were counterbalanced across the stimulus materials over subjects.

Upon completion of the experiment, subjects in the 50 msec exposure duration condition were asked to estimate the percentage of trials on which they were able to identify the prime because it seemed plausible that level of conscious awareness could influence the results.

Results

Pronunciation errors (less than 1 % of all trials), voice key activation errors, response times greater than a 1500 msec cutoff, and responses which lay three standard deviations above the mean for a given condition for a given subject were excluded from data analysis. Additionally, 16 subjects who were missing 25 % or more of the data in any condition due to voice key activation failures were replaced. 5 pairs of items that were missing 25 % or more of the data in any one cell were excluded.

The data were subjected to a 2 X 4 analysis of variance with exposure duration (50 or 200 msec) as a between subjects factor and prime type (appropriate, homophone, visually similar, different) as a within subjects factor. Two sets of data were analyzed -- one before removal of items and one after removal of items. Means of the subjects analysis are presented in Table 1.

The primary focus of the present experiment was on the ability of the homophone to prime naming of the target word. The main effect of prime type was signigicant, $F\ (3,\ 94) = 6.34$, $p < .001$. However, of greater interest were several planned comparisons. The appropriate condition was faster than the different condition, $F\ (1,\ 94) = 11.06$, $p < .005$. The homophone condition was faster than the different condition, $F\ (1,\ 94) = 8.42$, $p < .005$. The homophone condition was also faster than the visually similar condition, $F\ (1,\ 94) = 9.18$, $p < .005$, which did not differ significantly from the different condition, $F < 1$. There was no difference between the homophone and the appropriate conditions, $F < 1$.

Of equal interest was the effect of exposure duration on the priming effects. While there was no main effect of exposure duration, $F < 1$, there was a signigicant exposure duration X prime type interaction, $F\ (3,\ 282) = 2.97$, $p < .05$. Of greater interest were several planned comparisons. According to the verification model, one would expect the appropriate and homophone conditions to be more or less the same when the stimulus is masked after a brief presentation, but, in the longer exposure duration condition, one would expect more priming from the appropriate prime than from the homophone prime.

The appropriate versus homophone comparison interacted with exposure duration, $F\ (1,\ 94) = 5.90$, $p < .05$. Although the appropriate and homophone conditions did not differ significantly from each other in either exposure duration condition, $F(1, 47) = 3.00$, $p < .1$, for the short exposure duration condition and $F(1, 47) = 2.92$, $p < .1$ for the long exposure duration condition, an examination of the means in Table 1 indicates that, at the short exposure duration, the homophone condition was 6 msec faster than the appropriate condition while, at the long exposure duration, the homophone condition was 7 msec slower than the appropriate condition. Although the homophone versus visually similar comparison did not interact with exposure duration, $F(1, 94) = 2.87$, $p < .1$, the homophone condition was 11 msec faster than the visually similar condition at the short exposure duration, $F(1, 47) = 9.80$, $p < .005$, while there was no difference at the long exposure duration, $F < 1$. The homophone versus different comparison interacted with exposure duration, $F(1, 94) = 5.30$, $p < .05$, such that they differed significantly at the short exposure duration, $F(1, 47) =17.03$, but not at the long, $F < 1$.

To summarize, the results of the subjects analyses indicate that, at the short exposure duration, the homophone prime facilitated naming time of a target word as much as the appropriate prime did. The homophone prime also provided significantly more facilitation than a prime matched for visual similarity. In the longer exposure duration condition, only the appropriate prime provided facilitation.

At this point it should be noted that an examination of the means in Table 1 shows that the removal of the 5 pairs of items did not change the pattern of results. It did, however, effect the reliability of the results. The removal of the 5 pairs of items resulted in a significant prime type X exposure duration interaction, a significant interaction of the homophone versus different comparison with exposure duration, and a significant interaction of the appropriate versus homophone comparison with exposure duration. These interactions had only approached significance prior to the removal of the 5 pairs of items for which the subjects tended to fail to activate the voice key.

An items analysis, collapsing over exposure duration, replicated the results of the subjects analysis. Means are presented in Table 2. The effect of prime type was significant, $F(3, 159) = 4.58$, $p < .005$. The appropriate condition was faster than the different condition, $F(1, 53) = 10.00$, $p < .005$. The homophone condition was faster than the different condition, $F(1, 53) = 5.56$, $p < .05$. The homophone condition was also faster than the visually similar condition, $F(1, 53) = 4.54$, $p < .05$ which did not differ significantly from the different condition, $F < 1$. The appropriate and the homophone conditions did not differ, $F < 1$.

The items analysis for the short exposure duration replicated the results of the subjects analysis except that the difference between the homophone and visually similar conditions failed to reach significance, $F(1, 53) = 2.61$, $p < .2$. The appropriate condition was faster than the different condition, $F(1, 53) = 9.86$, $p < .005$. The homophone condition was faster than the different condition, $F(1, 53) = 13.91$, $p < .001$, but the visually similar condition was not, $F(1, 53) = 3.13$, $p < .1$. There was no difference between the appropriate and homophone conditions, $F < 1$.

The items analysis for the long exposure duration failed to replicate the subjects analysis in that there were no significant differences -- the difference between the appropriate and different conditions was significant in the subjects analysis but not in the items analysis, $F(1, 53) = 1.10$, $p < .3$.

Van Orden's (1987) verification model also makes predictions concerning the frequency of the homophone. According to Van Orden (1987), the lower frequency member of the homophone pair is more likely than the higher frequency member of the homophone pair to prime the associate of the other member of the pair. In order to examine the effect of frequency of the homophone, a separate subjects analysis was performed with the factors: exposure duration, prime, and frequency of the homophone. Means are presented in Table 3.

