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Lexical Access With and Without Awareness

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SUMMARY

Marcel reported some startling findings regarding the processing of briefly presented, pattern-masked words. His results suggest that perceivers access the meanings of words that, due to the effects of the mask, they are unaware even of having seen. These results imply that central pattern masking does not interrupt perceptual processing of words as some theorists have supposed. Instead it may prevent *awareness* of perceptual products. The present series of investigations examines some potential artifacts of design or execution of Marcel's studies and of a related study reported by Allport.

Three studies (Experiments 1, 2, 4) examine the perceivers' judgments of certain properties of masked words. Experiments 1 and 2 replicate Marcel's early studies in demonstrating better-than-chance judgments about semantic properties of a word at target-mask intervals at which detection judgments and judgments of the physical properties of the work are at or near chance. However, a control "nonexperiment" (Experiment 3) in which no words are presented before the mask yields a similar outcome. Experiment 4 examines the relative semantic relatedness, as assessed by naive judges, of masked-target/response pairs of the sort obtained by Allport and of randomly associated words and responses. Judges did not distinquish the two kinds of word pairs.

Despite these negative findings, a final pair of experiments (Experiments 5 and 6) replicates Marcel's demonstration that masked words, no less than unmasked words, facilitate lexical decisions concerning subsequently presented semantically related words. Experiment 5 also obtains graphic and phonetic priming under mask and no-mask conditions.

Marcel (Marcel, in press; Marcel & Patterson, 1978) and Allport (1977) recently reported some important and rather startling results concerning the processing of briefly presented pattern-masked words. The findings of several experiments appear to indicate that subjects have accessed the meanings of words that, due to the effects of the mask, they may be unaware even of having seen.

These results are counterintuitive, but what is perhaps more critical, they are unexpected on theoretical grounds relating to the supposed effects of pattern masking and the processing of written words. If the findings are real, at the very least they force a change in our understanding of masking as a methodological tool. In addition, they may require that we acknowledge a distinction of some functional significance between conscious and unconscious knowledge or processes (an acknowledgment also promoted, for example, by the work of Posner, e.g., 1978).

Because the implications of the work are major, and the results counterintuitive, we considered it important to repeat some of the studies, examining several potential artifacts of design or execution of the experiments and considering alternative accounts of the findings. We saw as primarily significant Marcel's finding that the meanings of words masked at detection-level stimulus-onset asynchronies (SOAs) are fully activated. We should say, in anticipation, that this result has resisted our efforts to eliminate it as artifactual.

Below, we summarize two of Marcel's recent experiments and the experiment described by Allport (1977). Then we turn to our efforts to replicate their findings.

In Marcel's initial investigations (Marcel, in press), his procedure was to discover for each subject the longest SOA at which he or she was unable to determine whether a word or a blank card had been presented prior to a pattern mask. At this SOA, despite an inability to make presence/absence (detection) judgments, subjects did exceed chance in choosing which of two words presented after the mask was most closely associated with the masked word in meaning or form. As the SOA was gradually reduced, Marcel found for most subjects that form judgments dropped to chance before meaning judgments did. Thus, subjects showed a sensitivity to meaning at SOAs at which they could provide no form information, and a sensitivity to form and meaning at SOAs at which they could not make presence/absence judgments.

In these experiments, the mask was a pattern mask presented binocularly. The range of SOAs at which detection judgments fell to chance (the "detection-level SOA") varied widely across individuals, from 20 to 110 msec. Marcel assumed that the masking that he obtained under these conditions was "central" masking (Turvey, 1973)—that is, masking that requires a mask similar in its component features to the target, that can be obtained dichoptically, and that depends on SOA for its effectiveness but not on the energy relations between target and mask. This kind of masking contrasts with "peripheral" masking, which does not require feature similarity between target and mask, is ineffective dichoptically, and depends strongly both on the energy relations between target and mask and on the time between target offset and mask onset (the interstimulus interval).

Whereas peripheral masking has been attributed to an integration or summing of the target and mask representations when a higher energy mask overtakes the lower energy target, central masking is held to terminate perceptual processing of the target (Turvey, 1973). According to this interpretation of central masking, the information that is available even at very brief SOAs is that which is extracted earliest from a stimulus in the course of perceptual processing (cf. Merikle, 1977; Michaels & Turvey, 1979). Information that is available only at longer SOAs is extracted later in perceptual processing. According to this view, central masking is a powerful tool for examining the gradual accumulation of information from a stimulus that is believed to characterize perceptual processing.

However, Marcel's (in press) data cast serious doubt on the foregoing interpretation of the effects of central masking. If the interpretation were correct, we would be forced to conclude from Marcel's findings that semantic information is extracted prior to form information and form information is extracted before a stimulus is detected. Since this temporal ordering of perceptual processes is nonsensical, Marcel concluded, apparently inescapably, that central masking does not terminate perceptual processing. Rather, masking may only prevent awareness that a stimulus has been witnessed. The backward ordering of semantic, form, and detection influences on behavior, then, may have to do with the relative rates at which these three kinds of information begin to affect conscious decision-making endeavors.

Allport (1977) described some findings, compatible with those of Marcel, that he discovered in the error data of subjects participating in a masking experiment. In his studies, subjects were shown a pair or tetrad of words followed after a brief delay by a pattern mask. The SOAs in these studies were chosen so that subjects reported ap-

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proximately 25% of the target items correctly. Allport found that 6%–9% of the whole-word errors made by subjects in these studies were semantically related to the presented word but did not resemble them physically. Thus, for example, "wine" was reported for "drink" and "jazz" for "blues." Allport presumed this 6%–9% of semantically related target-response pairs to exceed the percentage that would be obtained by a random pairing of words. (This presumption has been convincingly challenged by Ellis and Marshall, 1978; see below.)

As Marcel (in press) pointed out, the design of his preceding experiment is less than optimal because it requires subjects to make semantic and form judgments about words that they are not aware of having seen. Subjects found it peculiar to perform the task, and the data from some had to be discarded because the subjects had used strategies that precluded any real assessment of the availability of the various kinds of information that they were asked to provide. Allport's study is subject to the same criticism, though to a lesser degree since he did not use detection-level SOAs.

To avoid the awkwardness of the foregoing procedures, Marcel (in press) turned to a number of different designs that did not require a direct response to a masked stimulus. Instead, the experiments measured any effects of facilitation or interference ("priming") that a masked word might have on the response to a subsequently presented unmasked word. In these later experiments, the assessment of relative rates of availability of form and meaning information was abandoned. Only the accessibility of semantic information at detection-level SOAs was examined. In these studies, semantically related primes were found to facilitate lexical decisions to subsequently presented targets. Priming effects of essentially the same magnitude were obtained when the priming word was masked dichoptically at a detection-level SOA as when it was unmasked.

Comparable with the pair of paradigm types used by Marcel (in press), the designs that we employed fall into two general classes. One paradigm type is exemplified by the first Marcel study described above and by Allport's (1977) study. It requires that subjects make judgments about the masked words themselves—that is, about words that subjects may profess not to have seen. The second type of paradigm is exemplified by Marcel's priming study described above. It requires subjects to respond to words that they see clearly, and it looks for influences on response time and errors of a preceding masked word. Our research indicates that this difference in type of paradigm is critical. In particular, findings based on paradigms of the first type may well be spurious, but those based on the second, priming paradigms, are not.

In accordance with the foregoing distinction in paradigm types and experimental outcomes, we partition the following description of our investigations into two parts. One part summarizes our efforts to replicate and understand procedures that ask subjects to report the masked items or to judge their properties. The second part describes two studies that replicate and extend Marcel's priming study (in press).

Part 1

We have run a number of variants of Marcel's first masking experiment. All had essentially the same outcome. In view of the results of a control experiment here reported as Experiment 3, the variations in stimuli and design that we attempted over replications become unimportant. Here we report two of the early experiments.

In both experiments, our procedure differed somewhat from Marcel's. As described earlier, Marcel's procedure was to discover the longest SOA at which detection judgments fell to chance. This SOA was then gradually reduced while subjects were asked to make additional detection judgments and judgments of the semantic and physical properties of the masked stimuli. The physical judgments tended to fall to chance at an SOA approximately 5–10 msec lower than the critical detection SOA; semantic judgments, at an SOA approximately 5 msec after that. We are unable to replicate exactly that outcome because for our subjects the critical detection SOA hovered between 10 and 20 msec, most typically. Our modified procedure, then, was to discover the critical detection SOA and then, at that SOA, to obtain measures of accuracy on semantic and physical judgments.

Experiment 1

Method

Subjects. Subjects were 10 undergraduates at Dartmouth College, who participated in the experiment for course credit. All had normal or corrected-to-normal vision.

Design. The experiment had one independent variable, type of judgment. Its three levels (excluding detection judgments) were semantic, phonetic, and graphic. Subjects participated at all levels. The dependent measure is the proportion of correct judgments as a function of type of judgment.

