The perceptual and cognitive distractor-previewing effect

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The time it takes to respond to an odd-colored target (e.g., a red diamond among green diamonds) is reduced when distractor-colored items in an appropriate geometric configuration (e.g., multiple red diamonds) are previewed in a preceding trial. B. A. Goolsby and S. Suzuki (2002) suggested that this phenomenon, the distractor-previewing effect, occurs because target saliency is increased by global adaptation to the previewed distractors. The present study tested and extended this idea with visual search experiments using color, face, motion, and word stimuli. We found that the distractor-previewing effect can be obtained with all of these stimuli. In particular, we found that the distractor-previewing effect was elicited by prior activation of distractors by word labels, suggesting a high-level locus for the effect.

Keywords: distractor-previewing effect, pop-out, visual search, semantic activation, perceptual adaptation

Introduction

We may find that little effort is required to detect the presence of a unique item in a stimulus array (e.g., finding a mature red tomato within a group of green ones). This efficient visual search effect, called "pop-out," occurs when the target is defined by a unique feature (Treisman & Gelade, 1980). The phenomenon of pop-out, supported by reaction times that are unchanged by the presence of different numbers of distractors, implies that the visual system can detect in parallel and over the visual field a unique feature that defines the target.

Such efficient visual search performance has been attributed, mainly, to bottom-up components of visual input. Support for this notion has been obtained from visual search tasks using odd-ball targets. For example, Bravo and Nakayama (1992) argued that if the observers did not have knowledge about the target-defining feature (i.e., a red target among green distractors or a green target among red distractors) before the stimulus onset, the target could be detected only on the basis of the bottom-up perceptual salience of the odd-colored target. Thus, the time needed to visually detect a target should decrease with set size because a larger distractor density provides stronger feature gradient and local feature contrast, and also facilitates grouping of distractors (e.g., in the limit of the highest distractor density, a green spot would be presented in a uniform red background) (Bravo & Nakayama, 1992; Humphreys, Quinlan, & Riddoch, 1989).

In addition to the effects of bottom-up signals, Maljkovic and Nakayama (1994) revealed that the efficiency of visual search could be modulated by a sort of memory related to the relationships between trials. In one of their experiments, they presented three colored (red or green) diamonds, each with a chipped corner (right or left side), and asked observers to indicate the missing corner of an incongruently colored diamond. They found that visual search performance was enhanced by repeating a specific pair of colors, applied to the target and distractors. For example, the reaction times in a trial with a red target and green distractors were less when the red target and green distractors were presented in an immediately preceding trial. Maljkovic and Nakayama (1994) labeled this facilitation as the priming of pop-out. This effect, due to color-based priming, cannot be attributed to response-based priming because the observer responds to the target shape in the color-singleton search, as in Bravo and Nakayama (1992). When the target location is pre-cued in the current trial, this priming effect of the immediately preceding trial is eliminated (Goolsby & Suzuki, 2001a); thus, encoding the preceding display primes the direction of attention to the color-singleton target in the current trial.

Goolsby and Suzuki (2001b) reported that such a priming effect is obtained, regardless of the necessity to encode both target and distractor colors in the immediately preceding trial; that is, encoding only the distractor color is sufficient for priming to take place. They modified the procedure used in Goolsby and Suzuki (2001a) so that a trial with distractors only was inserted among the trials that required the observer to identify the chipped side of the incongruently colored diamond. In those trials with no targets, observers were not required to respond, but passively viewed the display. Their results showed that response times to an odd-colored target were speeded when distractor-colored diamonds were previewed and slowed when target-colored diamonds were previewed, relative to when achromatic diamonds were previewed. For example, in a trial in which the target was red and the distractors were

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green, the reaction time was speeded when the diamonds in the immediately preceding preview trial were all green (the distractor-previewing condition) and slowed when the preview diamonds were all red (the target-previewing condition), compared to when the preview diamonds were all gray. This suggested that previewing produced an adaptation-like color suppression effect such that the salience of the previewed color was reduced in the subsequent color-based stimulus selection (Goolsby & Suzuki, 2001b; Goolsby, Grabowecky, & Suzuki, 2004).