This analysis indicated that target words associated with the lower frequency member of the homophone pair were significantly slower than the target words associated with the higher frequency member of the homophone pair, $F(1, 94) = 32.95$, $p < .00001$, but this factor did not interact with any other factor (all F's < 1).

In order to examine the effect of "level of conscious awareness", subjects in the short exposure duration condition were classified as belonging to one of two groups based on their reported estimates of percentage of primes identified. Those reporting estimates of 50% or higher were classified as "more aware" while those reporting estimates lower than 50% were classified as "less aware". An analysis of variance, with "level of conscious awareness" as a between subjects variable, suggested that "more aware" subjects responded 28 msec faster than "less aware" subjects, $F(1, 46) = 3.50$, $p < .07$. Means from this analysis are presented in Table 4. Although this factor did not interact with prime type ($F < 1$), an examination of the means in Table 4 reveals that the visually similar condition is 9 msec faster than the different condition for the "less aware" group while there is no difference between the visually similar and the different conditions for the "more aware" group. Possible implications of this difference will be considered in the Discussion section.

A final analysis of variance was performed on the data from the filler trials. Exposure duration was a between subjects factor and prime type was a within subjects factor. Means are presented in Table 5. It should be noted that, as discussed in the Method section, a pair of "visually similar" words was used instead of homophone pairs so that, in Table 5, the first column represents means from the appropriate condition whereas the next two columns represent means from conditions that correspond to decreasing levels of "visual similarity". The last column corresponds to the different condition. As in the analyses based on data from the experimental trials, there was a significant effect of prime type, $F\ (3, 282) = 8.21$, $p < .001$. The appropriate condition was faster than the different condition; $F\ (1, 94) = 25.46$, $p < .0001$. None of the other conditions were significantly different from the different condition but examination of the means reveals that naming times decrease with increasing visual similarity. Also note that the magnitude of the appropriate priming effect (12 msec) is similar to that in the experimental condition (9 msec). This suggests that there was nothing "special" about homophones in Experiment 1.

Discussion

The results of Experiment 1 support a model of word recognition in which meaning is accessed through a phonological code. Specifically, the results support a verification model such as that proposed by Van Orden (1987). Van Orden's (1987) verification model asserts that early processes in word recognition result in the production of a phonological code. Only in later verification stages is an orthographic representation checked to discriminate among homophones. If the brief exposure duration in the present experiment is successful in preventing later verification stages, then one would expect priming in this condition to primarily reflect the activation of phonological representations. This is in fact what happened. At the shorter exposure duration, the homophone prime provided as much facilitation as the appropriate prime and, more importantly, more facilitation than the visually similar prime (which did not provide any facilitation).

On the other hand, if the longer exposure duration allowed sufficient time for verification to proceed normally, then one would expect the representation of the "inappropriate" homophone to be inhibited and priming to only occur from the "appropriate" homophone. This is what happened. At the longer exposure duration the only prime to show facilitation was the appropriate prime. The homophone and visually similar primes were no faster than the different prime.

Van Orden's (1987) model also makes predictions concerning the frequency of the homophone. Specifically, the verification model suggests that the low frequency homophone should be more likely to prime the other homophone's associate than the high frequency homophone is to prime the other homophone's associate. That is, "beech" should be more likely to prime "sand" than "beach" is to prime "tree" because of the greater likelihood that the reader would not have complete knowledge of the lower frequency member's spelling. The present experiment failed to provide any evidence for this prediction.

The use of different exposure durations in the present experiment also allowed for an examination of the time course of the activation of visual information in visual word recognition. The Van Orden (1987) and the Rayner and Posnansky (1978) studies provide conflicting results regarding the effects of visual similarity in visual word recognition. Van Orden (1987) found an effect of visual similarity that was restricted to the longer exposure duration in his experiments while Rayner and Posnansky (1978) found an effect of visual similarity at their shortest exposure duration.

There are at least two possible interpretations of the present failure to find an effect of visual similarity. The first is that the lack of an effect is due to the relative insensitivity of the task to priming effects -- all the effects are small -- possibly there would be a real effect of visual similarity if the task were more senstive to priming effects. The second is that, at the shorter exposure duration, the pattern mask terminated processing after a visual analysis of the stimulus had been completed. This explanation is suggested by the results of the Rayner and Posnansky (1978) study in which they found an effect of visual similarity on the word recognition process that appeared early (at an exposure duration of approximately 40 msec) and faded quickly (by about 60 msec).

This interpretation receives some support from the "level of conscious awareness" analysis. As was noted in the Results section, an examination of the means in Table 4 reveals no differences between the visually similar and the different conditions for the "more aware" group while the visually similar condition is 9 msec faster than the different condition for the "less aware" group. This difference is similar in magnitude to the significant difference between the appropriate and different conditions in the overall analysis (see Table 1). As was suggested in the introduction to Experiment 1, it may be possible to infer different stages of processing from reports of percentage of identified primes. If it is assumed that low identification rates (less than 50%) are associated with early stages of processing while higher identification rates are associated with later stages of processing, the present analysis suggests an effect of visual similarity early in the word recognition process. It further suggests that the

50 msec exposure duration allowed some subjects -- specifically, those classified here as "more aware" -- to proceed to later stages of word recognition (stages beyond that in which a visual analysis had been completed) than was possible for other subjects (those classified here as "less aware").