Procedure. Subjects were run individually. They viewed the stimuli via a three-channel Scientific Prototype tachistoscope. At the beginning of a session, each subject was given time to dark adapt. Following that, 50 trials were given in which the subject was required to make detection judgments. On each trial, the subject fixated a + situated in the middle of a dim field. When ready, he or she pressed a button that initiated the sequence of events for the trial. Each detection trial presented a word or a blank card followed by a pattern mask consisting of superimposed uppercase letters, which was displayed for 500 msec. The subject's task on each trial was to judge whether the field preceding the mask had included a word or was blank. On half of the trials, a word was presented; on the remaining half, a blank card. Stimulus presentation and masking were binocular.

The detection trials were presented in blocks of 10, and the subject's accuracy at the end of a block dictated whether the SOA would be lowered on the next block. If the subject's probability correct was .7 or better, the SOA was reduced for the next block.

At the beginning of a session, the SOA was set at 50 msec. If accuracy was very high on the initial blocks, the SOA was reduced in large decrements of 10–15 msec until the subject began to make errors. Following that, the SOA was reduced in smaller decrements until a near-chance level of performance was reached. The highest SOA at which detection performance fell below .7 was used for the subsequent trials.

In the second phase of the experiment, trials were sequenced in four blocks of 25. On each trial, as before, a word or a blank card was presented, followed by the pattern mask. On 10 of the 25 trials, subjects were asked to make detection judgments. On half of these trials, a word was presented; on the remaining half, a blank card. As before, if the subject's performance on these trials reached .7 or better, the SOA was reduced for the next block. On all the remaining trials, a word preceded the mask. On these trials, two words were presented, one above and one below the mask. On five of the trials, one of the words resembled the masked word in meaning (e.g., COOK followed by BAKE and VIEW); on five trials, one word of the pair resembled the masked word graphically but not phonetically, insofar as possible (e.g., ROUGH followed by BOUGH and TRASH); on the remaining five trials, one of the words resembled the masked word phonetically but not graphically, insofar as possible (e.g., SOUP followed by TUBE and MASK).

On the 15 trials in each block that were not detection trials, when the word pair was presented flanking the mask, the subject was asked to report aloud the position (i.e., top or bottom) of the word that more closely resembled the masked word. The nature of the resemblance (semantic, graphic, phonetic) was specified at the time that the judgment was called for.

The foils were selected not to resemble the masked word on any of the three dimensions of similarity being manipulated in the experiment. On half of the trials of each type, the foil appeared above the mask, and the target appeared below the mask. On the remaining trials, the positioning was reversed. The four types of trials—detection, semantic, phonetic, and graphic—were randomized within each block.

Stimuli. Both within each class of trials and across masked words, targets, and foils, words were matched for length and frequency according to the Thorndike and Lorge (1944) tables. Overall, the mean word lengths were 4.4, 4.3, and 4.2 letters for the semantic, graphic, and phonetic trials, respectively, and the mean frequencies were 57.8, 57.1, and 56.0 words per million. There were 20 tokens of each trial type.

On the semantic trials, the masked word and target were synonyms or close associates. On phonetic trials, the target and foil differed in most instances by no more than two distinctive features. In a small number of instances, they differed by the addition of a single phoneme (e.g., SLEIGH and SAY). Graphic targets and masked words were selected to share as many letters as possible but to differ in respect to the vowel sound and at least one consonant.

Words were typed in blank primer type in the center of 5 × 8 in. file cards. Each letter subtended vertical and horizontal angles of .26° and .15°, respectively. The words subtended from .99° to 2.40° of horizontal visual angle.

Results

The critical detection SOA ranged between 10 and 25 msec, averaging 15 msec.

The dependent measure is the proportion of correct selections as a function of type of judgment. Chance performance is .5.

The mean probabilities of correct responses for each type of judgment are shown in the first column of the upper portion of Table 1. The semantic judgments are significantly different from the chance value of .5, $t(9) = 5.17$, $p = .008$. Nine of the 10 subjects exceeded chance performance on the semantic trials. The mean performance on the phonetic judgments, while greater than .5, is only marginally significant, $t(9) = 1.89$, $.10 > p > .05$. Seven of the 10 subjects selected correctly more than half of the time on phonetic trials. Subjects were also near chance on visual trials, $t(9) = 1.68$, $p = .12$. Eight subjects obtained more than 50% correct selections on these trials.

A one-way analysis of variance comparing the trial types showed the differences among the groups to be significant, $F(2, 18) = 8.65$, $p = .002$. Scheffé tests revealed that the significant outcome is due to the difference between the semantic trials and the other two types of trials. Performance on phonetic and graphic trials did not differ, $F(1, 18) < 1$.

Discussion

These results replicate those of Marcel (in press) in showing a sensitivity to the semantic properties of a word under conditions in which subjects profess not to have seen the word. Moreover, under these conditions, subjects demonstrate a limited sensitivity, if any, to ostensibly lower level properties of a word, namely, their graphic and phonetic properties.

Our procedure for setting SOAs probably ensured a slightly better than chance detection performance across subjects—perhaps even as good as performance on semantic trials. This remains the case in all our replications of the Marcel paradigm that we report here. However, it does not alter the important conclusion that these findings seem to promote, namely, that meaning judgments are made with better than chance accuracy, based on information that subjects do not know they have. At the SOAs used here, subjects are very far from being able to read the words they are reporting on. Indeed, they do not even see the component letters of the word. Hence when they make accurate meaning judgments, they apparently are using information of which they are entirely unaware.

Table 1

Percentage of Correct Choices as a Function of Item Type in Experiments 1 and 3 and Experiments 2 and 3

Item type	Experiment 1	Experiment 3
Semantically related	68.00	56.04
Phonetically related	54.80	55.83
Visually related	52.80	44.79
	Experiment 2	Experiment 3
Semantically related	57.23	58.17
Visually related (hard)	50.03	46.93
Visually related (easy)	48.87	57.80

One interpretation of the outcome of Experiment 1 is Marcel's (in press), namely, that masks do not halt perceptual processing but instead prevent awareness that anything has been witnessed. An alternative interpretation of the findings must be considered, however. Perhaps, due to an infelicitous selection of targets and foils, the three types of judgments differ in difficulty. It is possible that the masked words and their semantic targets are closer in semantic space than are the masked words and their phonetic or graphic targets in phonetic and graphic space, respectively. Similarly, it may be that the masked words and foils are more distant on semantic than on phonetic and graphic trials. According to this interpretation, differences in performance on the three trial types may arise because relatively more graphic or phonetic than semantic information must be extracted and preserved about the masked word in order to make the required judgments.

That the masked words and foils were more distant on semantic trials than on graphic trials seemed possible to us, since the graphic foils had been selected to be similar in word length to the targets and masked words, even though the identities of their component letters were different. Experiment 2 was designed to assess this possibility.

Experiment 2

Method

Subjects. The subjects were 12 undergraduates at Dartmouth College. All had normal or corrected-to-normal vision.

Design. In addition to the control trials required to establish a near-chance level of detection performance, subjects were exposed to three types of trials. Subjects were asked to make meaning judgments as before and, in addition, to make form judgments at two levels of difficulty. On one visual trial type, "visual-hard," both alternatives involved in the judgment matched the masked word in length, as in Experiment 1, but differed in the number of letters shared with the masked word (e.g., ACT followed by ANT and AND). On the other trial type, "visual-easy," only one alternative matched the target in length; the other was either substantially longer or shorter (e.g., ACT followed by ANT and FOLLOWING).

Subjects were partitioned into two groups in respect to the visual-hard and visual-easy trials that they received. Each masked word and target were paired once with a similar foil (visual-hard) and once with a dissimilar foil (visual-easy). A subject who saw a given masked word paired with a similar foil did not see it a second time with the dissimilar foil. Thus, each subject saw each visual masked word just once; half of the masked words were followed by judgments expected to be difficult, and half by judgments expected to be easy. Subjects were not told about the hard/easy manipulation.

The hard/easy manipulation was designed to assess whether performance on visual form judgments would approach that on semantic judgments if the amount of visual information about the masked word required to make the judgments was reduced substantially.

Procedure. The procedure for this experiment was essentially identical to that for Experiment 1 except that the stimuli were presented via a four-channel Gerbrands tachistoscope and the pattern mask consisted of superimposed letter parts.

Following the control trials to establish the critical detection SOA, subjects participated in five blocks of 24 trials each. Twelve trials of the 24 were control trials to check the critical SOA. If performance exceeded eight correct on these trials, the SOA was reduced. Of the remaining trials, six were semantic trials, three were visual-hard, and three were visual-easy. On these trials, after the fixation point, the masked word, and the pattern mask (presented for 500 msec as before), two choice words were presented, one above and one below the center of the field. In addition, a letter, M or V, appeared to the right of the words and in the vertical center of the card. The M signified that the subject was to make a meaning judgment; V, a visual form judgment. The three trial types were randomly intermixed among the 24 trials of each block.

Stimuli. The stimuli for the experiment, discounting the control trials, were 30 triads for the semantic trials and 30 sets of four words for the visual trials. In each of the semantic triads, a pair of words (the masked word and the target) were synonyms or close associates, and the remaining word was unrelated to the pair. These were not the same words as those used in Experiment 1. An example of a triad is CENT, PENNY, RABBIT.

