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The word without the tachistoscope

WILLIAM PRINZMETAL
University of California, Berkeley, California

and

BETH SILVERS
California School of Professional Psychology, Alameda, California

In experiments with an unlimited viewing time, we were able to isolate specific stimulus factors that lead to the word-superiority effect. We discovered that advantages of words over nonwords, and words over single letters, are caused by different factors. The word-nonword effect was found in a variety of circumstances, such as with small type, low contrast, or a simultaneously present mask. The advantage of words over single letters occurs only when the stimuli are embedded in a mask making it difficult to find a single letter. In addition, we obtained a word-detection effect without a brief exposure: Subjects were more accurate detecting the presence of words than nonwords. However, this effect only occurred when subjects were required to discriminate letters from nonletters. Thus, the word-superiority (word-nonword difference) and word-detection effects both involve letter discrimination and can be explained by similar mechanisms.

One of the most popular paradigms in visual perception uses the following method: A stimulus is presented for a fraction of a second and is followed by some type of visual mask. The stimulus may consist of alphanumeric characters, objects, or faces. The subject's task is frequently to report some aspect of the stimulus such as the identity of a letter or digit (e.g., Ranney, 1987; Reicher, 1969; Wheeler, 1970), a facial feature (e.g., Homa, Haver, & Schwartz, 1976; Mermelstein, Banks, & Prinzmetal, 1979), or a line segment (e.g., Weisstein & Harris, 1974). Alternatively, subjects may be asked to discriminate whether a target item was present or not when the stimulus consists of a letter string (e.g., Doyle & Leach, 1988), a face (e.g., Purcell & Stewart, 1986), or a line drawing (e.g., Purcell & Stewart, 1991). The purpose of the brief exposure and the mask is to make the stimulus difficult to perceive so that report accuracy can serve as the dependent variable.

Although thousands of experiments have used the brief exposure paradigm, they have not been without their critics. Dodge (1907) likened experiments with a brief exposure to reading in a lightning storm. He believed that not only would the results of such experiments not generalize to other situations, but that experiments with overly brief exposures would mislead investigators. Gibson (1979) referred to experiments using a brief exposure as "snapshot vision" (p. 1). In the pages of this journal, Eriksen (1980) solemnly expounded against the indiscriminate use of a visual mask in an article titled "The Use of a Visual Mask May Seriously Confound Your Experiment." Eriksen was concerned about specific feature interference between the mask and stimulus, but as we will show, the perils of using a mask are more ubiquitous.

In this paper, we report experiments in word perception that use methods other than a brief exposure to limit the accuracy of perception. We suggest that not only has the use of a mask confounded experiments (as suggested by Eriksen), but also that the use of a brief exposure has misled investigators (as suggested by Dodge). In order to understand how a brief exposure and a mask may confound a number of stimulus factors, consider some effects that could differentially limit performance with stimuli such as words, nonwords, and single letters. The abrupt visual onset can capture attention (e.g., Yantis & Jonides, 1990), and this effect may be different for larger stimuli (e.g., words) than for smaller stimuli (e.g., single letters). With a brief exposure, processing time is limited, and there may be differences in the rate of information processing between different types of stimuli (Massaro & Klitzke, 1979). A brief exposure not only affects processing time, but it also reduces the effective contrast. Furthermore, the sensitivity to high spatial frequencies is reduced with brief exposures. Finally, a brief exposure can cause uncertainty as to the location of stimulus items (e.g., Allport, 1977; Chastain, 1986; Mozer, 1983; Prinzmetal & Keysar, 1989; Treisman & Souther, 1986; Wolford & Shum, 1980).

The onset of the mask can affect processing in at least two general ways, in addition to the feature-specific interference that concerned Eriksen (1980). The poststimulus mask may cause *interruption* masking (Turvey, 1973) or

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integration masking (Eriksen & Collins, 1967, 1968). It has been proposed that interruption masking is necessary for some effects in word perception because the mask must interrupt ongoing processing (e.g., McClelland & Rumelhart, 1981; Richman & Simon, 1989). Additionally, Johnston and McClelland (1980) proposed that the mask differentially interrupts processing for different types of stimuli, such as letters and words.

Alternatively, masking may affect processing by integrating with the stimulus, thus forming a montage (e.g., Eriksen & Collins, 1967, 1968). The integration of the stimulus and the mask would add contours to the target, thus increasing lateral masking (Johnston & McClelland, 1973). The mask may add features to the stimulus, creating feature-specific interference between features of the stimulus and the mask, so that the exact character of the mask and stimulus may be critical for some perceptual effects (Eriksen, 1980). Finally, the integration of the mask and the stimulus may also camouflage the letters, making some stimuli difficult to find and/or segregate from the mask. In the typical experiment, it is impossible to isolate these and other factors.

In the present paper, we investigate the word-superiority and word-detection effects, without using a brief exposure, in order to isolate the factors necessary for these effects. In the first half of the paper, we investigate the word-superiority effect, which was first observed by Reicher (1969). Reicher briefly presented to subjects a word (e.g., WIND), a nonword anagram of the word (e.g., IWND), or a single letter by itself (e.g., N). The stimuli were followed by a visual mask. Subjects had to determine which of two alternative target letters was present in the stimulus. With the word stimuli, both alternatives formed a word (e.g., WIND and WILD) so that subjects could not improve their performance by merely guessing a letter that formed a word. Reicher found that subjects were significantly more accurate in letter identification when the stimulus consisted of a word than when it consisted of a nonword or a single letter. Note that the "word-superiority effect" could consist of two potentially separate effects: an advantage of words over nonwords and an advantage of words over single letters.

We then turned our attention to the word-detection effect (Doyle & Leach, 1988; Merikle & Reingold, 1990). In these experiments, subjects were briefly presented with a word, a nonword, or a blank field. They had to decide whether the field contained a letter string or was blank. These experiments have always used a complex sequence of masks. It has been found that presence-absence judgments are more accurate for words than for nonwords (Doyle & Leach, 1988; Merikle & Reingold, 1990).

Because we will report numerous experiments using these two paradigms, it may be useful to anticipate our major findings:

1. *Neither the word-superiority effect nor the word-detection effect requires a brief exposure.* A tempting conclusion from limited-exposure experiments is that features in words are processed faster than features in other stimuli (Massaro & Cohen, 1991; Massaro & Klitzke, 1979). Furthermore, in reaction-time search experiments, subjects are faster searching for a target letter in a word than in a nonword (e.g., Krueger, 1970). This latter finding also might seem to implicate an advantage in the rate of processing for words. The fact that the word-superiority and word-detection effects can be obtained without a brief exposure, or any pressure to respond quickly, argues against differential rates of processing as an explanation for the word-superiority and word-detection effects.

2. *Neither the advantage of words over nonwords in the word-superiority effect nor the word-detection effect requires a mask.* Our findings argue against theories that give the mask a central role in the advantage of identifying letters in words versus nonwords (e.g., Johnston, 1981b; Johnston & McClelland, 1980; McClelland & Rumelhart, 1981; Richman & Simon, 1989; Rumelhart & McClelland, 1982). Our findings also argue against accounts assigning a central role to a mask in the word-detection effect (Doyle & Leach, 1988; Merikle & Reingold, 1990).

3. *The advantage in identifying letters in words over isolated letters in the word-superiority effect requires a mask.* The mask hurts single-letter performance in the word-superiority effect by adding lateral contours to the single-letter stimulus and by making the single letter difficult to find and segregate from the mask.

4. *The "word-superiority effect" is really two separate effects.* The advantage of words over nonwords and the advantage of words over letters are caused by different stimulus factors that are confounded in the typical experiment. This conclusion is inescapable given that the word-nonword and word-letter differences arise in different circumstances.

5. *The word-detection effect reflects identification processes similar to those in the word-superiority effect.* Doyle and Leach (1988) claimed that detection in the word-detection effect reflects more primitive processes than identification (as in the word-superiority effect). We find that part of the word-superiority effect (i.e., the word-nonword difference) and the word-detection effect are remarkably similar. Though our paper is divided into two parts, we will argue that part of the word-superiority effect and the word-detection effect may be caused by similar mechanisms.

PART 1: WORD-SUPERIORITY EFFECT

We have proposed that the word-superiority effect is really composed of two separate effects: an advantage of identifying letters in words over nonwords, and an advantage of identifying letters in words over letters presented alone. Some of the above stimulus factors lead to an advantage of words over nonwords, and other factors lead to an advantage of words over letters. The typical procedure using a brief exposure and poststimulus mask may have obscured this possibility. Fortunately, it is possible to obtain the word-nonword effect and the word-letter effect without a brief exposure. Prinzmetal (1992) obtained an advantage of words over nonwords with unlimited exposure. He made the stimuli difficult to perceive by having subjects view the stimuli from a distance so that the stimuli subtended a small visual angle. Subjects were allowed to view the stimuli as long as they wanted. The paradigm was identical to Reicher's experiment in that, on the word trials, both alternative target letters formed a word and the nonwords were made of anagrams of the words. Prinzmetal also observed an advantage of words over single letters using unlimited viewing time with stimuli placed in a simultaneously presented mask that consisted of line contours.