The present experiment provides further evidence that the activation of phonological information in visual word recognition is automatic because it occurs under brief-pattern masking conditions. One possible argument against that interpretation is that, because the task used was naming, and since naming requires the output of a phonological code, subjects may have been biased to use a phonological processing strategy that isn't normally used during visual word recognition. This alternative explanation seems unlikely given the short (250 msec) SOA used in this experiment. Neely's (1977) results suggest that 250 msec is insufficient time for the development and use of a conscious prediction. Furthermore, the present experiment employed a very short (50 msec) exposure duration. Subjects' estimates of identification rates suggest that many of the subjects (40 %) were never consciously aware of the prime in this short exposure duration condition. It is difficult to see how subjects could benefit from special processing strategies without conscious awareness of the prime. That the magnitude of the difference between the homophone and different primes is similar for the "more aware" and "less aware" groups (15 and 16 msec, respectively), suggests that strategic processing did not occur because there was no increased homophone benefit associated with the performance of "more aware" subjects (those presumably more able to take advantage of strategic processes). Finally, if the effect of the homophone is merely due to the use of the naming task, then why does the effect disappear at the longer exposure duration?

Although it seems unlikely that subjects in Experiment 1 were biased to use a phonological processing strategy not normally used in visual word recognition, it would be reassuring to replicate the results of Experiment 1 using a task that doesn't logically require the use of a phonological code. For this reason, the lexical decision task was used in Experiment 2 in an attempt to replicate the present pattern of results.

CHAPTER 3

EXPERIMENT 2

The pattern of results of Experiment 1 supports Van Orden's (1987) verification model. There is some concern, however, that the observed pattern of results may not reflect the operation of processes that normally occur in visual word recognition. Specifically, the use of the naming task, a task that requires the computation and output of a phonological code, may have biased subjects to use an optional phonological processing strategy.

Experiment 2 served as an attempt to replicate the pattern of results obtained in Experiment 1 using a task that does not logically require the use of a phonological code. The task chosen was the lexical decision task. The use of the lexical decision task necessitated the inclusion of nonword targets. These additional stimulus materials will be described below. Other than the use of a different response measure and the inclusion of nonword targets, the experimental design and logic of Experiment 2 was identical to that of Experiment 1. It was predicted that, at the short exposure duration, the homophone prime would provide as much facilitation as the appropriate prime and more facilitation than a visually similar prime while, at the longer exposure duration, only the appropriate prime would provide facilitation relative to the different prime.

Method

Subjects

48 subjects, who were members of the University of Massachusetts community, received money or experimental credit for their participation. All were native English speakers and had normal or corrected-to-normal vision.

Materials

The stimulus materials from Experiment 1 were expanded to include an additional set of 16 homophone pairs (comparable to the experimental stimuli in Experiment 1) and 16 "visually similar" pairs (comparable to the filler stimuli in Experiment 1). As in Experiment 1, a "visually similar" and a "different" word were associated with each of these pairs. These words served as primes for 32 pairs of nonwords. The only constraints concerning the construction of nonwords were that: (1) they be pronounceable and (2) they not be pseudohomophones. The nonword targets had a mean length of 5 and SD of 1.30 while the word targets had a mean length of 4.72 and SD of 1.20.

Procedure and Design

The apparatus and general procedure were the same as in Experiment 1. Subjects were instructed to attend to the prime word and to decide whether or not the target word was a real word. They were instructed to make this decision as quickly and as accurately as possible. Subjects indicated whether or not the target was a real word by pressing one telegraph key with their right hand if it was, and another with their left hand if it was not. Subjects received feedback on a trial-by-trial basis as to the accuracy of their judgments.

32 practice trials were followed by 192 trials in the experimental session. Of these 192 trials, 128 employed the stimulus pairs used in Experiment 1 -- 64 experimental trials (2 trials per homophone pair) and 64 filler trials. There were also 64 nonword trials (2 trials for each of the additional 16 homophone pairs and 2 trials for each of the additional 16 "visually similar" pairs). Thus, two-thirds of the targets were words and one-third were nonwords. The pairing of primes with nonwords was accomplished in the same way that prime-target pairing had been accomplished in Experiment 1 -- for each homophone and "visually similar" pair, one member of the pair appeared as a prime for a given target and either the visually similar or different prime was used instead of the other member of the pair to prime the other target. Thus no prime or target was repeated for a subject. The experimental conditions were counterbalanced across the stimulus materials over subjects.

Results

The purpose of Experiment 2 was to replicate the pattern of results obtained in Experiment 1 using a task that does not logically require the use of a phonological code -- the lexical decision task. Therefore, the same analyses that were of interest in Experiment 1 are of interest in Experiment 2. The primary finding of Experiment 1 was that, in the short exposure duration condition, the homophone prime facilitated naming time of a target word as much as the appropriate prime did. Furthermore, this facilitation could not be attributed to the visual similarity of the two homophones as the homophone prime provided significantly more facilitation than a prime matched for visual similarity. In the longer exposure duration condition, only the appropriate prime provided facilitation. Experiment 2 failed to replicate these results for the shorter exposure duration.

Lexical decision errors, response times greater than a 1500 msec cutoff, and responses which lay three standard deviations above the mean for a given condition for a given subject were excluded from data analysis. Error rates are presented in Table 6. As in Experiment 1, the data were subjected to a 2 X 4 analysis of variance with exposure duration (50 or 200 msec) as a between subjects factor and prime type (appropriate, homophone, visually similar, different) as a within subjects factor. Means of this analysis are presented in Table 7.

In the subjects analysis, there was no main effect of prime type, $F(3, 138) = 2.06$, $p < .2$. Furthermore, of the planned comparisons performed in Experiment 1, only one reached statistical significance in Experiment 2: the appropriate and homophone conditions were significantly different, $F (1, 46) = 4.65, p < .05$. Especially troublesome is the lack of a standard priming effect -- there was no significant difference between the appropriate and the different conditions, $F (1, 46) = 2.22, p < .2$. In order to provide a more statistically powerful test of the standard priming effect, the appropriate condition was compared to the average of the three other conditions. This analysis resulted in a marginally significant difference, $F (1, 46) = 3.61, p < .07$.