The sets of four words included a pair that were matched closely in word length and that shared letters (e.g., FOOL vs. FOOD). These were the masked words and targets. A third word matched the masked word in length but shared fewer letters with it than did the target (e.g., FORM). The fourth word matched the masked word neither in length nor in shared letters (e.g., ARRANGE). These last two word types were foils for the visual-hard and visual-easy trials, respectively.

The masked words, targets, and foils were matched within and across conditions in mean frequency, according to Thorndike and Lorge (1944), and in mean word length in letters. Overall, the words used on semantic trials averaged 54 words per million in frequency and 5.6 letters in length. The visual targets and correct selections averaged 53 words per million and 5.2 letters in length. The corresponding values for the visual-easy foils are 51 words per million and 5.3 letters; those for the visual-hard foils are 54 words per million and 5.1 letters long.

Words were typed in uppercase blank primer type on 5 × 8 in. file cards. Each letter subtended vertical and horizontal visual angles of .39° and .23°, respectively. The words subtended from .99° to 5.79° of horizontal visual angle.

Results and Discussion

Critical SOAs ranged between 12 and 25 msec and averaged 18 msec overall.

The first column in the lower portion of Table 1 gives the results of the experiment. Among the 30 semantic trials, subjects chose correctly 57% of the time on the average. This value exceeds the chance value of 50% according to the results of a paired t test, $t(11) = 2.36$, $p = .04$. Performance on the visual-hard and visual-easy trials was at chance, subjects choosing correctly 49% of the time on the one set of trials and 51% of the time on the other. Neither mean value differs from the chance value of 50%, $t(11) = -.30$, $p = .77$ and $t(11) = .22$, $p = .82$, respectively. Nor do the two values differ significantly, $t(11) = -.32$, $p = .37$.

These results confirm that subjects are able to make semantic judgments at SOAs at which they cannot make judgments of form. Moreover, the results tend to disconfirm an account of this finding that attributes the difference to any difference in the amounts of information required by a subject to make each type of judgment. Performance judging that ANT more closely resembles ACT than does FOLLOWING was no better than judging that ANT more closely resembles ACT than does AND.

The results of Experiments 1 and 2 essentially replicate Marcel's (in press) findings. However, because Marcel's interpretation of findings such as these includes an unconventional view of the effects of pattern masking, it is important to consider carefully whether the interpretation is required by the results of these experiments.

In fact, we suspect that designs of this sort do not isolate the nature of the information supporting semantic judgments. More specifically, positive results from these designs may be subject to the kinds of alternative explanations suggested by Neisser (1967) in his reinterpretation of the "subliminal perception" literature of the late 1950s and the 1960s because the designs provide inadequate controls for experimental demand characteristics (Orne, 1969).

As an example, let us make the assumption that no information about any aspect of the masked word survives the masking. As Marcel's (in press) subjects indicated to him, they found the judgments exceedingly hard to make and were in general frustrated by the task. The question then is how to explain the subjects' greater than chance performance on the semantic judgments, given that they had no knowledge, tacit or otherwise, of the masked word. One possibility is that in an effort to remain "good subjects" (Orne, 1962, 1969), subjects tried to use whatever information they had (the two choice words) to make a best guess. Since word length and word frequency of the choices were matched, the use of that information could not have led to the facilitation of semantic judgments.

However, there is at least one strategy that we, and perhaps Marcel as well, failed to guard against. It is that when forced to make a choice, subjects asked themselves which of the two choice words had more words like it (semantically, graphically, phonetically). Possibly our semantic word pairs were chosen inadvertently so that the correct choice tended to have more (or closer) associates or synonyms available than the incorrect choice. This suggestion seems plausible, given that to be selected for inclusion in the experiment as a correct choice, a word had to have at least one close associate or synonym—namely, the masked word. However, this was not a criterion used to select the foils. For their part, perhaps, the choices in the phonetic or graphic conditions may have had equal numbers of phonetic or graphic associates.

Experiment 3 attempted to assess the plausibility of this explanation of the results of Experiments 1 and 2 by using a technique specifically designed for uncovering effects of demand characteristics—namely, the nonexperiment (Orne, 1969; Reicken, 1962).

Experiment 3

Method

Subjects. The subjects were 24 undergraduates at Dartmouth College, who participated in the experiment for course credit.

Design. The design of the nonexperiment was essentially identical to that of Experiments 1 and 2 except that there was no masked word presented prior to presentation of the response choices. On each trial, subjects chose one of the members of a response pair, on the basis of a semantic, graphic, or phonetic criterion as specified for each block of trials. Subjects made choices based on each of the three criteria. The dependent measure is the proportion of judgments of each type that conform to judgments scored as correct in Experiments 1 and 2.

Procedure. All subjects were run at the same time in a classroom. Each was given a list of word pairs and a set of instructions. The word pairs had been the pairs of response choices from Experiments 1 and 2. The instructions described the design of the earlier experiments, explained the confounding strategy that we were considering, and outlined the general procedure of the control experiment in which they were participating. The particular results of the previous experiments—that is, that performance only on semantic trials had exceeded chance—were not described. Subjects were asked to read each word pair in a block of trials and to select the word in each pair that they believed was most likely to have another word like it. "Like it" was defined differently for each block as semantic, phonetic, or graphic similarity. The instructions specified the type of relatedness that was relevant to the different blocks of trials on the answer sheet.

Subjects were encouraged to ask questions regarding either the design of the earlier experiments or the procedure of the currect control study.

Stimuli. One hundred fifty pairs of response choices from Experiments 1 and 2 were blocked by type of trial and were typed in a vertical list on an answer sheet. On the answer sheet, Word Pairs 1-20 were phonetic trials from Experiment 1, Word Pairs 21-100 were the visual trials from Experiments 1 and 2, and Word Pairs 101-150 were the semantic trials from Experiments 1 and 2. (Due to experimenter error, one block of trials from Experiment 1—that is, five trials of semantic, graphic, and phonetic pairs—was excluded from the answer sheet.) The different blocks of trial types were separated by a dotted line on the answer sheet to cue the change in response criterion from block to block.

Results and Discussion

The mean percentage of correct responses for each type of judgment is shown in the second column of Table 1. The first column gives the corresponding outcomes for Experiments 1 and 2. In the present experiment, the semantic judgments were significantly better than the chance value of .5 for the word pairs of both Experiments 1 and 2, $t(23) = 3.06$, $p = .006$ and $t(23) = 5.27$, $p < .001$, respectively. The mean percentage correct on the phonetic trials also exceeded chance performance, $t(23) = 3.39$, $p = .003$, and performance on the visual pairs of Experiment 1 was at chance, $t(23) = -1.70$, $p = .099$. Performance on the visual-hard pairs of Experiment 2 was likewise at chance, $t(23) = .93$, $p = .637$; however, subjects performed significantly above chance on the visual-easy pairs, $t(23) = 3.39$, $p = .003$.

As Table 1 shows, overall, Experiment 3 replicated the pattern of results of Experiments 1 and 2, with the single major exception, on statistical grounds, of the visual-easy pairs. These pairs showed better than chance performance in the control experiment and chance performance in the masking experiment.

In addition to the single statistical departure of the pattern of results of this experiment from the earlier two, several of the mean performance levels in the control experiment differ in magnitude from those of Experiments 1 and 2. This suggests, perhaps, that the particular response strategy we encouraged the subjects to use does not exhaust the sources of influence on performance in Experiments 1 and 2. However, the degree of similarity between the outcome of the control experiment and those of Experiments 1 and 2 is remarkable and suggests caution in attributing the results of the latter experiments to effects of the masked word on the subjects' choices.

We should point out that the present findings do not necessarily invalidate findings obtained by Marcel (in press) using a slightly different procedure. In Marcel's procedure, the dependent measure was not proportion correct but rather the SOA at which judgments of each type fell to chance. Were subjects' choices determined solely by the confounding strategy examined in the present control study, judgments of a given type should have been invariant over changes in SOAs at detection level and below. Instead, Marcel found that judgments declined with SOA; semantic judgments survived at shorter SOAs than graphic judgments, and graphic judgments at shorter SOAs than detection judgments. Although it is possible that the semantic judgments required of Marcel's subjects demanded less semantic information about the masked word than graphic judgments demanded graphic information, our Experiment 2 suggests that this variable may not matter at or below detection-level SOAs. As we have noted, we are unable to replicate Marcel's procedure because typical detection-level SOAs among our subjects are too short to permit substantial reduction.

Although the design of Experiments 1 and 2 could be modified in order to eliminate any confounding response strategies that might occur to us, we chose not to pursue that investigatory route. Our reasons were, first, that it is probably impossible to control for all strategies that inventive subjects might devise and, second, that the design of Experiments 1 and 2 is unattractive, since it requires the subjects to make an explicit judgment about properties of a word they have no awareness of having seen.

Experiment 4

We turn now briefly to consider a final investigation within the general class of paradigms that require a subject to respond directly to the masked word itself. This last investigation is similar to Allport's (1977), described earlier. In that study, instances of semantic paralexic errors (e.g., jazz–blues) were found among subjects' responses to briefly presented pattern-masked words. Ellis and Marshall (1978) criticized the study on statistical grounds. They estimated the proportion of randomly paired words that are likely to be considered semantically similar by judges and compared that value to Allport's. They found the two proportions to be essentially identical. We elected to fix the proportion of word pairs labeled semantically related by judges and to ask whether among those word pairs that they selected, the judges could distinguish target-response pairs of the sort obtained by Allport from random pairings of target words with responses.