Importantly, Goolsby et al. (2004) provided additional evidence that makes it difficult to explain this effect in terms of low-level, local color adaptation. For example, they showed that the distractor-color previewing effect did not occur when a preview display was a large colored patch, which ought to have produced strong color adaptation. Their additional experiments, in which the preview items were connected with lines to form a triangle or were organized into a face configuration with additional colored items, also eliminated the distractor-color previewing effect. On the basis of these and other findings, Goolsby et al. (2004) suggested that the suppression of the previewed color (underlying the distractor-color previewing effect) is not due entirely to local color adaptation, but also to high-level color suppression that is global-pattern contingent. Specifically, Goolsby et al. results suggested that the geometric configuration of the preview display must be consistent with a typical search context (e.g., the presence of multiple items outside the point of fixation).

Although Goolsby et al. suggested that the distractor-previewing effect is due to suppression of the previewed items induced by perceptual adaptation, current understanding of this effect is limited to targets and distractors defined by color. It is necessary to explore this effect with different stimuli (e.g., faces, motion, and words) to examine the generality of this effect. The characteristics of stimuli that do and do not produce the distractor-previewing effect will provide important clues as to the underlying mechanism(s).

The purpose of this study is to explore the boundary conditions for the distractor-previewing effect and, more specifically, to determine whether the distractor-previewing effect may be obtained with face (Experiment 2), motion (Experiment 3A and 3B), and word stimuli (Experiment 4A and 4B). We first replicated the basic distractor-previewing effect (Goolsby & Suzuki, 2001b) with color (Experiment 1).

Experiment 1: Replication

Observers searched for an incongruently colored diamond (target) among three diamonds and indicated the side (right or left) of the chipped corner of the target. There were two previewing conditions: the distractor-previewing and target-previewing conditions (Figure 1A). In the distractor-previewing condition, a search trial was preceded by a non-search trial in which all diamonds were the same color as the distractor of a current trial. A trial in the target-previewing condition was preceded by a non-search trial with all diamonds the same color as the target in a current search trial. These two conditions were mixed in an experimental block. We predicted that if the distractor-previewing effect is obtained, visual search for an incongruently colored target will be enhanced in the distractor-previewing condition, as compared to the target-previewing condition.

Method

Observers

Ten naive paid observers and the authors (12 participants in total) participated in Experiment 1. The observers' ages ranged from 20 to 32 years. All had normal or corrected-to-normal visual acuity and normal color vision, based on self-report.