The effect of exposure duration was also of interest in this experiment. As in Experiment 1, there was no main effect of exposure duration, $F < 1$, but there was a signficant exposure duration X prime type interaction, $F (3, 138) = 2.76, p < .05$. There was also a difference in the size of the difference between the homophone and visually similar conditions across the two exposure durations, $F (1, 46) = 4.75, p < .05$. At the short exposure duration, the homophone condition was 22 msec slower than the visually similar condition, $F (1, 23) = 4.49, p < .05$ while, at the longer exposure duration, the homophone condition was 16 msec faster than the visually similar condition though this difference was not significant, $F (1, 23) = 1.29, p < .3$. This result is in direct contrast with the results of Experiment 1 in which the homophone condition was faster than the visually similar condition at both exposure durations with the difference being greater at the short exposure duration. Finally, the difference between the appropriate condition and the average of the three other conditions also interacted with exposure duration, $F(1, 46) = 5.19$, $p < .05$. The 3 msec difference at the short exposure duration was not significant, $F < 1$, while the 28 msec difference at the long exposure duration was significant, $F(1, 23) = 11.93$, $p < .005$.

To summarize, at the shorter exposure duration the only reliable difference was that between the homophone and the visually similar conditions and the direction of this difference was in direct contrast to the direction of the difference in Experiment 1. At the longer exposure duration, the standard priming effect obtained: the semantically related prime was faster than all the other conditions.

An items analysis, collapsing over exposure duration, and separate items analyses for each exposure duration were also performed. Means are presented in Table 8. In contrast to the subjects analyses, the items analysis collapsing over exposure duration indicated an effect of prime type, $F(3, 189) = 2.84$, $p < .05$ and a significant priming effect of 15 msec for the appropriate condition relative to the different condition, $F(1, 63) = 4.48$, $p < .05$.

In the separate items analyses for each exposure duration several differences were significant that had not been significant in the subjects analyses: the difference between the appropriate and the different conditions and the difference between the appropriate and the homophone condition in the long exposure duration condition, $F(1, 63) = 5.86$, $p < .05$; $F(1, 63) = 4.67$, $p < .05$. Also in conflict with results of the subjects analysis is the lack of a difference between the homophone and visually similar conditions at the short exposure duration, $F(1, 63) = 2.56$, $p < .2$.

As was suggested in Experiment 1, it may be possible to infer different stages of processing for subjects in the short exposure duration condition from reports of percentage of identified primes. Therefore, a "level of conscious awareness" analysis may provide some insight regarding the results in the short exposure duration condition of Experiment 2. Subjects were classified as "less aware" or "more aware" as in Experiment 1. An analysis of variance with "level of conscious awareness" as a between subjects variable, suggested that more aware subjects had faster response times than less aware subjects; $F(1, 22) = 3.94$, $p < .06$. Means from this analysis are presented in Table 9. Although no other differences approached significance, an examination of the means suggests the presence of an inhibition effect for the more aware subjects. The appropriate condition was 9 msec slower than the different condition while the homophone condition was 22 msec slower than the different condition.

A final analysis of variance was performed on the data from the filler trials. Exposure duration was a between subjects factor and prime type was a within subjects factor. Means are presented in Table 10. As was the case with the experimental trials, there was no difference between the appropriate and the different primes in the short exposure duration condition, $F < 1$, but, in the long exposure duration condition, the difference between the appropriate and different primes approached significance, $F\ (1, 23) = 3.16$, $p < .09$.

Discussion

The primary motivation for Experiment 2 was the concern that the results of Experiment 1 may have been due to the use of a task (naming) that requires the use of a phonological code, and thus may not reflect processes that generally occur during visual word recognition. Experiment 2 was intended as a replication of Experiment 1 using the lexical decision task -- a task that doesn't logically require the use of phonological information. If Experiment 2 had replicated Experiment 1, this would have been evidence that the results of Experiment 1 are not task-dependent. However, Experiment 2 did not replicate the results of Experiment 1. What does this failure to replicate indicate?

It will be argued that the failure to replicate the results of Experiment 1 should not be interpreted as providing evidence that the results of Experiment 1 were dependent upon the use of the naming task.

The naming and lexical decision tasks differ in obvious ways and any of these differences could be responsible for the differing results of Experiments 1 and 2. As has already been noted, the naming task requires the use of phonological information while the lexical decision task does not. This difference could explain the failure of Experiment 2 to replicate Experiment 1 if it is assumed that phonological information is an optional source of information in visual word recognition -- a source that is used in the naming task but not in lexical decision. Another difference between the two tasks suggests an alternative interpretation: the lexical decision task requires that the subject decide whether or not a letter string is a real word while in naming, the subject is merely required to pronounce the target word correctly. Seidenberg, Waters, Sanders, and Langer (1984) have suggested that, because of the signal detection nature of the task, lexical decision is more prone to bias and postlexical processing than is the naming task. In the naming task, there is no decision to bias.

In a study examining the effects of sentence context on word recognition, Seidenberg et al. (1984) found that semantic and associative priming occurred with both naming and lexical decision but that "other facilitative contextual effects, due to syntactic relations between words, backward associations, or changes in the proportion of related items, occurred only with the lexical decision task" (p. 315). Therefore, it is possible that the different results of the present experiments could be due to the differing sensitivity of naming and lexical decision to postlexical processes. Although it is difficult to determine what strategies may have been operating in the present study, one thing seems clear: either the strategies had a different effect across exposure duration or different strategies were used in the two exposure duration conditions. At the short exposure duration, there is no indication of the standard ("appropriate" vs."different") priming effect while, at the long exposure duration, there was a nonsignificant difference of 21 msec. A recent study by Dagenbach, Carr, and Wilhelmsen (1989) suggests a possible interpretation of this difference across exposure duration.

