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Priming with and without awareness

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In two experiments, no evidence for perception without awareness was found in a Stroop-priming task when the threshold for detecting color-word primes was measured reliably by a forced-choice procedure. Color words and color patches were either congruent or incongruent, and no priming occurred when the words were presented at the detection threshold. However, systematic increases in the level of detection for the primes led to correlated increases in the magnitude of priming. The results provide no support for recent claims that priming is a more sensitive indicator of perceptual processing than detection based upon verbal report. A resolution to the apparent discrepancy between the present results and previously reported findings is suggested.

The present studies address the question of whether meaning is perceived without awareness. Several recent studies indicate that the meaning of visual stimuli is perceived even when it is impossible to decide if these stimuli have been presented (Balota, 1983; Fowler, Wolford, Slade, & Tassinary, 1981; Marcel, 1980, 1983a; McCauley, Parmelee, Sperber, & Carr, 1980). Although the reported observations are suggestive, the data do not necessarily support the conclusion that meaning is perceived prior to awareness, because serious questions can be raised concerning whether the visual stimuli used in these studies were actually presented below the subjects' awareness thresholds (Merikle, 1982; Nolan & Caramazza, 1982; Purcell, Stewart, & Stanovich, 1983). It is for this reason that the present studies were conducted. Care was taken to ensure accurate measurement of awareness thresholds and the perception-without-awareness hypothesis was evaluated by using a variant of the Stroop (1935) task similar to the one originally described by Marcel (1983a).

Many of the recent studies that provide evidence favoring the perception-without-awareness hypothesis have involved a priming procedure whereby reaction time to a target stimulus is facilitated by the presentation of a preceding, semantically related stimulus (cf. Meyer, Schvaneveldt, & Ruddy, 1975). In these studies, the priming effect was compared across two conditions. In the threshold condition, a backward pattern mask served to degrade the visibility of the priming stimuli to a point where subjects were unable either to identify the primes (McCauley et al., 1980) or to make presence-absence judgments significantly above chance (Balota, 1983; Fowler et al., 1981; Marcel, 1980, 1983a). This condition served to evaluate perceptual processing in the absence of awareness, and, according to the procedures used, awareness was defined as *the ability to make a discriminated verbal report*. In the second condition, the primes were presented without the mask, and this condition served to measure perceptual processing when subjects were aware of the primes.

Two critical findings were observed in these masked-prime studies: (1) Significant priming occurred even when the primes were masked, and (2) the magnitude of priming was independent of the presence or absence of the mask. In other words, even though the mask reduced verbal report accuracy to a chance level, it had little or no effect on the size of the semantic-priming effect. These results suggest that complete lexical access occurs independently of conscious awareness. The results thus appear to provide convincing evidence favoring the perception-without-awareness hypothesis.

The validity of the above conclusion, however, depends entirely upon the adequacy with which the thresholds for discriminated verbal reports were measured. Merikle (1982) has argued that the thresholds in these studies were based on such a small number of detection (Balota, 1983; Fowler et al., 1981; Marcel, 1980, 1983a) or identification (McCauley et al., 1980) trials that it was not possible to obtain a reliable estimate of each subject's response distribution. Thus, the nondiscriminative responding observed in these studies cannot necessarily be attributed to a genuine inability to utilize the available perceptual information. Furthermore, it has also been demonstrated by Purcell et al. (1983) that the masking stimulus used in the McCauley et al. (1980) study was less effective on the priming trials than on the threshold trials. It is for these reasons that both Merikle (1982) and Purcell et al. (1983) concluded that the results of the reported masked-prime studies do not necessarily indicate that perception of the primes occurred without awareness.

The present studies employed a method for testing the perception-without-awareness hypothesis that differed from the above studies in three major respects. First, each subject's ability to detect the primes was measured using

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a forced-choice discrimination procedure involving four response alternatives. This method was chosen because it has the advantage of removing the no or negative response from the set of possible answers. Individual differences in the willingness to guess a response were thus avoided. Second, thresholds were based on a sufficient number of trials to obtain reliable estimates of each subject's response distributions. Third, comparable masking conditions were used on the threshold and the priming trials to avoid any possible criticism that the masking conditions may have been less effective on the priming trials than on the threshold trials (cf. Purcell et al., 1983).

Following Marcel (1983a), a variant of the Stroop (1935) color-word task was used in the present studies. The task involved naming a color that was immediately preceded by the presentation of a congruent color word, incongruent color word, or control letter string. Previous research indicates that color-naming latencies in this task increase when a color is preceded by an incongruent color word (e.g., Dyer & Severance, 1973) and decrease when the prime word and the color target are congruent (e.g., Dalrymple-Alford, 1972). Thus, this variant of the Stroop task can be used to investigate both facilitation and inhibition at different levels of prime detectability.

EXPERIMENT 1

The purpose of this experiment was to measure priming in the Stroop task under several levels of prime detectability. Previous studies had measured priming only under a threshold and a no-mask condition (Balota, 1983; Fowler et al., 1981; Marcel, 1980, 1983a; McCauley et al., 1980). By using several different levels of prime detectability, it is possible to establish the functional relationship between priming magnitude and level of awareness.

The predictions for the study were quite straightforward. If thresholds were measured adequately in recent studies that appear to indicate perception without awareness, then significant facilitation and inhibition should be observed even when it is not possible to discriminate among the color words. Furthermore, if complete lexical access occurs prior to awareness (cf. Marcel, 1983b), then equal magnitudes of facilitation and inhibition should be observed across all levels of prime detectability. On the other hand, if thresholds were not measured adequately in previous studies, then it would be reasonable to expect that both facilitation and inhibition would increase with increased prime detectability when thresholds were determined by the more satisfactory procedures employed in the present study.

Method

Subjects

Each of eight volunteers, ranging in age from 16 to 28 years, received $25 for participating in the experiment. All had normal or corrected-to-normal vision.