However, Prinzmetal (1992) did not compare words, nonwords, and single letters within a single experiment. In the present research, we compared words, nonwords, and single letters with unlimited viewing time under three conditions: small stimuli, reduced contrast, and embedded in a line mask. Thus, we were able to isolate some of the factors involved in the typical experiment with a brief exposure.

A methodological note is in order. First, Reicher (1969) compared words with single letters *by themselves*. Since then, other investigators (e.g., Johnston & McClelland, 1980) have compared words with letters embedded in some other character, such as ampersands (e.g., &&N&) or pound signs (e.g., ##N#). The idea was to try to equate words and single letters in terms of lateral masking. However, there is no analytic way of a priori knowing whether the character chosen to pad the single letters creates the same amount of lateral masking as letters in words (Marchetti & Mewhort, 1986).[1] Not only must lateral masking be controlled, but the target must be equally confusable with the padding character and the other letters in a word. Furthermore, the similarity of the padding characters to each other may be important (e.g., Duncan & Humphreys, 1989; McIntyre, Fox, & Neale, 1970; McLaughlin, Masterson, & Herrmann, 1972). It would be difficult for an experimenter to chose a padding character that would control for these and other factors (see Marchetti & Mewhort, 1986; Prinzmetal, 1992). To illustrate this point, Prinzmetal (1992) found accuracy worse with single letters embedded in pound signs (#) than with nonwords (and words). However, single letters embedded in ampersands (&) were perceived more accurately than were nonwords. In a pilot experiment, subjects were more accurate with single letters embedded in bullets (e.g., ••N•) than they were with words. Thus, the results one obtains critically depend on the particular characters chosen to pad the single letter. For this reason, we chose to compare words and nonwords with single letters by themselves. This is a return to Reicher's original design. The surprising finding would be an advantage of words over single letters, despite the fact that (1) single letters by themselves have less lateral masking than do letters in words and (2) single letters have a higher signal-to-noise ratio than do letters in words.

EXPERIMENT 1

In the typical word-superiority effect experiment, the stimuli are rendered difficult to perceive by presenting them briefly (perhaps followed by a mask). In the present experiment, the stimuli were rendered difficult to perceive by presenting the stimuli in small type and viewing them from a distance. Erdmann and Dodge (1898; cited in Huey, 1908) should be credited with first using small stimuli viewed at a distance. The experiment is akin to trying to read signs from afar, a task in which we often engage. For example, while driving on a high-speed highway, it is often advantageous to be able to read road signs from a distance.

The stimuli were presented in small type, one at a time, in the center of a computer monitor. The two alternative strings, presented in a larger type, appeared on either side of the stimulus (see Figure 1). Subjects had to determine whether the stimulus matched the alternative to the left or to the right of the stimulus. The stimulus remained in view until subjects responded; they were under no pressure to respond quickly. In fact, subjects were encouraged to take as much time as they wanted, and they could pause and rest at any time (even during a trial).[2]

There has been some debate as to whether a word-superiority effect would be obtained if the alternatives were presented before the stimulus (e.g., Bjork & Estes, 1973; Thompson & Massaro, 1973), although Reicher obtained the word-superiority effect when the alternatives were presented both before and after the stimulus or just after the stimulus. To be conservative, in the present experiments, the alternatives remained on with the stimulus. To ensure that subjects were not simply conducting a template match of the alternatives and the stimulus, the alternatives and stimuli were presented in a different type face. Finally, to encourage subjects to process the words as words (rather than as collections of letters), both whole words and nonwords were presented as alternatives rather than just a single letter. To further encourage subjects to process the stimuli as words, we tested the different stimulus types in separate blocks. Note that Prinzmetal (1992) obtained an advantage of words over nonwords with single

Figure 1. Sample stimulus from Experiment 1.

letters presented as alternatives. Prinzmetal also obtained a difference between words and nonwords with mixed block presentation.

Method

Procedure. Each subject participated in a single 1-h session. The stimuli were presented one at a time on the monitor, and subjects responded verbally by reading aloud the alternative that they thought matched the stimulus. The alternatives flanked the stimulus (see Figure 1). For word trials, the alternatives were two words that differed by a single target letter. For nonword trials, the alternatives were two nonwords that differed by a single letter. Finally, for single letter stimuli, the alternatives were single letters. On word trials, the subjects read the whole word; on nonword and single-letter trials, the subjects responded with a single letter. Each subject participated in at least 20 practice trials. During the first practice trial, the subjects sat close to the monitor. The viewing distance was then gradually increased during practice. Data were then collected in six blocks of 80 trials per block.

The three stimulus conditions (words, nonwords, and single letters) were run in separate blocks. The order of the conditions was counterbalanced across subjects so that each of the three conditions was run once in Blocks 1-3 and once in Blocks 4-6. Furthermore, across subjects each condition was run equally often in each block. Each of the 80 stimuli was presented once in each block in a random order. Which alternative appeared on which side of the stimulus was randomly determined in each trial. The subjects were given verbal feedback at the end of each block.

Stimuli. The stimuli consisted of 80 four-letter words, four-letter nonwords, and single letters. The words are listed in Appendix A. Each of 40 pairs of words differed by a single letter. The target letter appeared equally often in each of the four letter positions. The nonwords were made up of anagrams of the words, so that the critical letter remained in the same position as in the word from which it was derived. The single letters consisted of the critical letters from the words, surrounded by spaces, so that they would appear in the same location on the monitor as the critical letters in the words and nonwords.

The displays were presented on a 13-in. Apple monitor controlled by a Macintosh II computer.[3] The stimulus and alternatives appeared as black letters on a white background with a screen resolution of 72 pixels/inch (approximately 28 pixels/centimeter). The brightness of the white background was 122 cd/m^2, and the black of the alternatives was 12 cd/m^2 when measured over a solid area. The stimuli and alternatives were all presented in uppercase letters. The stimuli were written in 9-point Helvetica type and the alternatives in 24-point Zapf Chancery type. The subjects viewed the displays from a distance of approximately 2.10 m. At this distance, the width of the four-letter stimulus display was approximately 0.78 cm (0.21°). The four-letter alternatives were 1.9 cm wide (0.51°). The alternatives were always in exactly the same location on the screen. The stimulus location was centered vertically, but its horizontal location randomly varied ±11 pixels (0.11°) from the screen center. The reason for varying the horizontal location was to make this experiment equivalent to Experiments 4 and 5.

Subjects. The subjects' ages ranged from 18 to 20 years. They were recruited from the introductory psychology course at the University of California, Berkeley, and were given course credit for participating in the experiment. There were 12 subjects in this and each experiment reported in this paper, except where explicitly indicated. All reported normal or corrected-to-normal vision.

Results and Discussion

The results are shown in Figure 2. The subjects were more accurate with words than with nonwords (88.5% vs. 84.6%). However, they were most accurate with single letters (96.7%). The difference between words, nonwords, and single letters was reliable both with subjects as the random variable [$F(2,22) = 39.34, p < .01$] and with items as the random variable [$F(2,228) = 39.04, p < .01$]. A post hoc comparison with the Newman-Keuls test revealed that all types of stimuli significantly differed from each other at the $p < .05$ level, with both subjects and items as the random variable. Hence, we obtained an advantage of words over nonwords, replicating Prinzmetal (1992). However, we did not find an advantage of words over single letters.

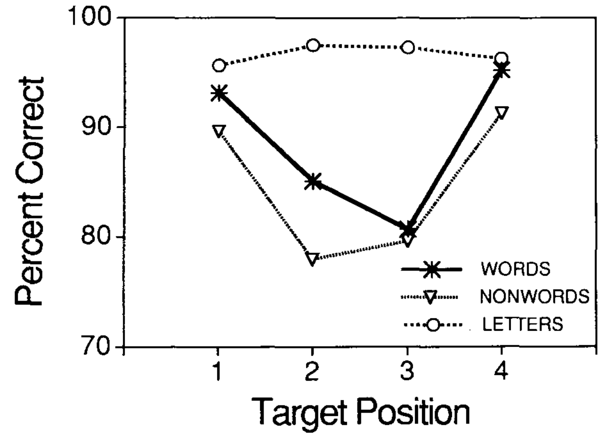

Figure 2. The percent correct from Experiment 1 as a function of stimulus type and target position.

Performance significantly varied as a function of the position of the letter in the string [$F(3,33) = 28.97$ and $F(3,228) = 13.65$, for subjects and items as the random variables, respectively, both $ps < .01$]. The interaction of type of string and position was also reliable both with subjects as the random variable [$F(6,66) = 9.04, p < .01$] and with items as the random variable [$F(6,228) = 5.23, p < .01$]. For words and nonwords, performance was apparently best with targets in the first and the last position (see Figure 2). These letter positions were flanked only on a single side and therefore had less lateral masking than target positions 2 and 3. For single letters, the target was always surrounded by space, and so there was no position effect.

EXPERIMENT 2

The results of Experiment 1 demonstrate that one can obtain the word-nonword effect (but not an advantage of words over letters) with small stimuli. In Experiment 2, we made the stimuli difficult to perceive by reducing contrast. If Experiment 1 was reminiscent of reading signs from a distance, low contrast is similar to reading signs in the fog.