Dagenbach et al. (1989) examined priming in the lexical decision task as a function of SOA and threshold setting procedure and found that "priming initially decreases as SOA is shortened in the threshold region, but increases as SOA is shortened further" (p. 412). They also found that priming is influenced by the type of information required by the judgment task used as a threshold setting procedure suggesting that different tasks induce different strategies for the retrieval of information. Finally, Dagenbach et al. (1989) suggest that conscious and unconscious processes interact such that unsuccessful attempts to retrieve semantic information into consciousness will result in inhibition. Therefore, the lack of any significant differences in the short exposure duration condition could be due to the presence of both facilitation and inhibition -- facilitation when retrieval attempts are successful and inhibition when retrieval attempts are not successful. This interpretation of the data does not seem supported by the results of the "level of conscious awareness" analysis (see Table 9) which shows a pattern of priming for the "less aware" subjects similar to that found at the long exposure duration with the naming task (there's an indication of a difference between the appropriate and the different primes but no other differences). For the "more aware" subjects, there is some indication of inhibition for both the appropriate and the homophone primes. Dagenbach et al. (1989) seem to suggest that inhibition should be more apparent for "less aware" subjects -- subjects more likely to have experienced unsuccessful retrieval attempts. One important difference between Dagenbach et al. (1989) and the present experiment that needs to be noted is that Dagenbach et al. (1989) determined thresholds for their subjects while in the present experiment, the same exposure duration (50 or

200 msec) was used for all subjects. The only indication of "level of conscious awareness" were estimates given by subjects after the completion of the experiment. Although these estimates are informative, they cannot be thought to be very precise. Because thresholds were not set, it is difficult to determine how "unconscious" and "conscious" processes may have interacted in the present experiment.

Although the present results are not easily interpreted, it seems reasonable to argue that the differences between Experiments 1 and 2 are not due solely to whether or not the use of phonological information was required by the task. Dagenbach et al. (1989) and Seidenberg et al. (1984; see also Waters & Seidenberg, 1985) found that the lexical decision task is susceptible to effects of strategic processing while Seidenberg et al. (1984) and Waters and Seidenberg (1985) found that the naming task is relatively insensitive to these effects.

Also, several aspects of the data from Experiment 2 suggest that the different results across experiments are due to something more than the requirement or non-requirement of the use of phonological information. If this were the sole cause of the differing results, then one would expect that the results of Experiment 2 would differ from Experiment 1 only in terms of whether or not a "homophone" priming effect was present. This clearly was not the case. There was no priming at the short exposure duration even from semantic primes. Therefore, it is reasonable to argue that the different results are due to the differing sensitivity of the naming and lexical decision tasks to strategic processing. Furthermore, it seems likely that in the lexical decision task conscious processes interact with unconscious processes (see Dagenbach et al., 1989).

CHAPTER 4

GENERAL DISCUSSION

The present set of experiments were designed to test Van Orden's (1987) verification model using a priming paradigm in which the primes (members of homophone pairs, e.g. BEECH, BEACH) are pattern-masked at two different exposure durations and time to name the target word (associates of each of the members of the homophone pair) is measured. As in the Rayner and Posnansky (1978) and the Van Orden (1987) studies, using different exposure durations allowed for an examination of the time course of the activation of visual and phonological information in visual word recognition.

A short exposure duration and a short (250 msec) SOA were also used in order to address the issue of the automaticity of the activation of phonological information during visual word recognition. A pattern mask is assumed to terminate processing of a word such that under brief pattern masking conditions only the most rapidly activated codes are available. Unlike the Rayner and Posnansky (1978), the Perfetti et al. (1988), and the Brysbaert et al. (1990) studies, the present experiments were concerned with semantic priming from words visually or homophonically related to an "appropriate" prime (e.g. priming of TREE from

BEACH or BENCH) rather than with strictly visual or homophonic priming (e.g. priming of MAID from MAYD or MARD).

Van Orden's (1987) verification model predicts that, if the brief pattern masking condition in the present experiments prevented verification from occurring, a homophone should prime both meanings associated with its sound representation. If the longer exposure duration allowed sufficient time for verification to occur, then priming should only occur from the "appropriate" homophone. This is in fact what happened in Experiment 1. At the shorter exposure duration, the homophone prime provided as much facilitation as the appropriate prime and, more importantly, more facilitation than the visually similar prime. At the longer exposure duration the only prime to show facilitation was the appropriate prime. The homophone and visually similar primes were no faster than the different prime.

The results of Experiment 1 suggested that visual information is a transient source of information early in the word recognition process. While there was no effect of visual similarity at either exposure duration, the "level of conscious awareness" analysis suggested a larger effect of visual similarity for "less aware" subjects than for "more aware" subjects -- subjects presumably at an earlier stage of processing than "more aware" subjects. The results further suggested that phonological information is activated automatically as part of the visual word recognition process. There was an effect of phonology in the 50 msec exposure duration with an SOA of 250 msec.

The results of a second lexical decision experiment failed to support Van Orden's (1987) verification model, as there was no "homophone" effect or standard priming effect on lexical decision time in the short exposure duration condition. What possible basis is there for the different results across experiments? Since Experiments 1 and 2 differed only in terms of the task used -- naming in Experiment 1 and lexical decision in Experiment 2 -- the different results across experiments must be related to differences between the two tasks.