Apparatus

An Iconix four-field tachistoscope was fitted with polarized filters in three fields to allow dichoptic presentation of the stimulus materials. The viewing distance was approximately 90 cm. The luminance of each field, as measured by a Pritchard photometer (Model 1970-PR) when a blank white card was displayed, was 60 cd/m² for the three polarized fields and 20 cd/m² for the binocular fixation field.

A handheld microswitch was used to initiate display presentation. It was connected in parallel to the tachistoscope controller and a PET/CBM 2001 microcomputer, which measured naming latencies from display onset to the activation of a voice key.

Material and Design

During the experimental trials, each stimulus display was composed of a letter-string prime and color-patch target. The color patches were centrally located rectangles of blue, green, yellow, and orange, which measured .95 cm (.6°)[1] horizontal × .65 cm (.4°) vertical. They were enclosed by black borders that formed a larger rectangle measuring 1.25 cm (.8°) horizontal and .95 cm (.6°) vertical. An identical rectangle drawn on a white card served as the fixation stimulus throughout the experiment.

The primes were letter strings that could appear either above or below the color patches. The primes included the four color words, BLUE, GREEN, YELLOW, and ORANGE, as well as a letter string consisting of five Xs. All primes were printed in uppercase 28-pt Helvetica Medium Outline Letraset (No. 2517). The dimensions of each letter were approximately .65 cm (.4°) horizontal × .80 cm (.5°) vertical, and the vertical distance from the center of a color patch to the center of a letter string was 1.45 cm (.9°).

There were three different relationships between primes and targets. For congruent trials, the prime had the same name as the color patch, whereas on incongruent trials, the prime and the target had different color names. For control trials, the letter string of five Xs served as the prime.

The stimuli were presented in blocks of 72 trials, consisting of equal numbers of control, congruent, and incongruent trials. The factorial combination of four color-patch targets, three color-word primes, and presentation either above or below the fixation rectangle yielded 24 unique incongruent trials. The congruent trials consisted of three repetitions of the set of eight different items formed by pairing the four color patches with the same color-word prime presented in each of the two locations. Similarly, the eight possible unique control trials were repeated three times per block.

The 72 trials within each block were presented randomly with two constraints. First, targets of the same color were never presented successively. Second, after any particular trial, the number of occurrences for the most frequently presented color patch never exceeded by more than two the number of occurrences for the least frequently presented color patch.

The overall experimental design was a 3 (prime-target relationship) × 4 (prime detectability) factorial. Prime detectability was measured using a four-alternative, forced-choice procedure, and the four levels of prime detectability were determined by varying the interstimulus interval (ISI) between the offset of a prime and the onset of a pattern mask. Three of the detectability conditions were defined as 25% (threshold), 55%, and 90% correct detections. The remaining detectability condition was a no-mask condition.

The pattern mask was constructed from uppercase letter pieces taken from 28-pt Helvetica Medium Letraset (No. 725). It consisted of two separate rectangles, each measuring 7.65 cm (4.9°) horizontal × 1.60 cm (1.0°) vertical, which completely overlapped the two possible letter-string locations.

The stimuli used for the detection trials were the color-word primes. They were presented in blocks of 24 trials consisting of three repetitions of the four color words × two spatial locations. The 24 stimulus displays in each block were randomly presented with the constraint that the same word never appeared three times in succession.

Experimental trials for the four levels of prime detectability were evaluated in separate sessions occurring over 4 consecutive days. The order for these conditions was balanced in the following manner. The comparison between the threshold (25%) and no-mask conditions was critical, so these experimental sessions were always administered successively. Likewise, the 55% and 90% conditions occurred over consecutive sessions. This yielded two pairs of sessions. Half of the subjects received one pair during the first two sessions, and the remaining subjects were initially presented with the second pair of sessions.

Procedure

The subjects were tested individually, and each session lasted approximately 2 h.

At the beginning of the first session, a sighting task was administered. Using a cone that covered both eyes, subjects binocularly sighted a distant spot and alternately closed each eye. The eye producing the monocular view with the least amount of displacement from the spot was assessed as dominant. During the detection and experimental trials, the pattern mask and color patches were presented to the dominant eye, while the primes were presented to the nondominant eye.

Detection trials. Each subject's detection threshold (25% accuracy) was determined at the beginning of the first session. The subjects were informed that one of the four color words would be presented on each trial and that each word would appear equally often above and below the fixation rectangle. In addition, the subjects were told to respond as accurately as possible and to restrict their responses to one of the four color words, even if it meant guessing. On each trial, the subjects first viewed the fixation rectangle. Following a verbal "ready" signal, they initiated a trial by pressing the handheld microswitch and, after a 150-msec delay, a color word was presented. Presentation of a color word was followed by a 300-msec presentation of the pattern mask. The subjects stated each response, and the experimenter informed them whether it was correct or incorrect.

Initially, the duration of the words was set at 100 msec. If, after a block of 24 trials, performance was 85% correct or better, the duration was lowered and another block of 24 trials was run. If performance was less than 85%, then the word duration was raised by 20 msec per block until 85% accuracy was achieved. This procedure was adopted because pilot data indicated that the most appropriate way to establish threshold was to have an initial high level of performance followed by a gradual decrease in word duration. Moreover, this method allowed the experimenter to attenuate any response biases by reminding subjects after every block of trials that all four color words appeared equally often.

Word duration was decremented 20 msec per trial block until accuracy approximated 50% correct. At this point, word duration was decreased in 10-msec steps until performance reached a level below 30% correct. Additional blocks of 24 trials were then presented at the duration at which performance was below 30% correct until a total of 120 trials had satisfied the criterion. If performance exceeded 30% correct after any block of trials, word duration was lowered an additional 5 msec and another five blocks of 24 trials were run.

Once the word duration for chance performance was established, it remained constant throughout the experiment. Thus, for each subject, threshold word duration was the maximum exposure duration at which the masked primes could not be discriminated from one another with above chance accuracy.