One of the consequences of a brief presentation is to reduce effective stimulus contrast. With a brief presentation, however, not only is contrast reduced but processing time and a host of other factors are also affected. With unlimited viewing time, the effect of contrast can be isolated. Furthermore, a great deal of work in visual science uses contrast sensitivity as a dependent variable (DeValois & DeValois, 1990). If low contrast leads to a word-superiority effect, it may help bridge the gap between experiments in visual science and cognition.

Method

The method was identical to that of Experiment 1, with the following exceptions. The stimulus items were larger: They were drawn in Helvetica 18-point type and the four-letter stimuli subtended a visual angle of approximately 0.47° in width. The alternatives were the same size and brightness as those in Experiment 1. The background of the monitor was white (brightest white generated by the computer). During practice, the stimulus letters were first presented in black and were gradually brightened until the subjects were performing approximately between 70% and 80% correct. After one block of each type of stimulus (words, nonwords, and letters), the brightness of the stimulus was adjusted if necessary with the goal of maintaining 70% to 80% accuracy. The brightness of the white background was 122 cd/m^2, and the black of the alternatives was 12 cd/m^2 when measured over a solid area. The gray used for the stimulus letters averaged 109 cd/m^2 and ranged from 113 to 98 cd/m^2 when measured over a solid area. Measurements were made with a Minolta Chroma meter (Model CS 100). Unlike in Experiment 1, in this and all subsequent experiments the subjects indicated their responses by pressing one of two keys.

Results and Discussion

The results were similar to those in Experiment 1 (see Figure 3). The subjects were more accurate with words than with nonwords (85.4% vs. 81.4%). However, the subjects were most accurate with single letters (89.7%). The three conditions were significantly different both with subjects as the random factor [$F(2,22) = 9.43, p < .01$] and with items as the random factor [$F(2,228) = 18.52, p < .01$]. A post hoc comparison with the Newman-Keuls test revealed that all stimuli significantly differed from each other at the $p < .05$ level, with both subjects and items as the random variable. Hence, as in Experiment 1, we observed the word-nonword effect, but not an advantage of words over single letters. The subjects were better with single letters than they were with words.

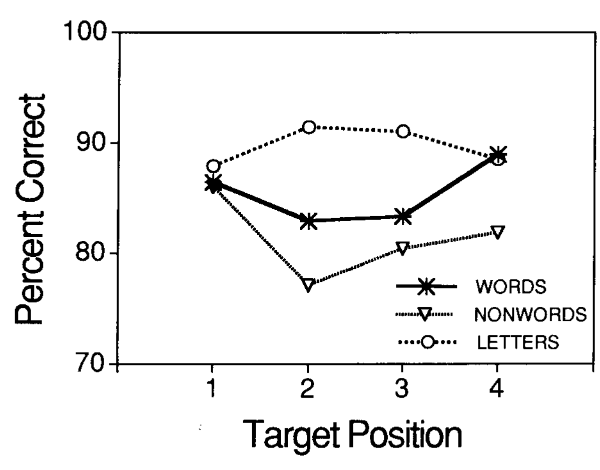

Figure 3. The percent correct from Experiment 2 as a function of stimulus type and target position.

There was a significant interaction of target position and stimulus type that was reliable both with subjects and with items as the random variable [$F(6,66) = 3.76$ and $F(6,228) = 11.07$, respectively, both $ps < .05$]. The pattern of results was similar to that in Experiment 1. For the words and nonwords, the subjects were apparently more accurate for targets that were flanked on only one side.

EXPERIMENT 3

The results of Experiments 1 and 2 demonstrated that one can obtain a word-nonword effect with an unlimited viewing time and without a pattern mask. However, we did not obtain an advantage of words over single letters. With a brief exposure, Johnston and McClelland (1973) found an advantage of words over single letters when the stimulus was followed by a pattern mask, but performance was better with single letters without a mask (also see Juola, Leavitt, & Choe, 1974; Massaro & Klitzke, 1979; Taylor & Chabot, 1978). In the displays without a mask, Johnston and McClelland presented the stimuli at reduced contrast. Hence, their results are consistent with our findings with respect to reduced contrast. Johnston and McClelland (1973) did not test nonwords, so the effect of reduced contrast and/or a pattern mask on the word-nonword difference could not be determined.

Johnston and McClelland (1980) attributed the effect of the pattern mask to interruption masking: The mask sets up "a wave of activation" (p. 507) that interferes with individual letter processing, but does not directly affect the word level of processing (Johnston & McClelland, 1980; also see Johnston, 1981b). With a brief exposure, it is not possible to determine whether the effect of the mask is to interrupt processing (e.g., Turvey, 1973) or if a mask affects performance by integrating with the stimulus (e.g., Eriksen & Collins, 1967, 1968). Prinzmetal (1992), however, demonstrated that it is not necessary to postulate interruption masking to explain the advantage of words over single letters. Prinzmetal presented words and letters for an unlimited exposure time embedded within a simultaneously presented pattern mask. There was no sudden onset to set up a wave of activation that would interrupt ongoing letter processing. Nevertheless, subjects were significantly more accurate with words than with single letters. Integration masking by itself can lead to an advantage of words over letters.

Integration masking might affect the word-letter difference in at least two ways. First, the combination of the mask and single-letter target could add lateral contours to the single letter, making the degree of lateral masking between words and single letters more equal. Second, the mask could make performance on single letters difficult by making it hard to perceptually segregate the letter features from the mask.

Prinzmetal did not test nonwords with the simultaneously presented pattern mask. The present experiment compared words, nonwords, and single letters with a

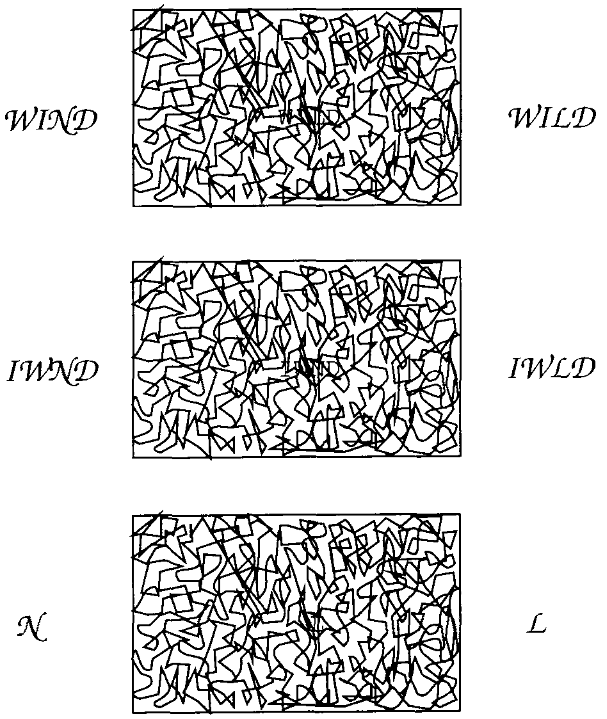

Figure 4. Sample stimuli from Experiment 3.

simultaneously presented pattern mask that was similar to the mask used by Johnston and McClelland (1973; see our Figure 4). If the viewing conditions in Experiment 1 are similar to reading signs from a distance and those in Experiment 2 are similar to reading in the fog, the viewing conditions in Experiment 3 can be likened to reading signs through a cracked windshield. If we obtained both word-nonword and word-letter effects, it would indicate that the word-nonword effect arises in a variety of situations, but the word-letter effect may be restricted to integration masking.

Method

Experiment 3 was identical to the previous experiments except for the following. The stimuli were presented embedded in a simultaneously presented mask (see Figure 4). The stimulus strings were written in Courier 18-point type, and the four-letter strings subtended a horizontal visual angle of 0.54°. The stimuli and mask were presented in high contrast, as in Experiment 1. For the experiments with a simultaneous presented mask, we switched to Courier type because it is the font used by Johnston and McClelland (1973). Furthermore, Courier type does not use proportional spacing. Hence, all characters, including spaces, occupy the same width. Thus, by padding the single letters with the appropriate spaces, single letters would fall on exactly the same location on the mask as the target letters in words and nonwords.

The masks were drawn to be similar to the mask used by Johnston and McClelland (1973). There were four masks that were created by rotating and reflecting the mask shown in Figure 4. As in the previous experiments, the stimulus location was centered vertically, but its horizontal location randomly varied ±11 pixels, or one character in Courier type (0.11°), from the screen center. The reason for perturbating the stimulus was to ensure that the target letter in a particular position would not always fall on a mask contour, artifactually lowering performance for that position (see Prinzmetal, 1992).

Results and Discussion

For the first time, we obtained both an advantage of words over nonwords and an advantage of words over single letters. The mean percent correct for words, nonwords, and letters were 76.72%, 72.97%, and 70.83%, respectively (see Figure 5). Overall, these means were significantly different with subjects as the random factor [$F(2,22) = 5.10, p < .05$] and with items as the random factor [$F(2,228) = 3.74, p < .05$]. The difference between words and nonwords was reliable when considered over subjects [$t(11) = 2.56, p < .05$, two-tailed]. The difference between words and nonwords just missed significance with items as the random variable [$t(158) = 1.86, p = .065$, two-tailed]. The difference between words and single letters was reliable when considered over subjects [$t(11) = 3.58, p < .01$, two-tailed] and over items [$t(158) = 2.77, p < .01$, two-tailed].