Method

Subjects. Nine subjects were run in the first phase of the experiment. A 10th subject, to match Subject 5, was not run. However, excluding Subject 5 makes no difference to the outcome of the experiment. Therefore, his data are included. The subjects were volunteers from an introductory course in psychology. The judges were 11 students from the same class; some of them had served as subjects in the first phase of the experiment.

Materials. A list of 50 words was created. The words in the list were selected to be both common and readily imageable (e.g., DOG, CHAIR, APPLE). The words were printed individually in uppercase in the middle of 5 × 8 in. file cards.

In addition to the word list, 10 lists of 50 numbers were generated. Each of five lists included twenty-five 1's and twenty-five 0's in a random order as generated by a computer program. A matched set of five more lists was created by changing each 1 in Lists 1–5 to a 0 in Lists 6–10 and vice versa.

These lists of numbers, when paired with the word list, were used to decide for each subject which 25 of the 50 words would be presented to him or her prior to the pattern mask and which would not. Each subject's sequence of trials corresponded to the pattern of 1's and 0's in one of the 10 lists. Any word paired with a 1 was shown to the subject. In addition, it was paired with the subject's response to it and stored in a computer file. In contrast to this, a word paired with a 0 was not shown. In its place, the nonsense string ASDIF was shown. However, even though the word was not shown to the subject, it was paired with the subject's vocal response on that trial and stored in the same computer file that held the true stimulus-response pairings.

Subjects 1 and 6, 2 and 7, and so on were yoked to one another in that the set of 25 words shown to the first subject of a yoked pair was just the set not shown to the second subject of the pair. This ensured that each of the 50 words was presented and not presented an equal number of times.

Procedure. Stimuli were presented to subjects via a four-channel tachistoscope. Differently oriented polarized filters were fitted to the eyepieces of the tachistoscope's viewport and to two of the four fields—the stimulus and mask fields. This ensured dichoptic, central masking of the target word. The mask consisted of overlaid uppercase letters.

One field of the tachistoscope, the fixation field, contained a centered fixation cross and was adjusted to a luminance of 2.2 ftL. (7.5 cd/m^2). The other three fields were adjusted to a luminance of 7 ftL. (23 cd/m^2). The fixation field was adjusted to a lower luminance than the other fields to avoid forward masking of the briefly presented target word by the fixation field.

Timing of events was determined by a custom-made controller, which determined the sequencing of the fields and controlled timing intervals with millisecond accuracy. A hand-held microswitch was connected to the controller and allowed the subject to initiate the display at the start of each trial.

Test trials were preceded by trials to determine each subject's detection SOA. These trials were identical to those of Experiments 1 and 2. The range of SOAs in this experiment was larger than in the previous studies due mainly to one extreme subject. The range was from 10 to 70 msec.

On each test trial, the subject fixated a dark cross in the middle of the field. He or she initiated a trial by means of a hand-held button. Following the button press, the stimulus field was illuminated for the time determined by the previous control trials. This was followed by the pattern mask for 500 msec. Subjects then guessed aloud the identity of the stimulus, and the experimenter recorded the response.

The sequencing of trials was controlled in part by a computer program. For each subject, the program matched the 50 stimulus words to the appropriate list of twenty-five 1's and twenty-five 0's. On each trial, if the word for the trial was paired with a 1, it was typed on the screen of a cathode-ray-tube terminal. The experimenter then inserted the appropriate stimulus card into the tachistoscope, said, "Ready," and waited for the subject to initiate the trial and provide his or her guess. If the word was paired with a 0, the nonsense sequence ASDIF was printed on the terminal screen with the target word not to be presented given in parentheses, that is, ASDIF (DOG) signified that ASDIF was to be presented instead of DOG. The experimenter put aside the card for the target word and inserted the card containing the nonsense sequence into the tachistoscope. On every trial, the experimenter typed the subject's response into the computer terminal. The response was paired with the target word for that trial, whether or not it had been presented. In addition, each word pair was given a code number, 1 or 0, to indicate whether or not the stimulus had in fact been shown.

Scoring. To determine the extent to which subjects tended to supply semantically related responses to target words, we obtained judgments from a group of raters. Each rater was given the protocols from the subjects in the experiment, with the code numbers deleted. For each subject, the judges were asked to circle the 10 pairs, among the 50, the members of which were most similar in meaning. Each judge scored the protocals for all subjects.

The judges' selections for each subject were partitioned into two categories: those word pairs in which the stimulus word had in fact been presented to the subject and those word pairs in which the target word had not been presented. No preference on the judges' part for words of either category would give a proportion of .5 of the selections falling into each category. Our measure was the proportion of selections in which the target items had been presented prior to the pattern mask. This was expressed as a deviation from .5.

This scoring procedure was complicated slightly by the occurrence of a few trials in which subjects correctly reported the stimulus word.[1] These pairs, of course, were

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[1] These occurrences are probably due to practice. In Experiments 1 and 2, detection trials were given on every block, and the subjects' SOAs were reduced if their performance exceeded chance significantly. In this study, detection trials were given only at the beginning of a session. In any event, Allport's (1977) subjects also were run at SOAs that enabled them to report some of the words correctly. In particular, the SOAs in his studies were adjusted to allow approximately 25% accuracy in identifying the target words. In Marcel's (in press) studies, performance was substantially less than that.

circled by the judges. But since they were trials on which the mask was ineffective, they were excluded from the analysis, and the assessment of chance had to be adjusted accordingly. Thus, if a subject reported 2 words correctly of the 25 presented target words, his or her effective pool of trials was reduced to 48 of which 23 were target words that had been presented and 25 were nonpresented words.

Results

The departure from chance of the judges' correct selections, averaged over judges and subjects, is −.002. This means that performance was very slightly below a chance level of performance. That is to say, judges failed to distinguish trials on which subjects had been shown a target word from trials on which they had not. The mean value, −.002, is not different from zero either when the data are collapsed over judges, $t(8) = -.09$, $p = .93$, or when they are collapsed over subjects, $t(10) = -.14$, $p = .89$.

These results are clear in failing to show evidence of semantic paralexic responses to which judges are sensitive.

General Discussion of Part 1

The investigations reported in Part 1 examined one class of studies reputed to show that the semantic properties of masked words are known to subjects even when the physical properties are not. In respect to both paradigms examined above, the findings are shown most probably to be spurious. We might conclude from this series of investigations that the more usual interpretation of central masking—namely, that it stops perceptual processing—has been upheld. But at this juncture, a more conservative conclusion may be more appropriate—namely, that whatever the perceivers know about a word that has been masked at a detection-level SOA, they do not know in any way that enables them to talk about the word's properties. Thus, they cannot guess the word's identity as they were asked to do in Experiment 4, nor can they judge its semantic, graphic, or phonetic relatedness to other words as they were asked to do in Experiments 1 and 2.

It remains possible, however, as Marcel (in press) suggested, that perceivers can nonetheless know about the masked word in another way—that is, unconsciously. Possibly their unconscious access to the properties of the masked word can be detected only by subtler techniques or by just different kinds of techniques than those already examined. To investigate this possibility, we next examine Marcel's use of the priming technique.

Part 2

The paradigms used in Part 1 failed to show any reliable effects of a word masked at detection levels that could not be attributed to a variety of confounding variables. We believe that a primary problem with those paradigms is that subjects were forced to respond directly to a word for which they professed no awareness. Subjects find this situation unnatural and may engage in counterproductive strategies or refuse to participate altogether. In Part 2, we consider two experiments in which the effects of the masked prime are measured indirectly. In addition, only dichoptic masking is used. The importance of the type of mask is described below.

One indirect measure of processing used by Marcel (in press) was semantic priming in a lexical decision task. The design was adapted from Meyer and Schvaneveldt (1971). On each trial, subjects were shown two letter strings in succession. Their task was to make a lexical decision to the second string. The pairs of letter strings were both words, both nonwords, or one a word and one a nonword (in either order). Among the real-word strings, members of a pair were either related in meaning or unrelated. Under similar conditions, Meyer and Schvaneveldt had obtained a priming effect due to semantic relatedness: A subject's time to make a lexical decision to a word was found to be 85 msec faster if the word was preceded by a semantically related prime than if it was preceded by an unrelated word.

In Marcel's version of the the experiment, subjects participated in three sessions. One session was essentially a replication of the experiment by Meyer and Schvaneveldt. A second session introduced a pattern mask that followed the first word of each pair at a detection-level SOA. In order to ensure central masking in this condition, the presentation of word and mask was dichoptic.

In a third session, the first word of each pair was masked with a noise mask presented monocularly to the same eye as the first word, at a detection-level SOA. The SOAs were individually determined for each subject and each masking condition, and the order of sessions was counterbalanced across subjects.

Marcel obtained a 62-msec facilitation effect due to semantic relatedness in the no-mask condition, a 56-msec effect in the pattern-masking condition, and a nonsignificant 4-msec effect in the peripheral, noise-masking condition. Thus, the effect of a word's meaning on lexical decision time to a following semantically related word is present and essentially undiminished when the first word is pattern masked, but it is eliminated by a noise mask.