After the threshold word duration was determined, subjects assigned to either the 25%-detection or the no-mask experimental condition for Session 1 proceeded directly with the experimental trials. Subjects assigned to the 55%- and 90%-detection conditions for Session 1 continued with detection trials to establish the appropriate ISI.

The procedure used to determine the 55% and 90% detection levels was identical to that used for the threshold trials, except that a blank field was presented between the offset of the word and the onset of the mask and the duration of the mask was 300 msec minus the ISI between the word and the mask. The number of trials necessary to establish the required level of performance remained at 120. The experimenter selected an ISI that approximated the desired level of detection performance and administered a block of trials. Acceptable levels of accuracy ranged from 50% to 60% correct for the 55% condition, and greater than 80% but less than 100% correct for the 90% condition. Accuracy levels outside these ranges resulted in an adjustment of the ISI by 5 or 10 msec, depending upon the size of the discrepancy.

In Sessions 2, 3, and 4, detection trials relevant to the experimental condition were administered immediately prior to the beginning of the experimental trials. All subjects who received the 25% detection-level experimental trials in these sessions had their threshold word durations verified across a minimum of 72 trials prior to the beginning of the session. On the other hand, subjects who received 25% detection-level experimental trials in Session 1 had their threshold word durations verified at the beginning of Session 2.

Color-naming trials. The subjects were informed that on every trial a color patch would appear within the fixation rectangle and that their task was simply to name the color as quickly as possible. The subjects were told to avoid naming any letter strings that might appear above or below the color patch but not to be concerned if they made an error. The subjects were cautioned to keep both eyes open at all times and to initiate a trial only when looking at the fixation rectangle.

The sequence of events for the experimental trials was similar to that used for the detection trials. The subjects first viewed the fixation rectangle until the experimenter gave a verbal "ready" signal. After the handheld microswitch was pressed, there was a further delay of 150 msec, followed by presentation of a prime to the nondominant eye. The duration of the prime equaled each subject's threshold word duration. Upon offset of the prime, a color patch that filled the fixation rectangle was presented to the dominant eye for 300 msec. Following the appropriate ISI, the pattern mask was also presented to the dominant eye for 300 msec minus the ISI. In order to ensure that luminance summation did not occur whenever a color patch and the mask were presented simultaneously, a separate field polarized for the dominant eye was used to present a single display containing both a color patch and the mask.

Every experimental session included 48 practice trials with the display parameters dictated by the particular condition. The first 36 trials involved substituting a blank card for the primes and presenting only the color patches. These trials familiarized the subjects with the appearance of the four different hues and allowed the experimenter to adjust the sensitivity of the voice-activated relay. The final block of 12 trials consisted of an exemplar of the three prime-target relationships for each color.

In each session, there were 216 experimental trials, divided into three blocks of 72 trials. The subjects were given a 5-min rest between the trial blocks.

Results

Detection Trials

The forced-choice procedure was successful in attenuating response bias during the detection trials, since all subjects used the four response categories with approximately equal frequencies. In addition, a substantial learning effect was observed when the stimuli were first presented at or near threshold durations. All subjects initially claimed they could not see anything at durations that were 30 to 50 msec above their actual objective thresholds. However, after approximately 200 detection trials in which the word durations were gradually lowered, the subjects were able to use the available information to perform the task.

The mean percentages of correct responses for the three detection conditions were 26.8% (SD = 2.7), 54.9% (SD = 4.5), and 90.6% (SD = 4.9). The color-word durations used for the threshold condition (25%) ranged from 50 to 70 msec, with a mean 60 msec. The ISIs necessary to obtain 55% correct detection ranged from 5 to 40 msec, with a mean of 21 msec, and for 90% correct detection, the ISIs ranged from 20 to 85 msec, with a mean of 59 msec.

Color-Naming Trials

Table 1 presents the mean naming latencies and percentage errors for the three types of prime-target relation-

Table 1
Mean Naming Latencies and Percentage Errors for Each Prime-Target Relationship and Level of Prime Detectability

Prime-Target Relationship	Prime Detectability: 25% RT	25% %E	55% RT	55% %E	90% RT	90% %E	No Mask RT	No Mask %E
Congruent	596	2.6	603	3.3	593	2.3	584	1.8
Control	598	3.7	615	3.2	621	5.0	640	3.7
Incongruent	597	4.5	624	5.4	650	6.9	741	11.6

ships at the four levels of prime detectability. Naming latencies for both control and incongruent trials increased with increased prime detectability. Moreover, the naming latencies for the incongruent trials increased at a faster rate than the naming latencies for control trials. On the other hand, the naming latencies for the congruent trials remained relatively constant except for a slight tendency to decrease when the primes were most visible. These observations indicate that the influence of the primes became more pronounced as prime detectability increased.

The magnitudes of facilitation (control minus congruent trials) and inhibition (incongruent minus control trials) at each level of prime detectability are presented in Figure 1. The data presented in the figure clearly indicate that color words masked at the threshold duration had no effect on subsequent color-naming performance. Thus, the experiment provides no evidence for unconscious priming. Priming effects emerged only at the 55% detection level, where there was some evidence for discriminated verbal report. Furthermore, it is clear from the figure that as prime detectability increased, the size of the priming effects also increased. Finally, the results depicted in Figure 1 suggest that a high level of prime detectability must be obtained before the typical finding of greater inhibition than facilitation (e.g., Dyer & Severance, 1973) becomes apparent.

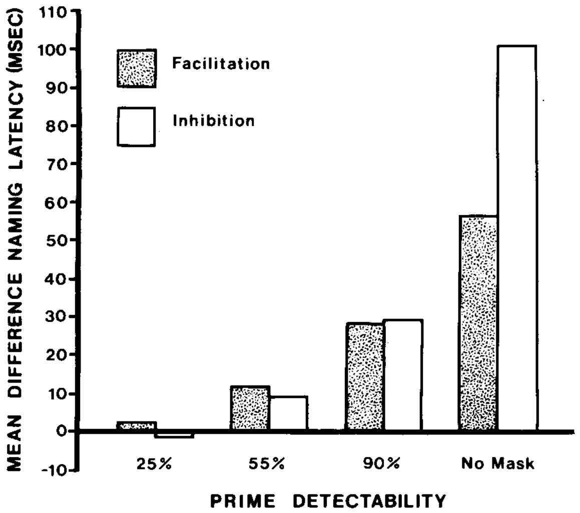

Figure 1. Mean facilitation and inhibition at each level of prime detectability in Experiment 1.