Unlike the previous experiments, there was no effect of target position, and no interaction between target position and condition (see Figure 5). The F ratios for the effect of position and the interaction of position and condition over both subjects and items were all less than 1.0. If the previous effects of target position with words and nonwords reflect lateral masking, then the simultaneously presented mask adds sufficient contours to the end letters to equate lateral masking. By the same token, the mask may be adding contours to single letters, equating them with words as far as lateral masking is concerned. We do not believe that this is the only effect of the mask, however.

Nearly every observer of the stimuli in Experiment 3 was struck by the idea that single letters are more difficult to locate in the mask than are words or nonwords. The phenomenology is very convincing. In Experiment 4, we directly tested the hypothesis that the advantage of

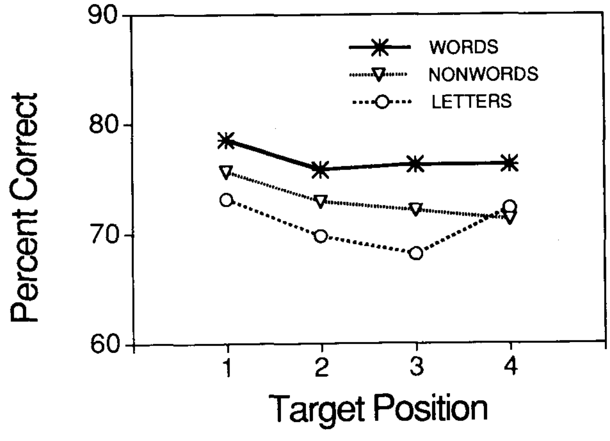

Figure 5. The percent correct from Experiment 3 as a function of stimulus type and target position.

words over single letters was due to a difficulty in finding the target and segregating it from the mask.

However, before proceeding to Experiment 4, we wanted to ensure that we had not artificially made the single-letter targets more difficult to find than they would be ordinarily. In Experiments 1-4, the location of the stimulus string was perturbated ±11 pixels (one character) in a horizontal direction. The reason for moving the stimulus was to ensure that letters in a particular position would not always fall on a contour in the mask (see Prinzmetal, 1992). To determine whether perturbating the stimulus location caused any particular difficulty, we ran an additional 15 subjects in an experiment identical to Experiment 3, except that the stimulus strings were always in the same location. The pattern of results remained unchanged. The accuracy for words, nonwords, and letters was 80.6%, 77.2%, and 74.4%, respectively. These were significantly different at the $p < .05$ level, with both words and items as the random variable. In this replication, there was still some location uncertainty with the single-letter stimuli. As in all of the experiments, the single-letter targets were surrounded by spaces so that they would occupy the same display position as the targets in words and nonwords. We expect that if there was no uncertainty about the single-letter location, the advantage of words over letters would disappear. This hypothesis was tested in Experiment 4.

EXPERIMENT 4

If the advantage of words over letters in Experiment 3 was caused by the relative difficulty of finding a single letter in the display (compared with a larger word or nonword), then the word advantage should be reversed by cuing the target location. In Experiment 4, we cued the target location by placing a red line just above and below the target letter. The lines were 2 pixels high and 5 pixels wide and were located 5 pixels above and 5 pixels below the target letter. In all other aspects, Experiment 4 was identical to Experiment 3.

Results and Discussion

Accuracy did not significantly differ for the three stimulus conditions (see Figure 6). The mean percent correct for words, nonwords, and single letters was 77.0%, 74.9%, and 77.7%, respectively. The differences did not approach significance with either subjects or items as the random variable [$F(2,22) = 2.33$ and $F(2,228) = .99$, respectively].

The effect of target position was significant with both subjects and items as the random variables [$F(3,33) = 12.87$ and $F(3,228) = 4.09$, respectively, both $ps < .01$]. The subjects were most accurate with targets in the first position. There were no other significant effects or interactions.

In Experiment 3, performance with words was better than with single letters, but when we cued the target location, the word advantage disappeared. We statistically compared the results from Experiments 3 and 4 in a combined analysis that treated experiment (i.e., target position cued vs. not cued) as a between-subject factor. There was a significant experiment × stimulus condition interaction with subjects and items as the random variables [$F(2,44) = 4.42$ and $F(2,228) = 6.16$, both $ps < .05$].

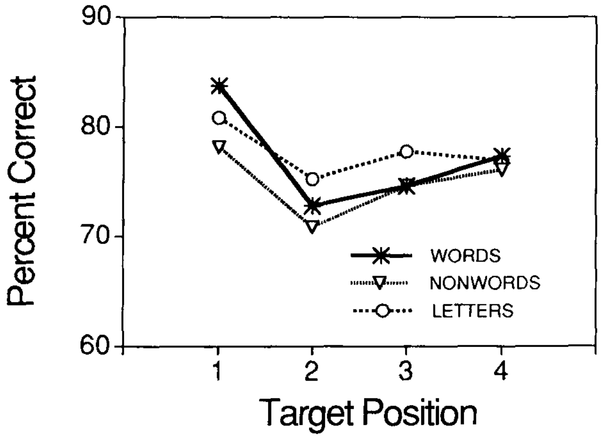

Figure 6. The percent correct from Experiment 4 as a function of stimulus type and target position.

We obtained an advantage of words over letters only when we used a pattern mask (Experiment 3). However, when we cued the location of the target letter, the advantage of words over single letters disappeared. This is consistent with the hypothesis that a pattern mask makes the target letter difficult to locate and perceptually segregate from the mask. Integration masking may also affect the word-letter difference because the mask contributes some degree of lateral masking to single letters, making the total amount of lateral masking for words, nonwords, and single letters more nearly equal. We believe that the mask helps equate the degree of lateral masking in words (and nonwords) with that of single letters. If locating the target was the sole cause of the single-letter disadvantage (a.k.a. word-letter effect), then when we cued the target location, single letters should have been easier to identify than words or nonwords, as they were in Experiments 1 and 2.

DISCUSSION OF EXPERIMENTS 1-4

The results of Experiments 1-4 are summarized in Table 1. The word-superiority effect, with unlimited viewing, is clearly composed of two separate effects that arise under different circumstances. The word-nonword effect can be observed with stimuli that subtend a small visual angle (such as reading a sign from a distance), with reduced contrast (such as reading a sign in the fog), or with a simultaneously presented pattern mask (such as reading a sign through a cracked windshield). The advantage of words over single letters, on the other hand, seems to occur only with a simultaneously presented patterned mask and is caused by a difficulty in locating a single letter. Locating a little object, such as a single letter, hidden in a mask is more difficult than locating a larger object, such

Table 1
Results of Experiments 1-4

Experiment	Stimulus Condition	Results
1	Small Letters	Letters > Words > Nonwords
2	Reduced Contrast	Letters > Words > Nonwords
3	Simultaneous Mask	Words > Nonwords Words > Letters
4	Mask and Position Cue	Letters = Words = Nonwords

as a word. With a simultaneously presented pattern mask, cuing the target location destroys the advantage of words over single letters. Thus, we have a dissociation between the word-nonword and word-letter effect. In the typical experiment with a brief exposure and poststimulus mask, factors that lead to the word-nonword effect (e.g., reduced contrast) and the word-letter effect (e.g., hiding the target) are confounded.

There is a serious objection that can be raised to our experiments. It may be that our word-superiority effect without a brief exposure is not the same as the word-superiority effect with a brief exposure. Our conclusions might apply to the word-superiority effect with unlimited viewing, but not with a brief exposure. We think not. The word-superiority effect literature is completely in accord with our present results. First, a word-nonword difference has been obtained with a brief exposure, but without a mask (e.g., Herrmann & McLaughlin, 1973; Juola et al., 1974; Krueger, 1975; Marchetti & Mewhort, 1986; Massaro & Klitzke, 1979; Solman, May, & Schwartz, 1981; Williams & Gaffney, 1985). Furthermore, without a mask, Krueger and his colleagues have found search for a target letter to be faster with words than with nonwords (Krueger, 1970; Krueger, Keen, & Rublevich, 1974; Krueger & Shapiro, 1979). Second, to our knowledge, a word-letter effect (single letters by themselves) has *never* been obtained without a pattern mask (e.g., see Johnston & McClelland, 1980; Juola et al., 1974; Massaro & Klitzke, 1979; Taylor & Chabot, 1978). Finally, as in Experiment 4, a position cue eliminates both the word-letter effect (Johnston, 1981a) and the word-nonword effect (Paap & Newsome, 1980) provided that the cue provides precise location information (cf. Johnston & McClelland, 1980). Thus far, our results without a brief exposure parallel previous research.