Marcel's experiment, then, demonstrated that dichoptically masked words must be processed to a semantic level, since they served as effective primes in a lexical decision paradigm. The importance of using dichoptic masking, according to Marcel, is that the peripheral component of a nondichoptic masking situation may preclude processing of the stimulus beyond a sensory level (see Turvey, 1973).[2]

In light of our difficulties with the paradigms described in Part 1, we thought it useful to try to replicate the priming results.

Experiment 5

Experiment 5 represents an attempt to replicate Marcel's (in press) finding of a semantic priming effect when the first word is masked at or near the detection threshold. An extension was also included to ascertain whether we could find a priming effect due to phonemic/graphemic incompatibility similar to that described by Meyer, Schvaneveldt, and Ruddy (1974). If such an effect were found with masked primes, it would indicate that subjects had phonemic and graphemic information as well as semantic information about words they were not aware of seeing.

The basic paradigm consisted of presenting pairs of items to subjects and asking them to make a lexical decision to the second item. There were two primary factors in the experiment. The first factor was the presence or absence of a patterned, dichoptic mask following the first member of each pair. Separate sessions were used for the two levels of this factor. We did not include Marcel's peripheral masking condition. The second primary factor was the type of relationship between the pair members. Eight types of relationship were used. Four of those types constituted an examination of semantic priming as in Marcel (in press) and Meyer and Schvaneveldt (1971). The other four types examined phonemic/graphemic priming as in Meyer et al. (1974).

Method

Subjects. Ten male and 10 female subjects were paid for their participation in the experiment. All subjects were required to have normal or corrected-to-normal vision.

Apparatus. The primary apparatus for this experiment consisted of the four-field Gerbrands tachistoscope used in Experiments 2 and 4. Two of the fields and the eyepiece were fitted with polaroid filters, arranged to allow dichoptic stimulus presentation. One field (the fixation field) contained a centered fixation cross and was adjusted to a luminance of 2.2 tfL. (7.5 cd/m^2). The other three fields were used for the presentation of the two pair members and the mask and were adjusted to a luminance of 7 tfL. (23 cd/m^2) The fixation field was adjusted to a lower luminance level than the other fields to prevent forward brightness masking of the prime.

Timing was determined by a custom-made controller, which allowed the sequencing of the fields and various delay intervals with millisecond accuracy. A hand-held microswitch was connected to the controller and allowed the subject to initiate the display at the start of each trial. A response panel containing two switches, labeled YES and NO, respectively, was placed in front of the subject. These switches were connected through a Poly-

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[2] Following Marcel's (in press) procedure in his early studies, we used a pattern mask presented binocularly in Experiments 1 and 2. According to Turvey (1973), a binocular pattern mask may yield either central or peripheral masking, depending on the energy relations between target and mask and the interstimulus interval. It is possible that masking was peripheral in Experiments 1 and 2 and that performance in these studies would have exceeded that in the control study (Experiment 3) had we ensured central masking by presenting target and mask dichoptically. We cannot discount this possibility; indeed, we have replicated Marcel's finding, described above, that priming is absent when the prime is masked peripherally. However, we consider this interpretation of Experiments 1 and 2 unlikely to be exhaustive of the reasons why performance in Experiments 1 and 2 failed to exceed that in Experiment 3. In Experiment 4, dichoptic masking was used, but subjects' performance was unaffected by the meaning properties of the masked words.

tronics Universal Timer to the university time-sharing system. With this system latencies could be collected with millisecond accuracy, and those latencies and associated responses were fed directly into the computer. A computer display was used by the experimenter to determine the randomization of trials for each subject.

Stimuli. The members of each pair of items were related in one of eight ways. Examples of each of the eight types of relationship are shown in Table 2. The pairs for Types 1, 2, 5, and 6 were taken from the pairs used by Meyer et al.(1974) and were used to examine the effect of graphemic/phonemic compatibility on lexical access. The pairs for Types 3, 4, 7, and 8 were constructed in the same fashion as the pairs used by Meyer and Schvaneveldt (1971) to look for semantic priming.

Among the stimuli employed were four types of Word-Word (W-W) pairs: graphemically similar words that were phonemically dissimilar (Type 1, e.g., LEMON-DEMON and BLOW-PLOW); control pairs for that type (Type 2, e.g., LEMON-PLOW and BLOW-DEMON), generated by interchanging pairs of target members in Type 1 pairs; semantically similar words (Type 3, e.g., OCEAN-WATER and START-BEGIN); and control pairs for that type (Type 4, e.g., OCEAN-BEGIN and START-WATER), generated by interchanging pairs of target members in Type 3 pairs. The words were balanced for frequency, length, and number of syllables across the types of relationship.

As shown in Table 2, there were four other types of stimulus pairs (Types 5-8), which were in the form of WORD-NONWORD (W-N). Each of the nonwords followed the general rules of orthography and phonology. In order to be consistent with each of the W-W types, the four W-N types were generated in the following manner: Type 5 consisted of W-N pairs which were graphemically similar (e.g., LEMON-PEMON and BLOW-CLOW), generated from Type 1 by replacing initial consonants of the response words with other consonants to create the nonwords. Pairs of this type could also have been perceived to be phonemically similar. Many of the pairs allowed for more than one possible pronunciation of the nonword, however, and so phonemic relations could not always be determined. Table 2 indicates this fact with a question mark. The control pairs of Type 6 (e.g., LEMON-BROVE and DROVE-PEMON) were generated by randomly interchanging pairs of target words appearing in Type 5. Type 7 pairs (e.g., OCEAN-SATER and START-FEGIN) were generated from those in Type 3 by replacing initial consonants in the response words with other consonants. And finally, W-N control pairs of Type 8 (e.g., OCEAN-SIRM and HARD-SATER) were generated by interchanging pairs of target words appearing in Type 7.

There were 32 pairs of each type. Any particular final pair member appeared in two pairs, once as a primed target and once as a control or neutral target. The various pairs were partitioned into two sets, so that any one subject saw each final pair member in only one of its

Table 2
Examples of Pairs of Letter Strings Used in the Lexical Decision Task of Experiment 5

Type of stimulus pair	Examples: Letter string 1	Examples: Letter string 2	No. practice trials	No. test trials
Word-Word				
Type 1: Graphemically similar, phonemically dissimilar	LEMON BLOW	DEMON PLOW	3	32
Type 2: Unassociated	LEMON BLOW	PLOW DEMON	2	32
Type 3: Semantically similar	OCEAN START	WATER BEGIN	3	32
Type 4: Unassociated	OCEAN START	BEGIN WATER	2	32
Word-Nonword				
Type 5: Graphemically similar, phonemically?	LEMON BLOW	PEMON CLOW	2	32
Type 6: Unassociated	LEMON DROVE	BROVE PEMON	3	32
Type 7: Unassociated	OCEAN START	SATER FEGIN	2	32
Type 8: Unassociated	OCEAN HARD	SIRM SATER	3	32

Note. The question mark in Type 5 indicates that subjects may or may not have perceived these pairs as being phonemically similar, since many of the nonword members may have more than one possible pronunciation.

conditions. Each subject, therefore, saw 16 pairs of each type during each session. Overall, each target appeared once and each prime appeared twice—once with a word target and once with a nonword target—within an experimental session. Letter strings were drawn with a black marker on 5 × 8 in. white cards with a Tektronix Plotter 4662. All letters were capitals subtending vertical and horizontal visual angles of .45° and .28°, respectively, when viewed in the tachistoscope. The letter strings subtended from 1.07° to 3.04° degrees of visual angle and were always centrally located in the viewing field. In addition, there was a fixation mark and a pattern mask. The fixation mark was a back + sign, subtending visual angles of .45° and drawn with a black stencil in the same thickness as the letter strings. The pattern mask was created with the same stencil and consisted of a group of scrambled letter pieces covering an area 2.5 × .75 in. (and subtending 4.5° by 1.35° of visual angle).

Procedure. There were two primary conditions in this experiment: one in which a pattern mask followed the prime and one in which there was no mask. Subjects were tested in the two masking conditions on separate days, 10 subjects in each of the two possible orders. The same set of stimuli was always used for each masking condition.

Each subject was familiarized with the function of the tachistoscope. Each subject determined his or her dominant eye by binocular and monocular alignment of the index finger with some farther stimulus subtending a similar visual angle. The subject was then seated in front of the tachistoscope, where an instruction sheet was read. Lights were then extinguished, and when the subject had adapted to the darkness and felt ready, the experiment began. The tachistoscope was prepared so that in its resting phase the subject would see the fixation mark in the center of the field. All stimuli were centered at this location.

Mask sessions. During the first part of the pattern-masking sessions, we determined the stimulus-onset asynchrony between prime and mask at which the subject no longer remained significantly above chance level when making presence/absence judgments of a word or blank field before the pattern mask. Prior to every trial the subject waited until the experimenter announced that he was ready, which indicated that the stimuli were loaded into the tachistoscope. The subject then initiated each trial by pressing a switch with the middle finger of his or her right hand, and the following sequence of stimuli was presented: (a) the fixation mark for 100 msec, (b) a word or a blank white field for 10 msec to the nondominant eye, (c) a dark field (initially lasting 50 msec but which was adjusted in the course of determining the experimental SOA), (d) the mask field for 20 msec to the dominant eye, and (e) a return to the fixation field.