Planned comparisons were used to evaluate the facilitation and inhibition at each level of prime detectability. At the detection threshold (25% accuracy), neither the mean facilitation [2 msec; $t(7) < 1$] nor the mean inhibition [−1 msec; $t(7) < 1$] was significantly different from zero.[2] While both facilitation (12 msec) and inhibition (9 msec) increased under the 55% detection condition, these means were also not reliably different from zero [$t(7) = 3.17$, $p > .10$, and $t(7) = 1.57$, $p > .20$, for facilitation and inhibition, respectively]. It was only when subjects could detect the primes at least 90% of the time, that significant amounts of facilitation [28 msec; $t(7) = 4.46$, $p < .05$] and inhibition [29 msec; $t(7) = 3.93$, $p < .05$] were observed. Likewise, when the primes were not masked, both significant facilitation [56 msec; $t(7) = 6.74$, $p < .01$] and inhibition [101 msec; $t(7) = 4.81$, $p < .05$] occurred.

Planned comparisons were also used to evaluate the error data. In the no-mask condition, significantly more errors occurred on the incongruent trials than on either the control trials [$t(7) = 6.98$, $p < .01$] or the congruent trials [$t(7) = 4.86$, $p < .05$]. However, the number of errors on the control and congruent trials did not differ significantly [$t(7) = 1.95$, $p > .20$]. In the three other detectability conditions, no significant differences in error rates were found. In general, the largest differences in error rates in these conditions occurred between the congruent and incongruent trials, and none of the t values associated with these comparisons exceeded the critical value of 3.13 [25%, $t(7) = 1.96$; 55%, $t(7) = 1.59$; 90%, $t(7) = 2.77$].

Discussion

The aim of this experiment was to determine if evidence favoring perception without awareness is observed when appropriate procedures for measuring awareness thresholds are employed. Overall, the results provide no support whatsoever for the perception-without-awareness hypothesis. When discrimination among the four color words was at a chance level, there was no evidence for either facilitation or inhibition in the Stroop task. Moreover, the magnitude of the Stroop priming effects was positively correlated with the level of prime detectability, with priming increasing continuously until some point beyond the 90% detectability level. Thus, when a four-alternative, forced-choice procedure is used to measure prime detectability and precautions are taken to ensure that the awareness thresholds are measured accurately, evidence for perception without awareness is not obtained during the performance of the Stroop task.

The strong positive relationship between prime detectability and the magnitude of the Stroop effects is particularly damaging to Marcel's (1983a) claim that unconscious Stroop effects should be maximal before detection performance rises above a chance level. In fact, it was not until the color words were detected with 90% accuracy that magnitudes of facilitation and inhibition comparable to Marcel's nonawareness condition were observed in the present study. Thus, the present results support the validity of previous criticisms (Merikle, 1982) directed at Marcel's (1983a) threshold procedures.

More generally, the present findings suggest that the threshold procedures used in other studies presumed to demonstrate perception without awareness (Balota, 1983; Fowler et al., 1981; Marcel, 1980, 1983a; McCauley et al., 1980) may also have provided unreliable threshold estimates. Given that the threshold procedures used in these studies are similar to the one used by Marcel (1983a) in his Stroop study, a reasonable expectation is that this evidence for perception without awareness may also disappear when awareness thresholds are determined by appropriate procedures.

In light of our failure to find evidence supporting the perception-without-awareness hypothesis, some anecdotal evidence concerning the visibility of the primes during the color-naming trials is relevant. On an informal basis, the subjects were asked after every block of 72 trials to estimate how often they noticed the primes. As expected, all subjects claimed to have absolutely no awareness of the primes in the 25% detection condition and to have complete awareness of the primes in the no-mask condition. Surprisingly, all subjects also reported that they rarely, if ever, noticed the primes in either the 55% or 90% detection conditions. In those conditions, subjects simply did not have any confidence that a prime may have preceded the presentation of a color target, even though the objective detection measure, administered immediately prior to these trials, had indicated that the subjects could perform a forced-choice discrimination task with a relatively high level of accuracy.

This lack of confidence that a prime may have preceded a color target is reminiscent of an earlier finding reported by Bernstein and Eriksen (1965). In their experiment, responses to nonsense-syllable paired associates were prompted by cues, and these cues were masked so that the subjects' forced-choice recognition performance approximated a predetermined level of accuracy. As in the present experiment, Bernstein and Eriksen found that the only effective cues were the ones that were presented above the detection threshold. More importantly, Bernstein and Eriksen also found, on the basis of postexperimental interviews, that at least half the subjects denied ever seeing the effective cues, even though a forced-choice recognition task indicated that these cues were detected with 70%-97% accuracy. Thus, Bernstein and Eriksen's results provide additional evidence that subjects may claim not to be aware of stimuli even when an objective detection measure indicates a relatively high level of performance.

These observations suggest that a major effect of a mask is to reduce confidence that a stimulus has been presented. If a mask reduces confidence, then it is very possible that subjects may claim consistently that no stimulus has been presented even when discriminative behavior can be demonstrated in a properly controlled forced-choice detection situation. This speculation is consistent with criticisms that have been directed at the methodology used to establish awareness thresholds in previous masked-prime studies (Merikle, 1982), and it suggests that previous investigators may have inadvertently measured a subjective rather than an objective threshold (e.g., Balota, 1983; Fowler, et al., 1981; Marcel, 1983a; Mc-Cauley et al., 1980). A *subjective threshold* may be defined as the detection level at which subjects claim not to be able to discriminate perceptual information at better than a chance level, whereas an *objective threshold* is the detection level at which perceptual information is actually discriminated at a chance level. Given that awareness thresholds in previous studies were based on very few trials, it is not possible to distinguish detection performance due to a lack of confidence that a particular stimulus had been presented (i.e., the subjective threshold) from detection performance due to a lack of perceptual sensitivity to the presence of the stimulus (i.e., the objective threshold).