Several investigators have used a mask that consisted of a single character at each letter position (e.g., Johnston & McClelland, 1980; Massaro & Klitzke, 1979). It might be suggested that such a mask would assist subjects in finding single-letter targets by indicating discrete target positions. Indeed, such a mask might help subjects locate a single-letter target. However, a brief exposure creates another problem that makes finding single-letter targets difficult. There is a plethora of evidence demonstrating that briefly presented stimuli are sometimes perceived in incorrect locations (e.g., Klein & Levi, 1987; Levi & Klein, 1989). For example, Estes (1975, Experiment 2), using discrete dollar signs as pre- and poststimulus masks (i.e., $ $ $ $), found that the main difference between words and nonwords was a large number of transposition errors in the nonwords. Subjects perceived the letters in nonwords nearly as well as in words, but in the wrong positions. Such mislocation errors have been observed in various tasks by many investigators (e.g., Allport, 1977; Chastain, 1986; Mozer, 1983; Treisman & Souther, 1986; Wolford & Shum, 1980). Estes (1975) pointed out that the perceptual mislocation of a letter might seriously affect single-letter performance. Assuming that there is integration masking, if the single-letter stimulus was in position *i* but the subject believed that it was in position *j*, the subject would incorrectly interpret mask features as the target letter.

We have attributed part of the word-letter advantage to a difficulty in locating the target. Consistent with this idea is a recent finding by Jordon and Bruijn (1993). They discovered that when a single-letter mask covered only the area of the single letter, the advantage for words disappeared. This condition is similar to our cue in Experiment 4 in that subjects do not have any uncertainty as to the target location. However, there is more to finding a target than knowing where it is on the monitor screen. We have been impressed by the following phenomenon. During the early stages of practice in experiments using the mask (e.g., Experiment 3), with the subject sitting close to the screen, we often pointed to a single target letter. Subjects occasionally still had difficulty locating and perceiving the single letter. In order to perceive the target, subjects must be able to locate the target and also to segregate it (i.e., the "figure") from the mask (i.e., the "ground"). The location cue that we used in Experiment 4 was quite explicit and probably helped subjects know where to look and to perceptually segregate the figure from the ground. However, the problem of segregating the single letter from a mask may have limited performance in an experiment conducted by Massaro and Klitzke (1979). Their single-letter stimuli were followed by a single pseudo-letter character. The mask clearly indicated to the subject where to look, but the subject still had to segregate the target and mask features.

Our results have interesting implications for theories of the word-superiority effect—or we should say, the word-letter and word-nonword effects. Several theories have been implemented in ways that seem misguided. For example, the theories of McClelland and Rumelhart (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982) and Richman and Simon (1989) propose that a poststimulus mask is necessary to interrupt or terminate ongoing letter-feature processing. The time between the onset of the target and the onset of the mask is critical in the implementation of these theories. Curiously, although a mask is important in these theories, both theories are used to model data from word-nonword experiments, not word-letter experiments. Although we believe that we have shed some light on the causes of the advantage of words over single letters, the word-nonword effect remains an important challenge. Instead of implementing particular models, it might be more useful to consider the kinds of information that observers use when they identify letters in words and nonwords. The nontarget letters are adding information to help determine the identity of the target, but the nature of this information and the level of its representation are still in question. Several theories propose that the word-nonword effect is due to information from specific lexical entities (e.g., McClelland & Rumelhart, 1981; Paap, Newsome, McDonald, & Schvaneveldt, 1982). Others have proposed that nonlexical orthographic information, perhaps in the form of legal letter sequences, causes the word-nonword effect (e.g., Richman & Simon, 1989). In terms of the nature of the representation, letters may be represented as abstract letter-identity code (e.g., Adams, 1979; Besner & Johnston, 1989; McClelland, 1976; Paap, Newsome, & Noel, 1984) or in terms of the graphemic code that retains important physical characteristics (e.g., Mewhort & Johns, 1988). Finally, none of the sources of information or form of representation are exclusive, and several may be operating (Prinzmetal, Hoffman, & Vest, 1991). If there is more than one source of information and/or representation, it then becomes important to determine how these factors interact. (See, e.g., Massaro & Cohen, 1991, for a discussion of independent and interactive interactions in perception.) We hope that future research, without a tachistoscopic exposure, may provide a better look into these issues.

PART 2: WORD-DETECTION EFFECT

In the word-detection effect paradigm, subjects must decide whether a briefly presented stimulus field contains a string of letters or is blank. Detection accuracy is greater if the letter string forms a word than if it forms a nonword (Doyle & Leach, 1988; Merikle & Reingold, 1990). The mystery is that subjects must detect a stimulus before they identify it. Yet the identity of the stimulus (as a word or nonword) determines the ease with which it is detected.

It has been proposed that a brief exposure and a certain type of poststimulus mask is necessary for the word-detection effect (Doyle & Leach, 1988; Merikle & Reingold, 1990). Hence, the effect would seem to be a poor candidate for an experiment with unlimited viewing. Furthermore, detection has been thought to involve more primitive processes than letter identification. If this characterization is correct, the word-superiority and word-detection effects must have different origins (Doyle & Leach, 1988). We will demonstrate that the word-detection effect, like the word-superiority effect, can be obtained without a brief exposure and that both effects involve similar processes.

The two studies that have found the word-detection effect have both used a poststimulus mask, and both studies were concerned with unconscious perception. Doyle and Leach (1988) briefly presented a word or nonword, followed by a rapid sequence of four visual masks. The visual masks consisted of a string of pseudo-letters: shapes made to be visually similar to letters. Merikle and Reingold (1990) presented masks, consisting of real letters, before and after the stimulus. The masks were presented to the right eye, and the stimulus was presented to the left eye. The reason for these elaborate masking procedures was to create "central masking" (Turvey, 1973), which is presumably necessary for unconscious perception. Central masking can be dichoptic in that the mask may be present to one eye and the stimulus to the other. Central masking usually involves a pattern rather than a simple luminance change, such as a bright flash of light.

The idea that masking is important for unconscious perception comes from the work of Marcel (1983a, 1983b). For example, Marcel (1983a, Experiment 4) demonstrated "subliminal" priming in a lexical decision task. Marcel's experiments had two parts. In one part, subjects simply had to detect a masked "prime" word. Subjects were approximately 60% correct detecting the prime (50% was chance). The other part of the experiment was a lexical decision task in which the prime word and mask were followed by a word or nonword. Even though detection was near chance, subjects showed semantic priming when the prime was followed by a central mask but not when followed by a peripheral mask. The central mask consisted of line contours presented to the dominant eye, whereas the prime was presented to the nondominant eye. The peripheral mask consisted of a bright flash of light and was presented to the same eye as the prime. According to Marcel (1983b), a central mask erases the conscious record of the stimulus, but unconscious processing is largely unaffected. Thus, the mask causes a kind of amnesia for conscious experience. In the present research, we are not concerned with unconscious perception per se, though our results will suggest an alternative explanation of the role of a mask in subliminal perception experiments. We are concerned with the role of the mask in the word-detection effect, however.

In the present experiments, subjects had to decide on each trial which of two boxes contained a string of letters (see Figure 7). Subjects were not required to identify the stimulus as a word or nonword. Our experiments differed from previous research in that we did not use a brief exposure. In Experiment 5, we attempted to find a word-detection effect without a mask. Experiment 6 compared word and nonword detection with a simultaneously presented mask. Finally, in Experiment 7, we show that a mask may not be critical for the word-detection effect.

Because the word-detection experiment allows for greater freedom in the selection of stimuli than the word-superiority experiment, we were able to explore an addi-

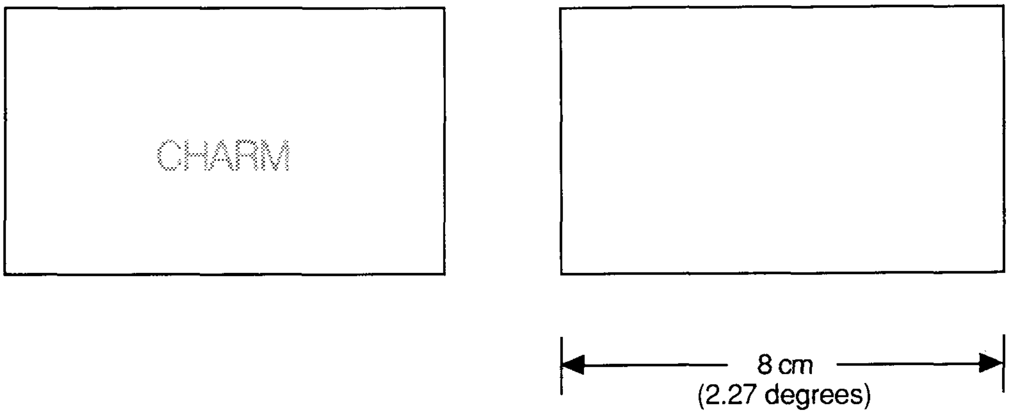

Figure 7. Sample stimulus from Experiment 5.

tional issue—that of the affective value of the stimulus in perception. McGinnes (1949) first reported that the identification threshold for taboo words was higher than for neutral words. This early work on "perceptual defense" was rightly criticized on methodological grounds (e.g., Eriksen, 1963). More recently, using research designs that address the methodological problems, investigators have found an effect of the emotional value of the stimulus on *identification* (e.g., Bootzin & Natsoulas, 1965; Kitayama, 1990, 1991; Natsoulas, 1965). It has also been found that "perceptual defense" is a misnomer. Identification of words with either positive or negative affect is worse than words with neutral affect (Broadbent & Gregory, 1967; Kitayama, 1990, 1991).[4] We wanted to determine if we could obtain a similar effect in detection. Thus, in our experiments, half of the stimuli were neutral in affect and half were positive. The nonwords were anagrams of the words.