The subjects were told that in 50% of the trials a familiar word would be presented to them; otherwise, only a blank white field would appear during that time interval. Each subject's task during such trials was to decide whether a word had been presented and to respond verbally either yes (a word was shown) or no (a word was not shown). This task was considered quite difficult by most subjects, because they almost never were confident that anything had been presented prior to the mask. Subjects were informed that detection of the word need not include its identification but that any perceived blur or flash suggesting its presence was grounds for a yes response. There were two sets of 40 trials in which presence/absence judgments were made, one set before and one set after the pattern-masking sessions. The SOA was initially set at 50 msec for each subject. If the subject got three or more correct during any block of five, the SOA was lowered by 5 msec unless the subject was especially confident, in which case the SOA was lowered by 10 msec. The SOA for one subject was initially raised due to chance responding in the first block. Experimental SOAs ranged from 10 to 70 msec, although all but one were within the range of 10–30 msec. The critical SOAs of nine subjects were lower by 5 to 20 msec during the latter block of presence/absence trials. Implications of this are discussed below.

Upon completion of the initial block of 40 presence/absence trials, subjects were instructed to make lexical decisions to the second members of the stimulus pairs to be shown during 20 practice and 128 experimental trials. When the experimenter said, "Ready," each subject initiated a trial and viewed the following sequence of stimuli: (a) the fixation mark for 100 msec, (b) a prime word presented to the nondominant eye for 10 msec, (c) a dark field for the predetermined SOA interval, (d) the pattern mask presented to the dominant eye for 20 msec, (e) a dark field adjusted so that Phases b–e would sum to 2,000 msec, (f) the second letter string binocularly for 500 msec, and (g) a return to the fixation field. At the onset of the second letter string, each subject's task was to respond as quickly and accurately as possible by pressing either the YES switch with the right index finger if a word had been seen or the NO switch with the left index finger if a nonword had been seen.

There was a planned 1-min break between the two experimental blocks in each session, but subjects were encouraged to pause at any time between trials if a question arose or a short rest was desired. At the conclusion of every 10 practice trials and every 16 experimental trials, subjects also had a chance to rest briefly as the experimenter reported the mean reaction time for those trials and the precentage correct.

The ordering of W-W and W-N pairs was randomized for each subject.

No-mask sessions. During the sessions in which the priming words were not masked, the above general procedure was followed except for the following changes: There were no presence/absence judgments made before and after the experimental session proper, since prime words appeared long enough for subjects easily to detect and recognize them and stimuli were presented in the following sequence: (a) a fixation mark binocularly for 100 msec, (b) a prime word for 500 msec to the dominant eye, (c) a dark field for 1,500 msec, (d) a second letter string binocularly for 500 msec, and (e) a return to the fixation field.

Results

The mean reaction times of correct responses and the mean percentage error rates for each of the W-W stimulus types and the combined W-N types under both masking

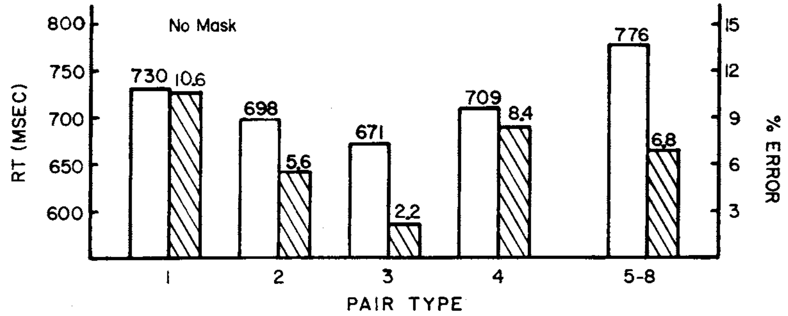

Figure 1. Mean reaction time and percentage error as a function of pair type for the no-mask conditions of Experiment 5.

conditions are shown in Figures 1 and 2. Reaction times are excluded from trials in which the response was incorrect and/or the subject's reaction time was outside the limits 200–2,000 msec. Since we were primarily interested in the effect of the different masking conditions on the various priming effects, most of our analyses were restricted to those cases in which the final pair member was a word (Types 1–4 in Table 2). Reaction times to nonwords, however, were reliably longer than reaction times to words in all conditions, $F(1, 72) = 99.3$, $p \sim 0$.

The first main analysis of the word data was carried out with type of relationship between the members of a pair (Types 1–4), masking condition (pattern mask vs. no mask), and order of sessions (mask first vs. mask second) as factors. For reaction times, the main effect of type of relationship was highly significant, $F(3, 54) = 13.48$, $p \sim 0$. What is important is that there was no interaction between mask condition and type of relationship, $F(3, 54) < 1$. No other main effects or interactions were significant at conventional levels, but two effects approached those levels. Mean reaction time for the mask condition averaged 35 msec faster than for the no-mask condition, $F(1, 18) = 3.61$, $p = .07$, and reaction times were 74 msec faster on Day 2 than on Day 1, $F(1, 18) = 4.06$, $p = .06$.

In examining the probabilities of correct responding, accuracy was generally negatively correlated with reaction time, with higher probabilities correct being associated with shorter latencies. An analysis of variance on accuracy revealed that the main effect of type of relationship was highly significant, $F(3, 54) = 10.81$, $p \sim 0$. No other main effect or interaction approached significance except for the three-way interaction of mask condition, type of relationship, and order, $F(3, 54) = 5.23$, $p = .03$. The cause of the three-way interaction is unclear except that the priming effect was larger in

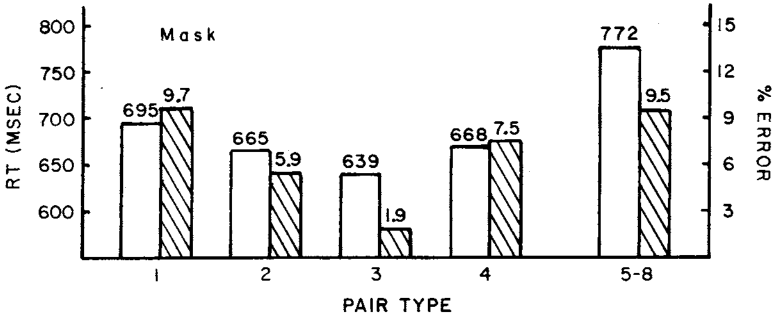

Figure 2. Mean reaction time (RT) and percentage error as a function of pair type for the mask condition of Experiment 5.

the masking condition if the masking condition was in Session 1 than it was if the masking condition was in Session 2, whereas the opposite was true in the no-mask condition.

As illustrated in Figures 1 and 2, the priming effects are quite similar in the two masking conditions. Those priming effects are summarized in Table 3. In order to check the statistical reliability of the various priming effects, separate analyses of variance were carried out for the no-mask and mask conditions. Planned comparisons were then carried out contrasting each of the priming conditions with its appropriate control. In the no-mask condition, the planned comparisons revealed a significant graphemic/phonemic interference effect both for reaction times, $F(3, 57) = 6.06$, $p = .016$, and accuracy, $F(1, 57) = 4.83$, $p = .03$. There was also a significant semantic facilitation effect both for reaction times, $F(1, 57) = 8.36$, $p = .005$, and accuracy, $F(1, 57) = 7.54$, $p = .008$.

Of primary importance is a significant graphemic/phonemic interference effect in the mask condition both for reaction times, $F(1, 57) = 6.75$, $p = .012$, and accuracy, $F(1, 57) = 4.91$, $p = .029$. There is also a significant semantic facilitation effect both for reaction times, $F(1, 57) = 6.63$, $p = .012$, and accuracy, $F(1, 57) = 11.05$, $p = .002$. Again, in each case reaction time was negatively correlated with accuracy.

There were a couple points of concern in Experiment 5 which warrant further attention. The first problem concerns the level of awareness that subjects had about the masked primes. The postmeasurement SOAs were lower for 9 of the 20 subjects. Possibly some of the subjects were aware of the masked primes on some of the trials. We believe that we can discount that possibility on the basis of two auxiliary analyses and some informal observations. We first compared the size of the priming effects for those 9 subjects whose post measurement SOAs were lower than their premeasurement SOAs with that for the other 11 subjects whose SOAs did not change. Those relative priming effects are shown in Table 4. An analysis of variance revealed no main effect of changed versus unchanged SOA and no interaction of that factor with type of relationship. Both Fs were less than 1.0. In addition, a series of correlations was carried out to determine whether a subject's SOA was related to the size of that subject's priming effects. There were four such correlations produced by crossing reaction times and accuracy with graphemic/phonemic and semantic priming and looking at the relationship between SOA and size of priming effect in each case. The values of the four correlations are −.22, .03, −.01, and .09. None of these values approaches significance.

On a more informal level, all subjects claimed to have no idea that anything was preceding the mask, let alone information concerning the identity of the word. It is true that had we used larger numbers of presence/absence judgments, we might have found that subjects responded with greater than chance accuracy. According to the subjects, however, when they were able to make presence/absence discriminations during the initial phase, it was on the basis of brightness changes or possibly some apparent motion rather than any sense of having seen a word. In other words, while the SOAs used may or may not ensure chance performance on detection trials, we believe that they are substantially below the identification threshold.