Two other observations are consistent with this speculation that subjective rather than objective thresholds may have been established inadvertently in previous masked-prime studies. First, even though Marcel (1983a) implies that awareness thresholds in his experiments were defined as the point at which presence/absence decisions were no better than chance, his actual criterion for threshold performance was less than 60% correct in a two-choice task (p. 213). Thus, some detection of the primes appears to have occurred in Marcel's experiments. The second observation supporting this conclusion is found in the Fowler et al. (1981) article. They admit that the awareness thresholds in their studies may have been established so that they were somewhat above the objective threshold (p. 355). Nonetheless, they argue that the important point concerning their experiment is that the subjects *claimed* that their decisions about the primes were always based upon movement or changes in brightness rather than the identity of the primes per se. What Fowler et al. appear to be stating is that their psychophysical technique may have established a subjective, rather than an objective, threshold.

If this distinction between subjective and objective thresholds is correct, it should be possible to demonstrate that the presence or absence of priming in the Stroop task is dependent upon which threshold is used to define awareness. The results of the present study suggest that no priming should occur when primes are presented at an energy level defined by the objective threshold. On the other hand, it is entirely possible that priming will occur when primes are presented at an energy level defined by the subjective threshold. The primary objective of Experiment 2 was to provide a direct test of this implication of the distinction between subjective and objective thresholds.

A secondary aim of Experiment 2 was to ascertain if the effectiveness of the masked primes in the Stroop task was dependent upon the prime-target SOA. It is possible to argue that our failure to find evidence supporting perception without awareness is due to the relatively short SOA (i.e., 60 msec) separating the primes from the targets. Both Balota (1983) and Fowler et al. (1981) failed to find any evidence for the perception of masked primes when short prime-target SOAs (i.e., 200-350 msec) were used. However, in both studies, significant priming was observed when the prime-target SOA was 2,000 msec. Exactly why masked primes should be effective only when the prime-target SOA is relatively long is not at all obvious. Neither Balota nor Fowler et al. stated any theoretical rationale for predicting such a limitation to the effects of masked primes, and even the empirical evidence is inconsistent in that Marcel (1980, 1983a) has reported that the magnitude of priming produced by masked primes is unaffected by the prime-target SOA. Nevertheless, given that certain investigators have found evidence favoring the perception-without-awareness hypothesis only when using relatively long prime-target SOAs, it is worthwhile to establish if masked primes in the Stroop task become more effective at longer prime-target SOAs.

EXPERIMENT 2

In this experiment, objective and subjective thresholds were established for each subject prior to the introduction of the priming trials. If the proposed distinction between objective and subjective thresholds is valid, then two critical findings should be observed. First, the prime-mask SOA should be longer for the subjective threshold than for the objective threshold condition. Consequently, objective detection performance should be above a chance level at each subject's subjective threshold. Second, significant priming should be observed only when the primes are masked at the SOA corresponding to the subjective threshold. This pattern of results would provide support for the proposition that a subjective rather than an objective threshold was inadvertently equated with the threshold for awareness in previous masked-prime studies.

The objective and subjective thresholds were established by following much the same procedure as was used in Experiment 1. The major procedural change involved requiring subjects to provide an estimate of their detection performance after every block of 48 threshold determination trials. In this way, it was possible to establish both subjective and objective thresholds and to determine the actual objective detection performance when subjects *claimed* their performance was at a chance level.

Finally, to establish if the primes were more effective at longer prime-target SOAs, priming in each threshold condition was evaluated at prime-target SOAs of 50, 550, and 1,050 msec.

Method

Subjects

Ten volunteers, ranging in age from 20 to 30 years, received $24 for participating in the experiment. All had normal or corrected-to-normal vision. Four volunteers had served in the previous experiment.

Apparatus

The stimulus materials were displayed on an Electrohome high-resolution color monitor that was interfaced to an Apple II Plus microcomputer via an Electrohome Supercolor board. The monitor was viewed through a hood that physically divided the screen into separate left-eye and right-eye fields; fusion of these fields was aided by a set of rotating prisms. The viewing distance was 65 cm and the luminance of each field measured 32 cd/m² when the light beige background color (color No. 91) was displayed.

A button box placed in front of the subject was used to initiate display presentations and to record responses on the detection trials. Color naming latencies were measured by the microcomputer from color onset to the activation of a voice key.

Materials and Design

The overall experimental design was a 2 (prime-target relationship) × 3 (prime-target SOA) × 3 (prime detectability) factorial. The two prime-target relationships were congruent and incongruent; the three prime-target SOAs were 50, 550, and 1,050 msec; and the three levels of prime detectability were objective threshold, subjective threshold, and suprathreshold. Objective and subjective thresholds were established for each subject by varying the prime-mask SOA in a four-alternative, forced-choice task. Objective thresholds were defined as 25% correct performance, whereas subjective thresholds were defined as the actual observed performance when subjects initially estimated that their detection performance was less than 30% correct. For all subjects, the suprathreshold condition had a constant, 300-msec, prime-mask SOA.