The simplest interpretation of the conflicting results concerns the motivation for the change in task across experiments. The change in task was motivated by the concern that the results of Experiment 1 may have been due to the use of a task (naming) that requires the use of a phonological code, and thus may not reflect processes that generally occur during visual word recognition. Therefore, the lexical decision task, a task that does not logically require the use of phonological information, was used in Experiment 2 in an attempt to replicate the results of Experiment 1. The failure to replicate the results of Experiment 1 using the lexical decision task may indicate that the results of Experiment 1 do not reflect processes that generally occur during visual word recognition but instead reflect strategic or optional processes that come into play only when the use of phonology is required by the task.

Although the above interpretation of the conflicting results is the simplest interpretation, there are many indications that it is not correct. First of all, there are data to suggest that the 250 msec SOA used in the present experiments is insufficient time for the development and use of a conscious prediction (Neely, 1977). Furthermore, subjects' estimates of identification rates suggest that the 50 msec exposure duration prevented many subjects from ever being consciously aware of the prime. It is difficult to see how subjects could benefit from special processing strategies without conscious awareness of the prime. Also, in Experiment 1, the magnitude of the difference between the homophone and different primes is similar for the "more aware" and "less aware" groups (15 and 16 msec respectively). This finding indicates that strategic processing did not occur as there was no increased homophone benefit associated with the performance of "more aware" subjects (those presumably more able to take advantage of strategic processes). Finally, the lack of a standard priming effect in the short exposure duration condition in Experiment 2 suggests that the differing results are due to something more than the operation or nonoperation of an optional phonological processing strategy.

Another difference between the two tasks suggests an alternative interpretation: the lexical decision task has been shown to be more prone to bias and postlexical processing than is the naming task (Seidenberg et al., 1984). Therefore, it is possible that the differing results in Experiments 1 and 2 are due to the differential sensitivity of naming and lexical decision to strategic processing. Although an in-depth discussion of strategies that may have been operating in Experiment 2 is beyond the scope of this paper, one possibility is suggested by Dagenbach et al. (1989). Dagenbach et al. (1989) suggest that conscious and unconscious processes interact such that "successful attempts to retrieve semantic information into consciousness will result in facilitatory priming whereas unsuccessful attempts will result in inhibition" (p. 440). Therefore, the lack of any significant differences in the short exposure duration in Experiment 2 could be due to the presence of both facilitation and inhibition -- facilitation when retrieval attempts are successful and inhibition when retrieval attempts are not successful.

Thus, in summary, it appears that the results of Experiment 2 do not invalidate the interpretation of the results of Experiment 1 as support for Van Orden's (1987) verification model. If the requirement or non-requirement of the use of phonological information by the task were the sole cause of the differing results across experiments, then one would expect that the results of Experiment 2 would differ from Experiment 1 only in terms of whether or not a "homophone" priming effect was present. This clearly was not the case. A reasonable interpretation of the data seems to be that the different results are due to the differing sensitivity of the naming and lexical decision tasks to strategic processing. Therefore, Experiment 1 can be taken as evidence for Van Orden's (1987) verification model.

The results of Experiment 1 provide support for a model of word recognition in which meaning is accessed through a phonological code -- that is, it provides evidence that visual word recognition is phonologically mediated. Prior to the Van Orden (1987; Van Orden, Johnston, & Hale, 1988) studies there was no strong evidence for phonological mediation. Few studies had shown an effect of phonology that couldn't be dismissed as a latecomer in the word identification process. Now, there are at least three studies that provide strong evidence for the automatic activation of phonology in the word recognition process. Perfetti et al. (1988) demonstrated the automatic activation of phonology while Van Orden (1987; Van Orden, Johnston, & Hale, 1988) went a step further by showing that meaning is accessed through the automatic activation of phonological information. The present experiments form a step in that same direction.

Beyond the controversy, what makes the question of phonological mediation so interesting? One reason is that, for beginning readers at least, speech is intimately tied to the reading process. Children come to the task of reading with a relatively well-developed knowledge of spoken language. It is a common observation that children "sound out" new words. Mattingly (1972) argues: "Speaking and listening are primary linguistic activities; reading is a secondary and rather special sort of activity that relies critically upon the reader's awareness of these primary activities . . . The process of learning to read is the process of transfer from the auditory signs for language signals which the child has already learned, to the new visual signs for the same signals" (pp. 133-134). Beginning readers clearly translate from spelling to sound, and it could be argued that adult readers also translate from spelling to sound. After all, speech remains the primary means of communication throughout life and, for that reason, reading may proceed more efficiently through the use of a speech code. Perhaps one distinction between new readers and skilled readers is that the spelling-to-sound translation process is a slow, effortful process in new readers while it is an automatic process in skilled readers. Therefore, the faster reading rates of skilled readers may be due to an automaticity of the spelling-to-sound translation process rather than to a bypassing of phonology.

This paper claims to be concerned with the role of phonology in reading. However, many people would argue that the present experiments do not have much to say about normal reading. Clearly, the present experiments were only concerned with one component of the reading process -- the recognition of printed words. However, the finding that phonology exerts a prelexical influence in visual word recognition indicates that it would be worthwhile performing experiments that more closely approximate normal reading.

One interesting question concerns the effect of context on word recognition. A great deal of research on the effects of context on the recognition of ambiguous words (e.g. "iron" in the sense of "clothes" and "iron" in the sense of "steel") has been performed within a framework of "modularity". The present experiments, along with those performed by Van Orden (1987; Van Orden, Johnston, & Hale, 1988) suggest that, until verification occurs, homophones are ambiguous words. Therefore, the types of experiments that have been performed within a modularity framework to examine recognition of ambiguous words could also be performed to examine the role of phonology in the recognition of words within context. Before discussing this possibility further, it will first be necessary to discuss "modularity".