EXPERIMENT 5

In previous word-detection experiments, subjects had to decide on each trial whether the stimulus contained a letter string. A potential problem with this paradigm is that subjects may adopt a different willingness to respond "present" for words versus nonwords. To address this criterion problem, we used the following method. On each trial, the subjects were presented with two rectangles (see Figure 7). One rectangle contained a letter string; the other was blank. The task was to decide which rectangle contained a letter string. The stimuli were made difficult to perceive by reducing the contrast of the letter string.

Method

Procedure. Each subject participated in a single 50-min session. The stimuli were presented one at a time on the monitor, and the subjects responded by pressing one of two keys to indicate whether the letter string was in the left or the right rectangle. The stimulus remained on the screen until the subjects responded. The subjects were encouraged to take as much time as they wanted. Each subject participated in at least 40 practice trials. During practice, the letter string was initially black on a white background. The background of the entire monitor was white (brightest white generated by the computer). During practice, the stimulus letters were first presented in black and were gradually lightened until the subjects were performing between 70% and 80% correct. Data were then collected in six blocks of 72 trials per block. After each trial, the subjects were given auditory feedback: A high tone indicated a correct response, and a low tone indicated an incorrect response. Within each block, half of the stimuli were words, and half were anagrams of these words. The order within a block and the side on which the letter string appeared were randomly determined. The brightness of the letter string was adjusted between blocks in an attempt to maintain 70% to 80% accuracy.

Stimuli. The stimuli consisted of 36 words and 36 nonwords. The words were four to six letters in length, and they were taken from Kitayama (1990). Half of the words were neutral in affect and half were positive in affect (see Appendix B). Kitayama had subjects rate these words on a 5-point scale (1 = *unpleasant*, 5 = *pleasant*). The positive words were rated significantly more affectively positive ($M = 4.3$) than the neutral words ($M = 3.1$). The positive and neutral words were matched for length and frequency. All of the words had a frequency of between 8 to 65 appearances per million according to Kučera and Francis's (1967) norm. The nonwords were anagrams of the words. For example, the nonwords HRAMC and YCUKL were anagrams of the positive words CHARM and LUCKY. Similarly, the neutral words TRACK and CHAIR yielded the nonwords KTCRA and HRICA.

The stimuli were presented in the center of the one of two black rectangles. The letter strings were written in Geneva 20-point type and viewed from a distance of approximately 2.0 m. The dimensions of the stimulus items were approximately 0.17° high and from 0.54° to 0.80° wide. Note that the items varied in length. Figure 7 is drawn to scale. The brightness of the white background was 122 cd/m^2 when measured as in Experiment 2. The gray used for the stimulus letters averaged 110 cd/m^2 and ranged from 106 to 113 cd/m^2.

Results and Discussion

Analysis of variance was performed on the percent correct with word versus nonword and neutral affect versus positive affect as factors. The results are easy to summarize. There were no significant effects or interactions with either words or subjects as random factors. The percent correct for positive and negative words was 83.0% and 82.1%, respectively. For positive and negative nonwords, the percent correct was 84.5% and 82.4%, respectively. The effect of word versus nonword was not reliable with either subjects or items as the random factor (both Fs < 1.0). The slightly *better* performance for positive stimuli was not reliable with either subjects or items as the random factor [$F(1,11) = 2.28$ and $F(1,68) = 2.19$, both $ps > .10$]. The interaction between these two factors was $F < 1.0$ in both analyses.

We were unsure if it was possible to obtain an effect of the emotional content of the stimuli in a detection task because no one, to our knowledge, has obtained such an effect with a brief presentation. We were very disappointed in not obtaining a word-detection effect, however. Perhaps a mask is necessary to obtain a word-detection effect. If so, the question arises whether the mask affects processing by interrupting or erasing conscious processes (leaving unconscious processes unaffected) or if integration masking is sufficient. If integration masking is sufficient, then we ought to be able to obtain a word-detection effect by simultaneously presenting the mask with the stimulus. Integration masking would work by removing any obvious cues that subjects could use to determine which rectangle contained the letter string. In Experiment 5, the subjects commented that they did not bother to try to read words or letters. They merely looked for a dark smudge. In Experiment 6, by placing a mask in one rectangle, and a mask and stimulus in the other, we hoped to eliminate any obvious cues to the target location.

EXPERIMENT 6

Doyle and Leach (1988) obtained their word-detection effect by briefly presenting a word, nonword, or blank, followed by a rapid sequence of four visual masks. The masks were "pseudoletters" that were made to resemble letters. We simulated the integration of the four rapidly presented masks by overprinting four strings of our own pseudoletters drawn randomly from an alphabet of 26 pseudoletters. Since with integration masking each mask would begin to fade as soon as it was presented, we drew each of the four masks in a different brightness (see Figure 8). Finally, in one of the rectangles, the stimulus string was drawn on the masks. The two montages, consisting of the four masks and masks plus stimulus, were presented simultaneously in the two rectangles and remained in view until the subject responded. As in the previous experiment, the task was to indicate which rectangle contained real letters. The contrast level of the stimulus string was set so that the subjects were approximately 70%-80% correct ($M = 89$ cd/m^2, range = 82-94 cd/m^2). The top mask on the target-absent side was presented at the same brightness as the stimulus so that there were no obvious brightness cues to help determine which rectangle contained the stimulus.

Results and Discussion

We did obtain a word-detection effect (see Figure 9). The subjects were significantly more accurate with words than with nonwords (81.9% vs. 76.5%). This difference was reliable both with subjects as the random variable [$F(1,11) = 82.74$, $p < .01$] and with items as the random variable [$F(1,68) = 12.29$, $p < .01$].

The subjects were also significantly more accurate with the affectively neutral stimuli than with the positive stimuli (80.9% vs. 77.6%). This difference was reliable with both

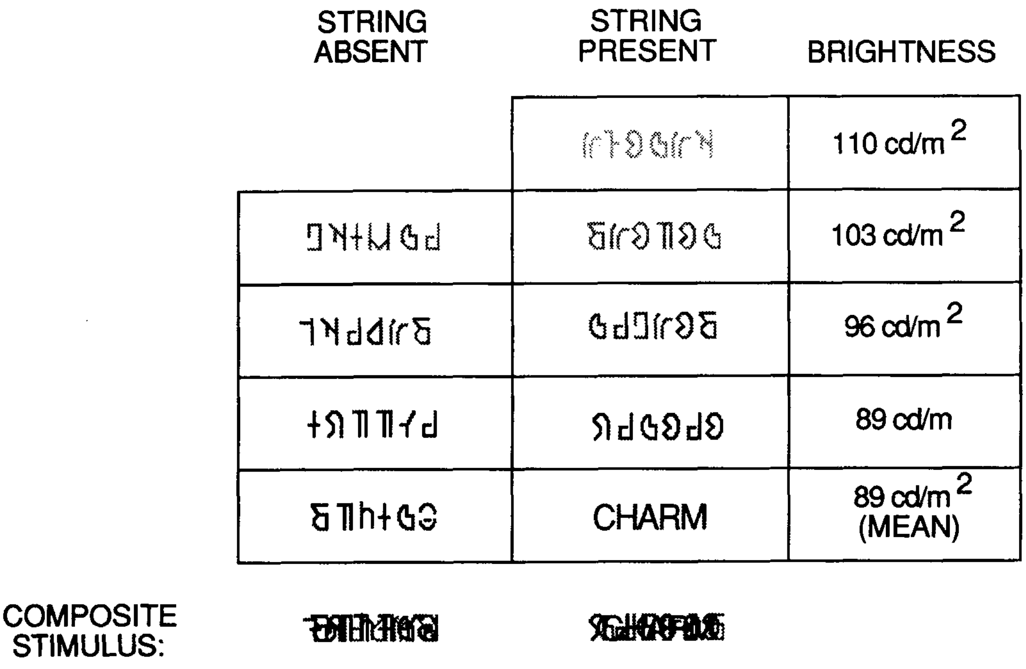

Figure 8. A schematic description of the stimuli in Experiment 6. Each successive pseudo-letter mask was darker than the preceding one. The stimuli were the sum of four strings.