Each stimulus display consisted of four separable components: a black fixation rectangle, a rectangular color frame (red, blue, green, or yellow), a color word (RED, BLUE, GREEN, or YELLOW), and a pattern mask. The fixation rectangle measured 4.8 cm (4.2°) horizontal × 2.1 cm (1.9°) vertical, and the color frames completely enclosed the fixation rectangle. Each side of each color frame was .3 cm (.3°) wide, and the outer dimensions of the frames were 6.6 cm (5.8°) horizontal × 3.9 cm (3.4°) vertical. The color words were centered within the fixation rectangle and were presented in black, uppercase letters using the standard character font provided by the microcomputer. Each letter measured approximately .5 cm (.4°) horizontal × .7 cm (.6°) vertical. The pattern mask consisted of two rows of eight, black, uppercase letters presented in the same character font as the color words. The 16 letters in the mask completely filled the fixation rectangle, and they were selected randomly with replacement from the following population: A, B, E, G, H, M, N, Q, R, S, and W. The only selection constraint was that the same letter never appear in adjacent positions.

For the color-naming trials, the displays were presented in blocks of 72 trials. Each block contained four displays for each of the 18 experimental conditions. Within each block, the four possible color frames and color words appeared equally often, and each unique, congruent, prime-color pair appeared once. Since there were 12 unique, incongruent, prime-color pairs, three blocks of trials were required to present all possible pairs. Presentation order for the 72 trials in each block was random within the same constraints as used in Experiment 1.

For the detection trials, the displays were presented in blocks of 48 trials. The color frames were not presented, and each block of 48 trials simply consisted of 12 presentations of each color word in a random order.

Procedure

Each subject was tested individually over three 90-min sessions. During the first two sessions, the appropriate prime-target SOAs for the objective and subjective thresholds were established. The final session involved presentation of the color-naming trials.

Detection trials. The subjects were informed that one of four color words would be presented within the fixation rectangle on every trial, and that responses should be indicated by pressing the button corresponding to the color word. The subjects were also told that each color word would appear equally often and that their guesses should be distributed across the four possible responses. In addition, the subjects were informed that they would be required to provide an estimate of their detection performance after every block of 48 trials. They were told that performance would be 25% correct with complete guessing and that therefore their estimates should be between 25% and 100% correct.

On each trial, the fixation rectangle was presented continuously to both eyes. The subjects fixated the center of the rectangle and initiated the trial sequence by pressing the start button. After a 250-msec delay, a color word was presented to the left eye for 16.7 msec, and following the prime-mask SOA, the pattern mask was presented to the right eye for 50 msec. When a response button was pressed, the screen went blank for approximately 500 msec before the fixation rectangles for the next trial were presented.

The pattern mask was changed after every 24 trials by selecting a new set of letters. After every block of 48 trials, the subjects' estimates of their performance were recorded and the prime-mask SOAs were changed if necessary. Feedback about detection performance was not provided.

In the first session, the prime-mask SOA was set initially at 300 msec. After a subject obtained 100% correct detections and indicated that the color words were clearly visible, the SOA was reduced to 200 msec. Further reductions of 33.3 msec per 48-trial block continued until detection performance fell below 100%. At this point, the prime-mask SOA was decreased by 16.7 msec after every block of 48 trials until detection performance approximated 25% correct. For each subject, this procedure provided both an estimate of the objective threshold and a specification of the level of accuracy associated with the subjective threshold.

During the second session, the objective and subjective thresholds were adjusted for the individual color words so that the detection of each word approximated a criterion accuracy level. Since detection performance in the first session was based on blocks of trials with a constant prime-mask SOA for all color words, occasionally there was a relatively large discrepancy in detection performance across the individual words. To eliminate these discrepancies, prime-mask SOAs were adjusted for the individual words. For the subjective-threshold condition, the SOAs for the individual color words were adjusted so that detection accuracy for each color word was within 10% of the accuracy level established in the first session. For the objective-threshold condition, the prime-mask SOAs were adjusted so that detection of each color word was below 35% correct.

The prime-mask SOAs for each subject's subjective threshold were adjusted prior to the adjustment of the SOAs for the objective threshold. For both threshold conditions, the prime-mask SOA was changed by 16.7 msec whenever detection accuracy for an individual color word fell outside the criterion range after a block of 48 trials. The prime-mask SOAs were adjusted following each block of 48 trials until three blocks of trials requiring no adjustments were completed.

Color-naming trials. The subjects were instructed to fixate the center of the fixation rectangle continually during each trial and to name, as quickly as possible, the color of the frame surrounding the fixation rectangle. Since all three threshold conditions were intermixed within each block of trials, the subjects were warned that a color word might be seen occasionally but that they should avoid naming it. In addition, the subjects were informed that a color frame would be presented either immediately following presentation of the mask or after a delay of up to 1 sec. For this reason, the subjects were instructed to be prepared to name the color frame at all times after the onset of a trial.

The sequence of events on each trial was similar to the event sequence on the detection trials. A color word was presented within the fixation rectangle for 16.7 msec and then masked. The prime-mask SOA was equal to the duration associated with each subject's objective threshold, subjective threshold, or 300 msec (i.e., the suprathreshold condition). Presentation of each color word was also followed by presentation of a color frame. The color frames were presented to both eyes for 1,000 msec, and the prime-target SOA was 50, 550, or 1,050 msec.

Seven blocks of 72 trials were administered to each subject. The first block of trials served as practice, and the remaining six blocks of trials provided the experimental observations. After every block of trials, the pattern mask was changed by randomly selecting a new set of letters. All trial blocks were separated by a 3-min interval.

Results

Detection Trials

For each subject, percentage correct detection was calculated for each color word at the final prime-mask SOAs established in the objective and subjective threshold conditions. At the objective threshold, overall mean detection performance, averaged across the four color words, was 27% (SD = 3.9) correct, and the means for individual subjects ranged from 22% to 31% correct. In sharp contrast to these results, the mean detection performance for individual subjects at the subjective threshold ranged from 53% to 75% correct, and the overall mean detection performance was 66% (SD = 7.4) correct. These results clearly establish that objective detection performance was considerably above the chance performance level (i.e., 25% correct) for all subjects at the subjective threshold. Thus, even though the subjects claimed not to be able to discriminate among the color words at better than a chance level, the data clearly indicate that they could discriminate among the primes.