Discussion

The findings in this experiment are consistent with those of Marcel (in press) and substantiate his conclusions concerning the role of pattern masking in visual word recognition. More specifically, semantic facilitation effects presently obtained of 38 msec

Table 3
Priming Effects for No-Mask and Mask Conditions in Experiment 5

	Priming effect	
Condition	Graphemic/phonemic	Semantic
No mask	32	−38
Mask	30	−29

Note. Each cell represents the mean reaction time (in msec) for a test condition minus the mean reaction time for a corresponding control condition.

Table 4
Priming Effects for Changed and Unchanged SOAs in Experiment 5

	Priming effect	
SOA	Graphemic/phonemic	Semantic
Changed	+29	−24.5
Unchanged	+30	−34

Note. Each cell represents the mean reaction time (in msec) for a test condition minus the mean reaction time for a corresponding control condition. SOA = stimulus-onset asynchrony.

and 29 msec in the no-mask and mask conditions, respectively, compare with corresponding effects of 62 and 56 msec found by Marcel. The differences in the magnitudes of the semantic priming effect between Marcel's and the present study might result from the use of different materials, as we did not use the same instances that Marcel used for the various types of relationship.

We also obtained a 32-msec interference effect due to graphemic similarity and phonemic dissimilarity in the no-mask condition and a 30-msec effect in the mask condition. Those magnitudes compare favorably with the 34-msec graphemic/phonemic interference effect obtained by Meyer et al. (1974, Experiment 2) with identical materials.

Error rates were found generally to be somewhat higher in our experiment than in Marcel's. Our subjects' mean reaction times in both masking conditions for semantically related words were coupled with lower error rates than for controls, while total mean reaction times for graphemically similar/phonemically dissimilar words consistently were matched with higher error rates than for controls. The fact that a graphemic/phonemic interference effect was found contributes further evidence of perceptual processing of pattern-masked words of which subjects are unaware.

Experiment 6

The final experiment was designed both to serve as a partial replication of Experiment 5 and to extend the findings of that study by examining the time course of the priming effects with a centrally masked prime. Neely (1976) studied the time course of priming effects for unmasked primes and targets. Following the work of Posner and Snyder (1975), Neely found evidence for two kinds of facilitative priming effects. One is fast-acting, reaching asymptote at prime-target intervals as short as 250 msec. This type of priming is considered automatic because it is insensitive to experimental manipulations that affect subjects' expectancies. The second facilitative effect is slower acting and "strategic." This second effect was not evident until intervals longer than 250 msec, and it increased in magnitude with further increases in that interval. The occurrence of the slower acting facilitation does depend on expectancy manipulations.

Investigators using other paradigms have also found evidence for associative priming at brief prime-target intervals. Warren (1977) found an associative priming effect with naming latencies at an interval of 150 msec between prime and target. Taylor (1977) found an associative priming effect in a letter-identification task that reached asymptote at an interval somewhere between 200 and 300 msec.

It seemed to us that the priming effects we observed with masked primes should bear closer resemblance to automatic than to strategic priming, since the mask should preclude the development of any overt prime-contingent expectancies.

Rather than explore a wide range of prime-target intervals, we chose to compare priming with a masked prime at one brief interval with that obtained at the longer interval used in Experiment 5.

Accordingly, we used two different delays between the onset of prime and the onset of target: short (200 msec) and long (2,000 msec). Each subject experienced both delays, but in separate sessions. In most other respects, Experiment 6 was similar to the preceding experiment except that only the mask condition was used and only semantic priming was studied.

Method

Subjects. Two female and eight male students from an introductory psychology class received course credit for their participation in the experiment. All subjects were required to have normal or corrected-to-normal vision.

Apparatus. The apparatus was identical to that used in Experiment 5.

Materials. Since only semantic priming was examined in Experiment 6, the materials were restricted to four of the eight types of relationship used in the preceding experiment (see Types 3, 4, 7, and 8 in Table 2.) The number of practice trials was increased to 32 in the present study and included eight instances of each of the four trial types.

Procedure. There were two different intervals between the onset of the prime and the onset of the target. Those delays are referred to as short (200 msec) and long (2,000 msec). Both intervals were administered to all subjects in separate sessions. Five subjects were assigned to each of the two possible orders.

Each session began with 40 presence/absence trials during which the SOA between the target and the mask was adjusted as in Experiment 5. During the presence/absence trials in the second session, the SOA was initially set at the level achieved in the first session. The final SOAs for Session 1 ranged from 10 to 80 msec, with only one subject having an SOA over 30 msec. The SOAs for two of the subjects had to be lowered by 5 msec during presence/absence trials at the start of the second session. Following the presence/absence trials in each session, there were two blocks of 16 practice trials on the lexical decision task and, then, four blocks of 16 test trials. Subjects were given feedback on their mean reaction time and percentage correct at the end of each block.

The trial sequence was the same as in Experiment 5 except that the dark interval following the pattern mask was adjusted to provide either the short or the long delay interval, as appropriate. The remaining procedural details were the same as in Experiment 5.

Results

Mean reaction times and percentage error in the various conditions of Experiment 6 are provided in Table 5. Reaction times from incorrect trials and from trials in which the reaction time was shorter than 200 msec or longer than 2,000 msec were excluded from these mean values. Less than 1% of correct reaction times were outside those boundaries.

As in the previous experiment, reaction times to nonwords were substantially longer (102 msec) than reaction times to words.

An analysis of variance was carried out on the word trials (Types 3 and 4), with type of relationship (semantic vs. control), delay interval (short vs. long), and order of sessions as factors. The only significant effect in the analysis of the reaction times is the interaction between the type of relationship and delay interval, $F(1, 8) = 9.48, p = .015$. That interaction is the result of a semantic priming effect at the long delay but not at the short delay. A similar analysis on the probabilities of correct responding yielded no effects that were significant or approached significance.

Table 5
Latencies (in msec) and Percentage Error as a Function of Item Type and SOA in Experiment 6

	SOA (in msec)	
Item type	200	2,000
Semantically related (Type 3)		
Latency	639	622
% error	8.8	8.8
Unrelated (Type 4)		
Latency	636	654
% error	6.9	3.8
Nonwords (Types 7–8)		
Latency	732	749
% error	8.1	10.0

Note. SOA = stimulus-onset asynchrony.

In order to study the priming effects directly, separate analyses were carried out at each delay interval, collapsed over order of sessions. For the long delay condition, there was significant 33-msec priming effect in the reaction times, $F(1, 9) = 13.14$, $p = .006$. For the accuracy data, the semantic priming effect was not significant, $F(1, 9) = 2.94$, $p = .12$. It should be pointed out that though this latter effect was not significant, it was in the direction opposite to that of the similar case in Experiment 5 for which semantically primed trials were significantly more accurate than the control pairs.

For the short delay condition, no effects either on reaction time or on accuracy approached significance (all Fs < 1).

Discussion

The 33-msec semantic priming effect in the long delay condition compares favorably with the 29-msec semantic priming effect obtained under similar conditions in the preceding experiment. Once again, we found a significant priming effect in a situation in which subjects were unaware of the presence or identity of the prime word. The accuracy data were more variable in Experiment 6 than in Experiment 5 and did not yield a similar pattern of effects. It is possible that subjects in Experiment 6 adopted a different criterion on a speed/accuracy dimension, but the fact that the overall reaction times and error rates were similar in the two experiments does not favor that interpretation.

Contrary to our expectations, there was no evidence for semantic priming at a prime-target interval of 200 msec. On the basis of previous research and the assumption that masked primes lead to automatic priming, we should have obtained priming at that interval. A comparison between masked and unmasked primes over a wide range of delay intervals is required to determine whether the time course of priming is similar in the two cases.

General Discussion

We first consider some ways in which the present findings and those of Marcel (in press) may be interpreted. We discuss two interpretations. One is compatible with Marcel's, and one is a counterproposal that cannot be discounted yet. Then we examine some methodological implications of the findings.

Interpretations of the Masking Findings

1. Masking reveals separate realms of conscious experience and unconscious processing.

The most obvious interpretation of the findings is that they demonstrate perception to be an unconscious process or set of processes that is impervious to central masking. According to this view, instead of interrupting perceptual processing, masking prevents conscious awareness of perceived information. Thus a perceiver identifies graphic, phonetic, and semantic properties of words unconsciously before he or she experiences the stimulation consciously. Moreover, whereas unconscious perception may invariably precede conscious experience, perception without eventual conscious awareness is possible (cf. Dixon, 1971).

Marcel's (in press) own view is an elaboration of the foregoing. He proposed that unconscious perceptual processes are the automatic processes described by Posner and Snyder (1975) and Neely (1976, 1977) and the "spreading activation" of Meyer and Schvaneveldt (1971). These processes access any representation of a visually presented word that the reader's degree of skill enables him or her to access automatically. For adults, this would include semantic, phonetic, and graphic as well as lower order visual representations. Each process of achieving or accessing a representation leaves behind a "record" of its product.