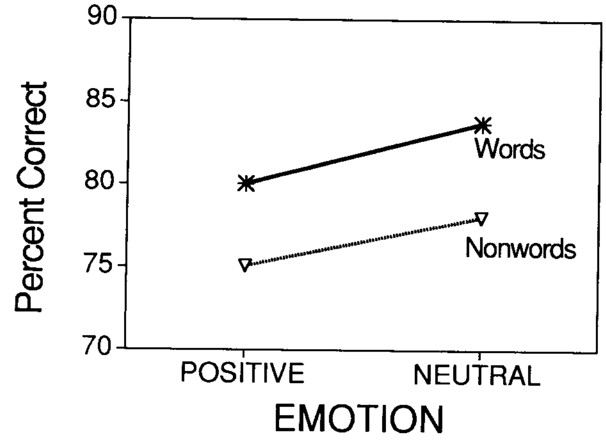

Figure 9. The percent correct from Experiment 6 as a function of stimulus type (word vs. nonword) and affect.

subjects and items as the random variable [$F(1,11) = 8.25$ and $F(1,68) = 4.77$, respectively, both $ps < .05$]. However, these results cannot be taken as support for an effect of the emotional value of the stimuli on detection because the main effect of emotion includes both words and nonwords. The most straightforward effect of emotion would affect only words, not nonwords. (The positive and negative nonwords were anagrams of the positive and negative words.) The interaction between the stimulus type (word vs. nonword) and emotion (positive vs. neutral) did not approach significance with either subjects or items as the random variable (both $Fs < 1.0$). The effect of emotion in this experiment might well be that the letters in the neutral stimuli were easier to detect than the letters in the positive stimuli.

The results of Experiment 6 demonstrate that a word-detection effect can be obtained with a simultaneously presented mask without a brief exposure. It is not necessary to postulate interruption masking to account for the word-detection effect, though of course we cannot rule out the possibility that interruption masking may play some role with a brief exposure.

We believe that our explanation of the role of a mask is simpler than previous accounts. In Experiment 5 (without masks), the subjects could decide which rectangle contained the letter string by simply searching for a luminance decrement (dark smudge). This luminance decrement could be detected at energy levels (i.e., contrast levels) far below what is required to identify words and letters. The contrast levels were probably so low that high-frequency information that is necessary for letter and word processing was below threshold (also see Purcell & Stewart, 1991). Under these circumstances, one should not expect a difference between words and nonwords. The presence of a mask that contains letter features makes it impossible to use a simple feature, such as a dark smudge, to discriminate the presence of a word or a nonword. In this case, the stimulus must be processed for the presence of letters and/or words.

If our account of the role of a mask is correct, it should be possible to obtain a word-detection effect without the elaborate masking procedure used in Experiment 6. It should only be necessary to place a stimulus in the target-absent rectangle that contains letter-string features. This prediction was tested in Experiment 7.

EXPERIMENT 7

Experiment 7 was similar to Experiments 5 and 6 except for the following. On each trial, in one of the two rectangles (randomly chosen) either a word or a nonword was presented at low contrast. In the other rectangle, a string of pseudoletters was presented. The pseudoletter string contained the same number of characters as the stimulus string and was presented at the same contrast. As in the previous experiments, the subjects had to indicate which rectangle contained a real letter string. The brightness of the stimulus strings was adjusted for each subject as before and averaged 100 cd/m^2 (range = 75–108 cd/m^2).

Results

The results are shown in Figure 10. The subjects were more accurate with words than with nonwords (83.2% vs. 77.9%). This word-detection effect was reliable with both subjects and items as the random variable [$F(1,11) = 11.97$ and $F(1,68) = 9.39$, both $ps < .01$].

There is some indication that the emotional value of the words affected performance. This is shown in Figure 10. For words, those with positive emotion were detected less accurately than were those with neutral emotion (81.1% vs. 85.2%). For nonwords, there was little difference between the positive nonwords and neutral nonwords (77.7% and 78.2%). However, the interaction shown in Figure 10 only approached significance with subjects as the random variable [$F(1,11) = 3.76, p = .079$]. With words as the random variable, the interaction was far from

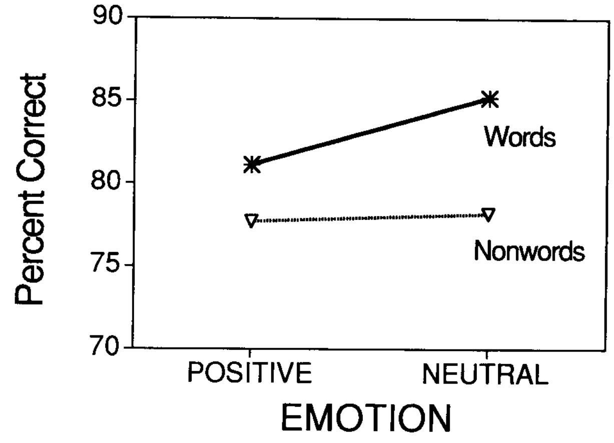

Figure 10. The percent correct from Experiment 7 as a function of stimulus type (word vs. nonword) and affect.

the conventional levels of reliability [$F(1,68) = 1.11$, $p = .30$]. Thus, although the results are in a pattern consistent with an effect of emotion in this paradigm, we cannot reject the null hypothesis. However, at this point it would be equally rash to assume that the null hypothesis is true. It should be pointed out that the design of this experiment was less powerful than many experiments that examine the effect of emotion on word perception. For example, Kitayama (1991) tested between 26 and 52 subjects (compared with our 12) and 66 words (compared with our 36). Thus, a more powerful design may yet uncover an effect of emotion in word detection without tachistoscopic exposure.

DISCUSSION OF EXPERIMENTS 5-7

Our results with the word-detection task with unlimited viewing demonstrate that (1) a mask may play a role in obtaining such an effect, but it is not necessary and (2) the effect does not occur with pure detection (i.e., Experiment 5), but only when subjects must discriminate a real letter string from pseudoletters or a mask. We will first discuss the role of the mask in word-detection experiments and then the nature of the discrimination that is made in the word-detection experiment.

We have proposed a different interpretation of the role of the mask in word-detection experiments. Unlike Doyle and Leach (1988), we do not find it necessary to postulate that a mask has different effects on conscious and unconscious processes. Rather, without a mask, or something like our pseudoletter string foils, subjects may make a presence/absence discrimination on an extraneous feature (e.g., dark smudge) that can be detected with less information than that required for word or letter processing. In Experiment 5, without a mask, it was quite obvious to our subjects and to us that it was irrelevant that the stimuli consisted of letters. The subjects simply looked for a dark smudge. Contrast levels were so low in that experiment that the high-spatial-frequency information that is necessary for letter processing was probably not available. To maintain comparable levels of performance, in Experiments 6 and 7 we used much higher contrast levels than those used in Experiment 5. As a consequence of the high contrast levels, the high-frequency information needed to process words and letters was available in Experiments 6 and 7.

According to our explanation, any mask will not do. The mask must equate the stimuli with and without letters in terms of features that are easier to detect than letters. For example, if our mask was drawn in black but the letter strings were drawn in red, subjects could have easily performed the task by looking for red. If the letters were made up of straight lines and the mask was made up of curvy lines, subjects could have searched for straight lines.

Merikle and Reingold (1990, Experiment 4) used a different masking procedure in their word-detection effect experiment. Pre- and poststimulus masks were presented to one eye, and the stimulus was presented to the other eye. The stimulus was either a letter string (word or nonword) or a blank field. The masks were nonwords. Subjects were more accurate at detecting words than nonwords. Merikle and Reingold then had subjects attempt to identify the stimulus string, but we are only concerned with the detection aspect of their experiment.

Merikle and Reingold's results can be understood by considering the task from the subjects' point of view. It has been found that subjects are not very good at determining the eye in which a stimulus is presented (Blake & Cormack, 1979; Smith, 1945). Hence, for the subject, a trial consists of a series of letter strings. If the subjects recognize that one of these strings is a word, then they know for sure that a target is present. This extra information occurs only for word trials. On nonword trials, the perception of nonwords does not indicate whether a stimulus is present because the masks also consist of nonwords.

We believe that our results suggest a different role of masks in subliminal perception experiments. We do not wish to enter the debate as to whether there are unconscious perceptual processes or whether specific experiments demonstrate the influence of these unconscious processes (a very controversial issue). Rather, we do think that we have a simple explanation of the role of visual masks in subliminal perception experiments. As discussed earlier, Marcel (1983a) found some evidence for subliminal processing with some types of poststimulus masks (i.e., contour masks), but not with others (i.e., an energy mask or a bright flash of light). Note that an energy mask effectively reduces contrast as in Experiment 5 in the present research. To understand Marcel's finding, it is necessary to consider the structure of the typical subliminal perception experiment. Subjects are presented a subliminal stimulus, followed by a mask and then a superliminal stimulus. The experiments have two parts. In one part, the experimenter finds exposure conditions such that subjects are at or near threshold at detecting the presence of the subliminal stimulus. In the other part, the experimenter looks for an effect of the subliminal stimulus on some response to the superliminal stimulus. We suggest that in finding the subliminal exposure conditions, different masks will lead subjects to employ different strategies. Without a pattern mask, subjects might simply look for a dark (or light) blur in an otherwise blank field; this task can be done at exposure durations where there is not enough information to process words or letters. With a contour mask, subjects must decide whether the stimulus plus mask contains letters or words. This latter task is usually much more difficult and requires exposure conditions with sufficient information to process the words. Without this information, there could not be any influence on the superliminal stimulus. If the typical subliminal perception experiment had been conducted with an unlimited viewing, we are fairly sure this simple explanation would have occurred to researchers.