The differences in detection performance for the objective and subjective threshold conditions are consistent with the different prime-mask SOAs established for each condition. The mean prime-mask SOA for the objective-threshold condition was 30 msec, with a range from 16.7 to 50 msec; for the subjective-threshold condition, the mean prime-mask SOA was 56 msec, with a range from 33.3 to 83.3 msec. Thus, relative to the objective-threshold condition, the higher detection performance observed in the subjective-threshold condition is perfectly consistent with the longer prime-mask SOAs used in this condition.

Color-Naming Trials

Table 2 presents the median naming latencies and the percentage errors for each condition.[3] In general, the magnitude of priming (incongruent minus congruent trials) increased with increased prime detectability. At the objective threshold, almost no priming was observed; in the subjective-threshold condition, a modest priming effect was found. The largest priming effect, however, occurred in the suprathreshold condition. This pattern of results is entirely consistent with the results obtained in Experiment 1.

As indicated in Table 2, none of the observed priming effects varied to a large degree as a function of the prime-target SOA. The major effect of an increase in the prime-

Table 2
Median Naming Latencies and Percentage Errors for Each Prime-Target Relationship and Prime-Target SOA at Each Level of Prime Detectability

		Prime-Target SOA (msec)					
		50		550		1,050	
Prime Detectability	Prime-Target Relationship	RT	%E	RT	%E	RT	%E
Detection	Incongruent	510	5.5	487	3.8	485	4.2
Threshold	Congruent	496	3.9	482	1.7	482	0.8
(27%)	Priming	14		5		3	
Subjective	Incongruent	516	4.3	491	5.1	487	3.9
Threshold	Congruent	486	4.6	448	2.5	449	1.7
(66%)	Priming	30		43		38	
	Incongruent	555	20.5	513	3.9	489	2.5
Suprathreshold	Congruent	456	2.9	421	1.7	395	2.5
	Priming	99		92		94	

target SOA was simply to decrease the overall naming latencies for the colors.

The data for each detectability condition were analyzed by a separate analysis of variance. This approach was required because variability in the data increased as a function of prime detectability. Each analysis of variance evaluated two factors: prime-target relationship and prime-target SOA. The results of these analyses revealed significant main effects for prime-target SOA [all $Fs(2,18) > 4.42$, $p < .05$], but no analysis revealed a significant interaction between prime-target SOA and prime-target relationship [all $Fs(2,18) < 1$]. Thus, although increases in the prime-target SOA decreased the overall naming latencies, variations in the prime-target SOA did not affect the magnitude of priming. On the other hand, significant main effects due to prime-target relationship were found in both the analysis of the suprathreshold data [$F(1,9) = 40.04$, $p < .01$] and the analysis of the subjective-threshold data [$F(1,9) = 8.29$, $p < .01$]. These main effects indicate that significant priming occurred in both conditions. However, the absence of a significant main effect due to prime-target relationship in the analysis of the objective-threshold data [$F(1,9) = 1.81$] indicates that no priming occurred in this condition.

The magnitude of priming at each prime-target SOA in each detectability condition was evaluated by a direct comparison of the naming latencies on the congruent and incongruent trials. In general, the results of these planned comparisons confirmed the implications of the analyses of variance. For the objective-threshold condition, no significant priming effects occurred, as all observed differences between congruent and incongruent trials were nonsignificant [all $ts(18) < 1.90$].[4] On the other hand, the differences in naming latencies between the congruent and incongruent trials were significant at all prime-target SOAs in both the subjective-threshold condition [all $ts(18) > 2.96$, $p < .05$] and the suprathreshold condition [all $ts(18) > 4.58$, $p < .01$]. These differences indicate that priming occurred in both the subjective-threshold and the suprathreshold conditions.

The error data summarized in Table 1 were also evaluated by separate 2 × 3 analyses of variance for each detectability condition. The analyses for the objective-threshold and the subjective-threshold conditions revealed no significant main effects or interactions (all $Fs < 3.16$). However, the analysis of the errors in the suprathreshold condition revealed significant effects for prime-target SOA [$F(1,9) = 19.96$, $p < .01$], prime-target relationship [$F(1,9) = 8.98$, $p < .01$], and the interaction between these two variables [$F(2,18) = 9.35$, $p < .01$]. Subsequent post-hoc comparisons using the Newman-Keuls procedure showed all these effects to be attributable solely to the large number of errors on the incongruent trials at the 50-msec prime-target SOA.

Discussion

The results of this experiment support three major conclusions. First, the absence of priming in the objective-threshold condition confirms the results of Experiment 1 and provides further confirmation that priming does not occur in the Stroop task when subjects cannot discriminate among the color words. Second, given that the magnitude of priming did not vary as a function of the prime-target SOA, the results do not support the suggestion made by both Balota (1983) and Fowler et al. (1981) that unconscious priming effects are more likely to be observed at relatively long prime-target SOAs. Finally, and most importantly, the presence of significant priming in the subjective-threshold condition indicates that priming occurs even when subjects claim not to be able to discriminate among the primes.

The reason priming occurred in the subjective-threshold condition becomes obvious when the detection performance in this condition is considered. Contrary to their professed claims, all subjects were able to detect the primes at a considerably better than chance level of performance. Given this evidence for considerable perceptual processing, it is not at all surprising that priming occurred in this condition. The only possible surprising result is that the subjects' self-reports concerning their ability to discriminate among the primes are so poor.

The results also indicate that priming occurs whenever detection performance deviates slightly from the objective threshold. The data presented in Table 2 show that we were not completely successful in establishing a proper level of detection performance in the objective-threshold condition in that the actual detection performance was 27% rather than 25% correct. Although significant overall priming was not observed in this condition, the data suggest that a small amount of priming may have occurred. When each subject's actual detection performance was correlated with the average magnitude of priming across the three prime-target SOAs, a significant correlation was obtained [$r(8) = .71$, $p < .05$] and the intercept for zero priming was 25% correct. Thus, the small amount of priming that did occur in the objective-threshold condition is attributable to those subjects whose detection performance was slightly above a chance level, and the magnitude of priming was directly related to the extent to which a subject's detection performance deviated from chance.