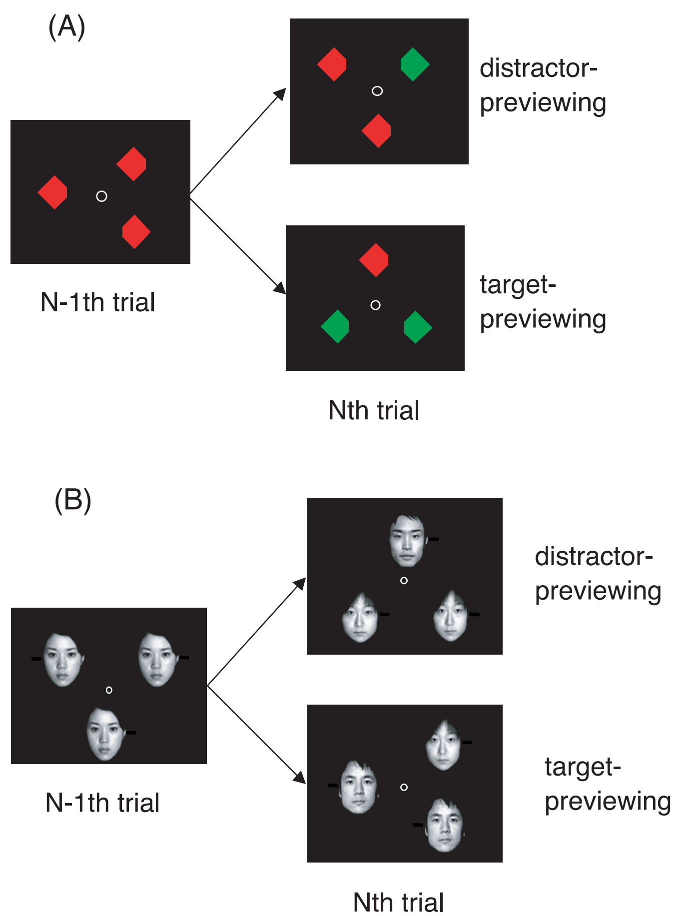

Figure 1. (A). Two preview conditions of color stimuli in Experiment 1: two consecutive trials displaying distractor-previewing and target-previewing conditions. (B). Two preview conditions of case stimuli in Experiment 2: two consecutive trials displaying distractor-previewing and target-previewing conditions..

Apparatus

The stimuli were displayed on a SONY GDM-19PS monitor controlled by a PC/AT compatible computer equipped with a Cambridge Research Systems VSG 2/5 frame store. The responses were recorded from a CB3 response box (Cambridge Research Systems).

Stimuli

The display consisted of three diamonds colored either red (5.0 cd/m^2, CIE [.629, .346]) or green (5.0 cd/m^2, CIE [.299, .598]). All items were presented on a black background. Three diamonds were arranged on an imaginary ellipse of which the vertical axis was 8.2° in visual angle and the horizontal axis was 10.1°, centered at the fixation point. Three diamonds could be presented at any of the 12 possible locations along the imaginary ellipse, as indicated by the small white circles in Figure 2, with the constraint that the three diamonds were separated from each other by the same angle of the ellipse (120°). Each diamond subtended 1.3° × 1.3° in visual angle and was chipped out on either the right or left side by 0.22°. The location and the chipped side of each diamond were randomly determined on every trial. The fixation point presented at the center of the display was a white (39 cd/m^2, CIE [.262, .282]) open circle. The observers viewed the displays from a distance of about 60 cm in a dark room.

On a search trial, the display consisted of an incongruently colored target and two distractors (e.g., a green target and two red distractors or vice versa), while on a non-search trial the display consisted of three uniform color distractors (e.g., all red or green distractors). These colors were chosen with equal probability.

Procedure

Both search and non-search trials began with the fixation point presented for a variable interval of 2000-2500 ms, followed by search displays or non-search displays with the fixation point. On search trials, there was an incongruently colored diamond (target) for which the observer was required to make a shape discrimination. The observer's task was to report which side of the target was chipped out by pressing the corresponding button (right or left) as fast as possible while keeping error rates low. The stimuli remained on the screen until a response, which was followed by the next trial. On non-search trials, all the diamonds were of a uniform color and the observers passively viewed the stimuli. The non-search display stayed on the screen for 604 ms as in Goolsby and Suzuki (2002). There were two previewing conditions: one was the distractor-previewing condition, in which a current search trial was preceded by a non-search trial, in which all of the diamonds were the current distractor color. The other was the target-previewing condition, in which a current search trial was preceded by a non-search trial, in which all of the diamonds were colored in the current target color.