According to Fodor (1983), word recognition is modular. Modules are special purpose computational devices characterized by the following properties: they are mandatory, fast, informationally encapsulated ("stupid"), and domain specific. Also, only the end result of a process is available to consciousness and the output produced by a module is shallow. According to a "modular" conception of word recognition, word recognition consists of sense activation and sense selection. Words are represented in the lexicon by one or more word senses and during sense activation all meanings/senses of a word are activated (unconsciously) regardless of thematic appropriateness. Later, during sense selection, the thematically appropriate meaning is selected and made available to consciousness. Many studies support this conception of word recognition.

Onifer and Swinney (1981) and Seidenberg, Tanenhaus, Leiman, and Bienkowski (1982) used a cross modal lexical priming task in which sentences containing a lexically ambiguous word (a homograph such as "iron") were presented auditorily. The homograph served as the prime and a target word related to the primary or secondary meaning of the ambiguous (e.g. "clothes" or "steel" given "iron") was presented visually, either immediately, or at a fixed delay. In the Seidenberg et al. (1982) study the subjects were required to name the target word while Onifer and Swinney (1981) required their subjects to make a lexical decision to the target word. The results of both these studies indicated that all meanings of the ambiguous word are initially activated regardless of prior context. That is, subjects were faster to respond to both "clothes" and "steel" given "iron" than to an unrelated control irrespective of which meaning was predicted by prior context. On the other hand, after about 200 msec, only the contextually appropriate meaning is still active. That is, only the meaning of "iron" that was predicted by the prior context is facilitated relative to an unrelated control.

Kintsch and Mross (1985) replicated and extended the Onifer and Swinney (1981) results. Using a rapid serial visual procedure (RSVP) in which the target word was clearly set off from the rest of the text, Kintsch and Mross (1985) found that both meanings of an ambiguous word were activated regardless of prior context. When presentation was self-paced, however, only thematically appropriate meanings were activated suggesting that the speed of the RSVP prevented sense selection from occurring prior to target presentation.

In order to better address the issue of what role phonology plays in reading, it will be necessary to perform experiments that more closely approximate the normal reading process. Several interesting possibilities are suggested by previous research on word recognition performed within a modularity framework. One possibility would be to replicate Kintsch and Mross (1985) using homophones. The Van Orden

(1987; Van Orden, Johnston, & Hale), the Perfetti et al. (1988), and the present experiments argue that phonology is automatically activated during the word recognition process and therefore may form part of the word recognition module. A replication of the Kintsch and Mross (1985) experiments would provide further evidence of the automatic activation of phonological information during visual word recognition and would also address the issue of the effect of context on the use of phonological information in lexical access.

APPENDIX A

VISUAL SIMILARITY RATING SYSTEM

In order to control for the visual similarity that is common between members of a homophone pair, a visual similarity rating system was devised in which visual similarity ranges from 0 to 1, where 1 indicates an exact match. Estimates of visual similarity (VS) were calculated as follows:

(1) $$\frac{1}{\text{\# of letters in the word}} = \text{"letter value"}$$

For example, for stair-stare, $\frac{1}{5} = .2$

(2) How many letters are "shared" between the two words (in and out of position)? Take number of letters shared and multiply by "letter value"

For stair-stare, (4) (.2) = .8

(3) How many "shared" letters occur in the same position within the two words? Multiply this number by "letter value"

For stair-stare, (3) (.2) = .6

(4) VS = the average of the results of (2) and (3)

For stair-stare, $\frac{.8 + .6}{2} = .7$

APPENDIX B

STIMULUS MATERIALS FOR EXPERIMENT 1

The first two columns are the homophone pairs. These words served as both Appropriate and Homophone primes. The third column is the Visually Similar prime and the fourth column is the Different prime. The fifth and sixth columns are the associated target words.

Experimental Trials:

beech	beach	bench	fluid	nut	sand
fur	fir	far	day	coat	tree
stare	stair	stars	lunch	look	step
mail	male	mall	knob	letter	female
vein	vane	vine	moth	blood	weather
fowl	foul	foal	tint	bird	ball
sail	sale	salt	crop	boat	clothes
tale	tail	talk	need	story	dog
bail	bale	ball	news	jail	hay
roll	role	rock	path	bun	play
loot	lute	list	fear	money	music
creek	creak	crook	bloom	stream	squeak
miner	minor	manor	pedal	coal	major
dough	doe	doom	pawn	bread	deer
night	knight	flight	branch	day	armor
time	thyme	tame	lust	clock	spice
maize	maze	haze	slug	corn	rat
rain	rein	ruin	boot	water	horse
poll	pole	pool	test	vote	stick
hair	hare	harm	nest	head	rabbit
sole	soul	soil	park	shoes	spirit
sun	son	sin	leg	moon	daughter
pain	pane	pans	lump	ache	window
piece	peace	peach	straw	part	war
suite	sweet	sweat	track	hotel	sour
waist	waste	warts	punch	hips	garbage
mussel	muscle	missile	blanket	clam	arm
right	rite	riot	bulb	left	passage
flour	flower	floor	teeth	sugar	rose
peer	pier	pies	mobs	friend	dock
gate	gait	gasp	crow	walk	fence
pair	pear	par	ton	two	fruit