We obtained a detection advantage for words only when subjects had to discriminate a letter string embedded in a pseudoletter mask from a mask alone (Experiment 6) or when subjects had to discriminate a real letter string from a foil of pseudoletters (Experiment 7). Another way to state this is that subjects are better at discriminating real letters from other patterns when the real letters are part of a word than when they are part of a nonword. Given a certain pattern on the monitor, subjects have to decide whether the pattern is a real letter. We are not surprised that high-level cognitive factors (e.g., words vs. nonwords) affect "detectability." The word-superiority effect (i.e., the word-nonword difference) and the word-detection effect are not fundamentally different. Both effects involve identifying stimulus patterns as letters. The only difference is that in the word-superiority effect subjects have to identify a specific letter as such, whereas in the letter-detection task subjects are making a generic decision as to whether a stimulus pattern consists of letters. In the word-superiority effect, the context of a word helps subjects identify a specific letter. In the word-detection effect, a word context helps subjects make this generic classification. The mystery of how detection can show effects of the identity of the stimulus disappears. However, the central question remains as to why context helps letter identification in either the specific or the generic sense. A satisfactory theory of the effect of context in the word-nonword effect may also explain the effect of context in the word-detection effect.

GENERAL DISCUSSION

Our experiments with unlimited viewing have been quite useful in understanding several phenomena in word and letter perception. In regard to the word-superiority effect, we found that the advantage of words over nonwords and the advantage of words over single letters arise under different stimulus conditions that are confounded in the typical experiment with a brief exposure. When we obtained an advantage of words over single letters (Experiment 3), it was immediately apparent that part of the difficulty of identifying single letters in a mask was finding the letters and perceptually isolating them from the mask. This hypothesis was confirmed in Experiment 4. In retrospect, our findings using unlimited viewing are perfectly in accord with previous findings using a brief exposure.

We then turned to the word-detection effect, where unlimited viewing has been equally fruitful. First, although a mask plays a role in the word-detection effect, it is not necessary for the effect. A mask that shares features with the stimulus makes it impossible for subjects to search for an easily detected feature difference between target-present and target-absent stimuli. Second, in conditions that lead to better detection performance for words over nonwords, subjects are discriminating letters from pseudoletters or mask features. Thus, the word-detection effect, like the word-superiority effect, involves letter identification. Finally, our results suggest an alternative explanation for the role of a mask in subliminal perception experiments. In setting the detection threshold in such experiments without a mask, subjects can discriminate stimulus presence from absence by searching for features (such as a dark smudge) that can be detected at energy levels lower than those needed to perceive words and letters. Our experiments without a tachistoscopic exposure could be said to have provided more than a brief glance at several word perception phenomena.

Our results with words and other alphanumeric stimuli are consistent with tachistoscopic experiments that used other types of stimuli. In addition to the word-superiority effect, there is an object-superiority effect (Weisstein & Harris, 1974). In the object-superiority effect, subjects must identify one of a small set of lines in a briefly presented stimulus. Like the word-superiority effect, the object-superiority effect has two parts: (1) subjects are more accurate at identifying a line in a coherent object than in a noncoherent object (Enns & Prinzmetal, 1984; Lanze, Maguire, & Weisstein, 1985), and (2) subjects are more accurate at identifying lines in coherent figures than lines alone (Williams & Weisstein, 1978). The coherent-noncoherent object difference can be obtained in a wide variety of circumstances (e.g., Weisstein & Harris, 1974; Lanze et al., 1985). The object-line difference may be caused by difficulty in locating the target line: McClelland (1978) obtained an object-line difference only when he used a line mask (cf. Weisstein, Williams, & Harris, 1982).

There is also a face-superiority effect. Subjects are more accurate in searching for a facial feature (e.g., a nose) in a normal face than in a scrambled face (Homa et al., 1976; Mermelstein et al., 1979). Interestingly, Davidoff and Donnelly (1990) found that whole-face (or chair) recognition is better than scrambled-face (or chair) recognition with 2-sec exposure durations. As far as we are aware, no one has yet found an advantage for identifying features in faces (vs. those features by themselves). Both Mermelstein et al. and Homa et al. found that performance for single features was better than that for features in faces. Note that in these experiments, there was little uncertainty about the location of the single feature.

Purcell and Stewart have also found an object-detection effect (Purcell & Stewart, 1991) and a face-detection effect (Purcell & Stewart, 1988). Subjects are more accurate in discriminating a stimulus versus a blank field when the stimulus is a coherent object than when it is a noncoherent object. Likewise, detection accuracy is greater for faces than for scrambled faces. Interestingly, both of these effects have only been found with a pattern mask (Purcell & Stewart, 1991; Purcell & Stewart, 1986). Thus, the literature on identification and detection with objects and faces using a brief exposure is consistent with our findings with letter strings using unlimited viewing. We believe that these other effects of context could be obtained without a brief exposure and that the results would not differ from the results that we have obtained with words.

Perception with and without a brief exposure are not necessarily identical. For example, without a brief exposure, subjects have more time to focus attention (and fixate) on an individual letter, provided they know where to look. This fact might make obtaining configurational effects without a brief exposure more difficult than obtaining these effects with a brief exposure. In word perception with a brief exposure, Johnston and McClelland (1974) found that subjects were worse at identifying a letter in a word when they were instructed to attend to the target letter than when they were instructed to attend to the word as a whole. For this reason, in the present experiments, we have used stimuli that subtended rather small visual angles so that it would be difficult for subjects to ignore the nontarget letters. Thus, there may be a difference in the range of visual angles for which one would obtain a word-superiority effect with and without a brief exposure. However, such a finding may not indicate a fundamental difference in processing. With a brief exposure, the word-superiority effect is also affected by the space between letters (Purcell & Stanovich, 1982).

In summary, our experiments with unlimited viewing have shed new light on several issues in word perception. However, we do not champion our methods because they are more "ecologically valid" than traditional experiments with a brief exposure. Whether viewing the world through the fog (i.e., low contrast) or in a lightning storm (i.e., brief exposure) is more ecologically valid probably depends more on climate than on visual science or cognition. Furthermore, our methods are perhaps less important than our findings. Some of our experiments have been performed, or could have been performed, with a brief exposure. There are several advantages to using unlimited exposure, however. Unlimited exposure has allowed us to unconfound several stimulus factors, such as integration and interruption masking. Additionally, ideas that were not obvious with a brief exposure were clearly suggested by the phenomenology of the experiments. It is easier to introspect with unlimited viewing than with a briefly presented stimulus. Introspection led to testable hypotheses that were previously overlooked. For these reasons, it may be useful to try unlimited-viewing techniques with other experiments that have used a brief exposure.

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NOTES

1. As far as we are aware, Marchetti and Mewhort (1986) were the first to seriously address this problem. These investigators tried to empirically equate the perceptibility of letters in words and single letters embedded in ampersands by comparing performance with the stimuli printed in a vertical orientation. The assumption was that vertically orienting words would prevent lexical access and the effects of orthography. However, Prinzmetal et al. (1991) found that some aspects of orthographic structure are processed when words are presented in a vertical orientation even if lexical access is prevented.

2. We did not record reaction times. Our instructions emphasized the self-paced nature of the task. Subjects occasionally took short breaks during a trial, rendering reaction times meaningless. Instructions to respond "fast and accurately" or "respond as soon as you can identify the target" would have changed the nature of the task and defeated part of our goal in this research.

3. The computer programs used to run the experiments reported in this paper can be obtained from the author. They were written in Light-Speed Pascal for Macintosh color computers, and both the source code and compiled versions are available. To receive them, please send a blank 3¼-in. disk and an appropriate self-addressed stamped envelope to the first author.

4. Kitayama (1990, 1991) has shown that "perceptual defense" changes to "perceptual vigilance" if the subject has an accurate expectation of the identity of the stimulus. In the present experiments, subjects did not expect particular stimuli so we were only concerned with worse performance with emotional words.

APPENDIX A
Word Stimuli for Word-Superiority Experiments

1st Position	2nd Position	3rd Position	4th Position
PARK-MARK	FARM-FIRM	STEP-STOP	FILM-FILE
FAST-VAST	BOAT-BEAT	ROLE-ROSE	HOLE-HOLY
WINE-MINE	WORE-WIRE	TEAM-TERM	DEAR-DEAN
NOSE-LOSE	SLOW-SNOW	SHIP-SHOP	MAIL-MAID
LAKE-SAKE	BAND-BOND	JURY-JULY	CAST-CASH
GOLD-SOLD	MILE-MALE	PAGE-PALE	MEAT-MEAL
GATE-FATE	LUCK-LOCK	WIND-WILD	COAT-COAL
DREW-GREW	LOAN-LEAN	SAVE-SALE	PACE-PACK
YARD-CARD	CORE-CURE	WAGE-WAVE	WEAR-WEAK
CORN-HORN	FAIL-FOIL	PICK-PINK	FISH-FIST

APPENDIX B
Word Stimuli for Word-Detection Experiments

Positive Words	Neutral Words
COMEDY	BORDER
WISDOM	MARGIN
TALENT	LOCATE
MATURE	DETECT
LUCKY	STAMP
HUMOR	LABEL
SMILE	TRACK
CHARM	ROUTE
FUNNY	SPARE
AWARD	STONE
TRUST	HABIT
ENJOY	TREND
GLORY	CHAIR
PRIZE	TRACE
PROUD	EXTRA
EAGER	PANEL
JOKE	WIRE
CASH	BONE

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