The present results provide clear evidence that the procedures used to determine thresholds in any study investigating the perception-without-awareness hypothesis must be capable of distinguishing the objective threshold from a subjective threshold. Otherwise, it is not possible to determine if the absence of discriminative responding is due to a lack of perceptual sensitivity to the presence of a stimulus or to a lack of confidence that a particular stimulus has been presented. The data from the objective-threshold condition suggest that evidence favoring perception without awareness will never be found when the awareness threshold is equated with the absence of perceptual sensitivity as defined by a properly established threshold. On the other hand, the data from the subjective-threshold condition indicate that a considerable amount of perceptual processing occurs when subjects lack confidence that a stimulus has been presented. Thus, if the awareness threshold were inadvertently equated with a subjective threshold, it would be possible to obtain evidence that appears to favor the perception-without-awareness hypothesis. Given that the methods used to establish awareness thresholds in recent studies presumed to demonstrate unconscious perceptual processing cannot distinguish objective from subjective thresholds (e.g., Balota, 1983; Fowler et al., 1981; Marcel, 1983a; McCauley et al., 1980), it is very probable that subjective rather than objective thresholds were inadvertently established in these studies.

CONCLUSIONS

The two reported experiments demonstrate that no evidence for perception without awareness is obtained in a masked-prime paradigm when precautions are taken to ensure that discriminated verbal reports concerning the primes actually approximate a chance level of performance. In addition, the results of both experiments indicate that there is a positive relationship between the magnitude of priming and the level of prime detectability. The results thus support Eriksen's (1960) position that verbal reports are an accurate indicator of perceptual processing and contradict recent claims that masked primes presented below the awareness threshold are nevertheless perceived (Balota, 1983; Fowler et al., 1981; Marcel, 1983a, 1983b; McCauley et al., 1980). Therefore, the present experiments refute the position that indirect measures (i.e., priming) are more sensitive indicators of perceptual processing than direct measures (i.e., verbal report).

A resolution to the apparent discrepancy beween the present results and previous results is suggested by the relatively large priming effects observed in the subjective-threshold condition in Experiment 2. If it is assumed that subjective, rather than objective, thresholds were actually measured in the previous masked-prime studies, then the present results are at least partially consistent with the results of these studies. However, this empirical consistency does not necessarily imply that the priming observed in the subjective-threshold condition supports the perception-without-awareness hypothesis. Awareness defined in terms of a subjective threshold has considerably different theoretical implications than awareness defined in terms of the objective threshold. Whether or not it is even meaningful to consider equating awareness with a subjective threshold is a question that future studies will have to answer.

REFERENCES

Balota, D. A. (1983). Automatic semantic activation and episodic memory encoding. *Journal of Verbal Learning and Verbal Behavior*, **22**, 88-104.

Bernstein, I. H., & Eriksen, C. W. (1965). Effects of "subliminal" prompting on paired-associate learning. *Journal of Experimental Research in Personality*, **1**, 33-38.

Dalrymple-Alford, E. C. (1972). Associative facilitation and interference in the Stroop color-word task. *Perception & Psychophysics*, **11**, 274-276.

Dyer, F. N., & Severance, L. J. (1973). Stroop interference with successive presentations of separate incongruent words and colours. *Journal of Experimental Psychology*, **98**, 438-439.

Eriksen, C. W. (1960). Discrimination and learning without awareness: A methodological survey and evaluation. *Psychological Review*, **67**, 279-300.

Fowler, C. A., Wolford, G., Slade, R., & Tassinary, L. (1981). Lexical access with and without awareness. *Journal of Experimental Psychology: General*, **110**, 341-362.

Marcel, [A. J.] (1980). Conscious and preconscious recognition of polysemous words: Locating the selective effects of prior verbal con text. In R. S. Nickerson (Ed.), *Attention and performance VIII* (pp. 435-457). Hillsdale, NJ: Erlbaum.

Marcel, A. J. (1983a). Conscious and unconscious perception: Experiments on visual masking and word recognition. *Cognitive Psychology*, **15**, 197-237.

Marcel, A. J. (1983b). Conscious and unconscious perception: An approach to the relations between phenomenal experience and perceptual processes. *Cognitive Psychology*, **15**, 238-300.

McCauley, C., Parmelee, C. M., Sperber, R. D., & Carr, T. H. (1980). Early extraction of meaning from pictures and its relation to conscious identification. *Journal of Experimental Psychology: Human Perception and Performance*, **6**, 265-276.

Merikle, P. M. (1982). Unconscious perception revisited. *Perception & Psychophysics*, **31**, 298-301.

Meyer, D. E., Schvaneveldt, R. W., & Ruddy, M. G. (1975). Loci of contextual effects on visual word-recognition. In P. M. A. Rabbitt & S. Dornic (Eds.), *Attention and performance V* (pp. 98-118). New York: Academic Press.

Nolan, K. A., & Caramazza, A. (1982). Unconscious perception of meaning: A failure to replicate. *Bulletin of the Psychonomic Society*, **20**, 23-26.

Purcell, D. G., Stewart, A. L., & Stanovich, K. E. (1983). Another look at semantic priming without awareness. *Perception & Psychophysics*, **34**, 65-71.

Stroop, J. R. (1935), Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, **18**, 643-661.

NOTES

1. The visual angle subtended by each stimulus dimension is given within parentheses following each linear measurement.

2. Individual error terms were calculated for each comparison, and Type I error rates were corrected using the Bonferroni t procedure.

3. Median naming latency was used because the maximum number of observations per cell was only 24, as compared with a maximum of 72 observations per cell in Experiment 1.

4. Each comparison was based upon the pooled error term from the corresponding ANOVA, and Type I error rates were corrected using the Bonferroni t procedure.

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