Fillers:

desk	dusk	dust	home	chair	dawn
dent	tent	rent	size	crash	camp

Continued, next page

STIMULUS MATERIALS FOR EXPERIMENT 1 continued

bride	broom	braid	chief	groom	sweep
purse	pearl	perch	diary	wallet	necklace
mouth	month	south	paper	lips	year
king	kite	kit	mast	queen	string
car	cap	cat	fig	truck	hat
cheese	church	chunk	task	mouse	priest
town	tune	tone	luck	city	song
doctor	dollar	dozen	larva	nurse	money
dream	drain	dread	panic	sleep	sink
hand	hall	harp	poet	finger	corridor
green	grain	grasp	labor	grass	wheat
nail	navy	name	mind	hammer	army
lamp	lamb	limb	index	light	sheep
lion	line	link	heap	tiger	row
spider	spine	spin	muzzle	web	back
snake	snack	sneak	gloom	lizard	treat
earth	heart	ear	prank	ground	love
bug	gag	bag	pit	fly	joke
death	breath	wreath	globe	life	air
dirt	drink	drill	pilot	mud	soda
sky	ski	skid	hog	blue	snow
circus	circle	curve	meteor	clown	square
stove	glove	cove	knee	oven	mitten
couch	coach	crack	metal	sofa	team
street	state	steam	pride	road	country
skull	skill	skirt	title	bones	ability
patio	piano	pinto	skunk	porch	concert
shirt	sheet	shore	goals	blouse	bed
pin	pan	pun	mop	needle	pot
candle	bundle	handle	tonsil	wax	package

APPENDIX C

```
      50 or 200 msec  200 or 50 msec
----> --------------> --------------> ------>
 +        BEACH           XXXXX       TREE

          prime           mask        target
```

Subjects were instructed to attend to the prime word and to name the target word as quickly as possible.

Figure 1. Paradigm used in Experiment 1

APPENDIX D

TABLES

TABLE 1

Mean naming times (in milliseconds) as a function of prime type and exposure duration. Subjects analysis.

	Prime type			
	Appropriate	Homophone	Visually Similar	Different
Short	598 (597)	592 (595)	603 (604)	608 (607)
Long	598 (588)	605 (594)	608 (599)	607 (597)
Overall	598 (592)	598 (595)	605 (602)	607 (602)

*Note. Numbers in parentheses are means before the removal of items.

TABLE 2

Mean naming times (in milliseconds) as a function of prime type and exposure duration. Items analysis.

	Prime type			
	Appropriate	Homophone	Visually Similar	Different
Short	595	592	599	608
Long	589	596	600	595
Overall	592	594	600	602

*Note. Numbers represent means after the removal of items.

TABLE 3

Mean naming time (in milliseconds) as a function of the frequency of the homophone.

		Prime type			
		Appropriate	Homophone	Visually Similar	Different
Short	LF	600	597	608	613
	HF	589	584	596	604
Long	LF	595	598	603	603
	HF	585	592	591	591
Overall	LF	598	598	606	608
	HF	587	588	593	597

*Note. LF = lower frequency member of the homophone pair. HF = higher frequency member of the homophone pair.

TABLE 4

Mean naming times (in milliseconds) as a function of prime type and "level of conscious awareness" in the short exposure duration condition.

	Prime type			
	Appropriate	Homophone	Visually Similar	Different
Less Aware	613	607	614	623
More Aware	583	577	591	592
Overall	598	592	603	608

TABLE 5

Mean naming times (in milliseconds) for filler trials as a function of prime type and exposure duration.

		Prime type		
	Appropriate	VS1	VS2	Different
Short	596	603	606	606
Long	600	608	614	614
Overall	598	605	610	610

*Note. VS1 and VS2 represent decreasing levels of visual similarity.

TABLE 6

Proportion of lexical decision errors in Experiment 2 as a function of experimental condition.

	Short Exposure Duration	
	errors	SD
Experimental trials:		
Appropriate	.008	.02
Homophone	.010	.03
Visually Similar	.018	.03
Different	.013	.03
Fillers (word trials):		
Appropriate	.013	.03
VS1	.003	.01
VS2	.021	.04
Different	.018	.03
Nonword trials (homophones):		
Homophone 1	.057	.12
Homophone 2	.068	.10
Visually Similar	.047	.08
Different	.073	.10
Nonword trials (VS pairs):		
VS	.073	.09
VS1	.047	.10
VS2	.078	.11
Different	.057	.06

Continued, next page

TABLE 6 continued

Long Exposure Duration

	errors	SD
Experimental trials:		
Appropriate	.021	.04
Homophone	.018	.05
Visually Similar	.016	.03
Different	.016	.03
Fillers (word trials):		
Appropriate	.008	.02
VS1	.013	.03
VS2	.013	.03
Different	.021	.04
Nonword trials (homophones):		
Homophone 1	.068	.09
Homophone 2	.136	.13
Visually Similar	.068	.07
Different	.083	.11
Nonword trials (VS pairs):		
VS	.068	.08
VS1	.089	.09
VS2	.083	.10
Different	.063	.09

TABLE 7

Mean lexical decision times (in milliseconds) in Experiment 2 as a function of prime type and exposure duration (subjects analysis).

	Prime type			
	Appropriate	Homophone	Visually Similar	Different
Short	669	684	662	671
Long	629	653	669	650
Overall	649	669	666	661

TABLE 8

Mean lexical decision times (in milliseconds) in Experiment 2 as a function of prime type and exposure duration (items analysis).

	Prime type			
	Appropriate	Homophone	Visually Similar	Different
Short	672	688	670	676
Long	635	657	672	660
Overall	653	673	671	668

TABLE 9

Mean lexical decision time (in milliseconds) as a function of prime type and "level of conscious awareness" in the short exposure duration condition.

	Prime type			
	Appropriate	Homophone	Visually Similar	Different
Less Aware	694	703	704	708
More Aware	644	657	620	635
Overall	669	680	662	671

TABLE 10

Mean lexical decision time (in milliseconds) for filler trials as a function of prime type and exposure duration.

	Prime type			
	Appropriate	VS1	VS2	Different
Short	673	673	674	675
Long	645	668	682	666
Overall	659	671	678	671

*Note. VS1 and VS2 represent decreasing levels of visual similarity.

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