In Marcel's view, consciousness requires recovery and integration of some of these records. The integration process ensures that conscious experience is of a coherent event the components of which receive mutually compatible interpretations. Moreover, conscious processes are selective and limited. In consequence, only one interpretation of an ambiguous event may be experienced at a time. Thus, only one perspective on a Necker cube is experienced at a time, and one meaning of an ambiguous word or sentence, although more than one may have been accessed unconsciously. Moreover, just what the conscious processes select depends on the perceiver's intentions or expectancies; that is, conscious experience depends on the "strategic" processes described by Neely (1976, 1977) and Posner and Snyder (1975).

So long as masking is central, it prevents recovery of some or all of the perceptual records perhaps by destroying them or by replacing them with records of the mask. Left intact are any effects of the target (e.g., spreading activation) to which unconscious perceptual processing may give rise. For its part, peripheral energy masking interferes with perceptual processing itself.

2. Masking causes forgetting of consciously perceived information.

An alternative interpretation of the masking findings accepts Marcel's (in press) description of the effects of masking in the main but denies the inference from the description that masking reveals a usually hidden domain of unconscious perception. According to this interpretation, masking may indeed prevent recovery or retrieval of "records" of perceptual processing, but it does so for the same or similar reasons that startling or otherwise disruptive events induce forgetting or even amnesia. An unexpected loud noise may induce forgetting of a telephone number that a person has just found in the telephone book. That forgetting may be explained as a failure of the individual to establish a useful means of retrieving the telephone number before the sudden noise distracted his or her attention from it. What is important is that the individual's inability to reproduce the number after being startled does not imply that prior to the startling event he or she was unconscious of the number. By analogy, an inability to report the occurrence or identity of a target presented before a mask may be a failure to recall the information induced by the attention-distracting effects of the mask's sudden onset; it may not be an indication that the perceptual information had failed to reach consciousness before the mask. Hence one need not conclude that unconscious perception typically precedes an awareness of having perceived or that consciousness requires recovery of records. Instead, it may be *recall* that requires record recovery.

The present findings and those of Marcel (in press) do not distinguish this interpretation from Marcel's in any compelling way. However, there seems to us at least one set of experimental findings provided by Marcel (1980) that is not explained in terms of the present interpretation. Dixon (1971) suggested that support for the occurrence of perception without concurrent awareness is obtained when patterns of responding are affected by stimuli presented below the awareness threshold, but are affected in a way that is different in pattern from the effects of supraliminal stimulation. Marcel (1980) provides just this outcome in a study that compares priming effects of two preceding words on a third word. A critical comparison for the present purposes is between the priming effects of TREE and PALM on WRIST, depending on whether PALM is masked. When it is unmasked, reaction time to WRIST is slowed in comparison both to HAND PALM WRIST and to CLOCK PALM WRIST, as if TREE were biasing the inappropriate meaning of PALM. However, when the second word of each triad is masked, WRIST is facilitated by TREE PALM as well as by HAND PALM and CLOCK PALM. Marcel suggested that in the absence of a mask, perceivers are aware of the second word and, due to the limited, selective nature of consciousness, can be aware only of the meaning of PALM that is compatible with TREE, a situation that leads to a slowing of the reaction time to WRIST. By hypothesis, these selective processes are precluded by the mask.

These results suggest a qualitative difference in processing mode between the masked and unmasked conditions, and they are not particularly expected on an interpretation of the priming effects that invokes forgetting.

Methodological Implications

Several experimental paradigms, considered at one time to access perceptual processing, are now understood differently. Their reinterpretation has been forced by findings of "familiarity effects" (see Krueger, 1975). Thus, for example, the partial sampling procedure was first believed to provide evidence concerning the nature of the precategorical (later "iconic") representation of visually presented stimulation (e.g., Sperling, 1960). However, several studies have shown that row report, for example, is affected by properties of the unreported row that should be unavailable in a precategorical store (e.g., Butler, 1973; Fryklund, 1975; Mewhort, 1967). Moreover, Merikle (1980) succeeded in obtaining a partial report superiority for categorical as well as physical selection criteria. Thus, the studies show unexpected effects of properties of stimulation that should be available only *after* pattern recognition, on stages of processing that were understood to precede pattern recognition.

Various explanations for these effects are given. One, of particular relevance here, is that any stages of processing prior to and including pattern recognition take place automatically and outside the domain of a skilled perceiver's intentional control. Thus, in these experiments, a perceiver cannot halt his or her perceptual processing at an early stage just because the logic of the experiment requires only primitive kinds of information about the stimulus. In consequence, paradigms such as the partial sampling procedure or Posner's (1978) same/different physical matching technique, among others, do not access a precategorical stage of perceptual processing but perhaps, instead, measure procedures that follow automatic identification of input.

From this viewpoint, central backward masking has appeared to have an advantage over other paradigms as a procedure for examining perceptual processing. Its advantage is that it does not depend on the subject's being able to halt the analysis of input at some preterminal stage. Instead, (by interpretation) the central mask itself interrupts processing at a stage determined by the SOA.

However, the findings reported by Marcel (in press) and substantiated by our experiments cast serious doubt on this interpretation. The findings indicate that perceivers extract meaning from words masked at detection-level SOAs. Since the SOA may be as short as 10–20 msec, it is implausible to suppose that meaning has already been processed by the time masking takes place. It is more likely, as Marcel (in press) suggests, that the effect of the mask is on something other than representations and processes necessary for perception. That is to say, the findings indicate that masking prevents awareness, but not perception.

Moreover, in comparing the results of the experiments of Parts 1 and 2 of the present series of investigations, we can perhaps explain why central masking has appeared to other investigators to halt perceptual processing. The reason may have to do with the response measure generally used in masking studies—namely, direct report of the masked item. This measure apparently does not necessarily reveal what perceivers know about a masked item but, instead, reveals only what they "know they know."

Indeed, we can point to other instances in the literature in which direct report has been found to provide an inappropriate measure of what has been perceived. One example is given in the literature on selective attention. Cherry's early shadowing studies (1953), in which subjects were asked to report properties of the unattended channel, revealed knowledge of physical properties of the unattended message, but not of its meaning. Later studies looking at the *influence* of unattended information of responses to attended stimuli (e.g., Lackner & Garrett, 1974; Lewis, 1970; MacKay, 1973) showed that the unattended message is processed to a deeper level than direct report had suggested.

Similarly, until quite recently (Merikle, 1980), differences in response measure provided the major difference between studies that did not and those that did find evidence of semantic and categorical information on the icon in the partial report paradigm. The set of studies that required selection of stimuli on the basis of semantic or categorical properties found no evidence for availability of semantic or categorical information (e.g., von Wright, 1968, 1970). In contrast, the studies that used an indirect measure (of the influence of semantic and categorical properties of unreported items on reported items when selection criteria are physically defined) obtained evidence that these properties were available even among unreported items (e.g., Butler, 1973; Fryklund, 1975; Mewhort, 1967).

Third, in a study by McCauley, Parmelee, Sperber, and Carr (1980), facilitative effects on picture naming of a masked, categorically related priming picture were obtained at a range of exposure durations of the prime. Significant priming was obtained even when the masked prime was presented at an exposure duration well below that required for identification of the picture.

Finally, in the literature on binocular rivalry, Walker and others (see Walker, 1978, for a review) found that information presented to the suppressed eye influences reports of information presented to the dominant eye, even though the observer reports seeing nothing of the nondominant eye's stimulus.

In sum, then, central masking does not halt perceptual processing, and previous evidence suggesting that it does may have used a response measure that is not appropriate for the assessment of perceptual processing. In view of the foregoing reinterpretation of central masking, we now consider whether masking itself is eliminated as a tool for examining the early stages of perceptual processing. We do not think that it is, and we suggest some ways in which it might be used.

First, peripheral masking, unlike central masking, apparently works by degrading the representation of the physical stimulus before semantic access. It is possible that peripheral masking can be used to test views relating to early stages of extraction of information about the physical form of the stimulus.

More interesting, however, central masking perhaps can be used as well so long as it is used in conjunction with an indirect response measure such as priming; for example, the procedure of Experiment 6, which varies the onset-onset time of prime and target, may enable an examination of the time course and character of perceptual processing. Thus, given equally sensitive measures of graphic and semantic priming (a serious difficulty in itself), by varying the prime-target SOA in the paradigm of Experiment 6, it may be possible to observe differential times after the prime's onset that graphic and semantic priming begin. If these priming effects reflect perceptual extraction of graphic and semantic information about the prime, then we would expect to observe graphic priming beginning prior to semantic priming under these conditions.

Concluding Remarks

Marcel's (in press) claims concerning the effects of briefly presented pattern-masked words have been substantiated by our investigations reported in Part 2. We are confident that the priming effects of words masked well below the recognition threshold are quite real. We are less confident that we or Marcel have discovered their most plausible interpretation. However, of the two interpretations that we have considered, Marcel's seems more satisfactory to us.

In any interpretation that we have considered, the findings suggest necessary revisions in our thinking about the effects of central masking and about the ways in which masking may be used as a tool to examine perceptual processing. In addition, in conjunction with the reports of familiarity effects in the literature, the findings suggest the importance of using indirect assessments of perceptual processing rather than direct report.

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