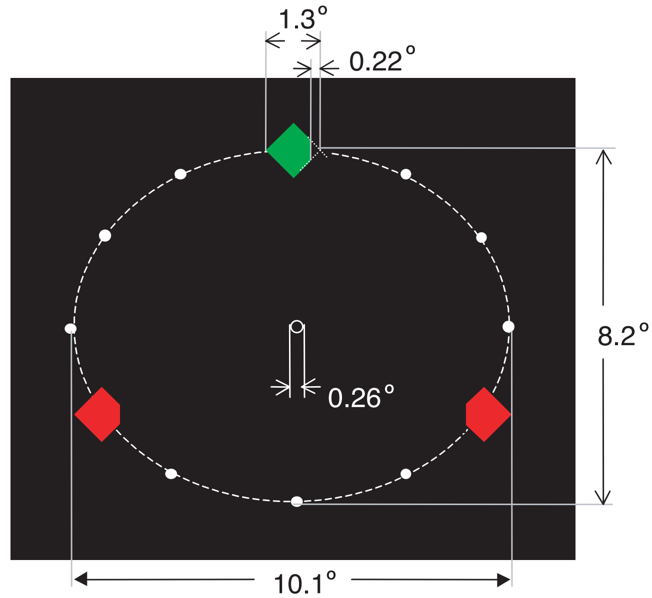

Figure 2. Example of a target (white diamond) and two distractors (gray diamonds), with right or left corners chipped out. The 12 possible diamond locations (small white circles) are shown along with the elliptical path.

The sequence of trials was generated for each participant. Pairs of trials were constructed such that a search display was preceded by either a preview or a search display. The color of the items in the preview display and the color of the target in the search display were orthogonally varied between red and green, yielding four combinations. Combining these factors resulted in 8 possible pairs of trials. The order of these pairs was randomly shuffled. To avoid the participants from expecting the order of sequence, 8 preview (4 red and 4 green) and 8 search trials (4 red and 4 green targets) were randomly inserted between the above pairs, yielding a set of 32 trials. This procedure was repeated 10 times to prepare 320 trials for each participant.

Each observer was given 20 practice trials prior to the experiment, which consisted of 320 trials (two blocks of 160 experimental trials). Observers were allowed to have a break between the blocks.

Results

Reaction times for the current search trials were averaged for each condition. Figure 3A displays the mean reaction times of correct responses for each condition. A within-subject *t* test revealed that reaction times in the distractor-previewing condition (609 ms) were significantly less than in the target-previewing condition (685 ms), $t(11) = 9.32$, $p < .001$.

The error rates were quite low, less than 5% (Table 1). Error rates in the distractor-previewing condition were significantly lower than those in the target-previewing condition, $t(11) = 5.00$, $p < .001$.

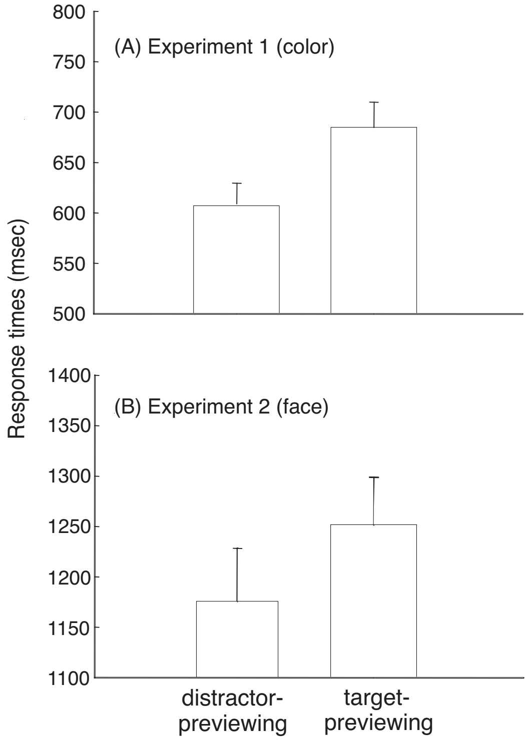

Figure 3. (A). Mean reaction times for the shape discrimination of an incongruently colored diamond in the distractor-previewing and target-previewing conditions of Experiment 1. (B). Mean reaction times to discriminate on which side of an incongruent-sex face the white bar appeared in the distractor-previewing and target-previewing conditions of Experiment 2. Bars on the figures indicate the *SEM*.

Discussion

The results revealed that observers reacted more quickly to targets in the distractor-previewing condition than to those in the target-previewing condition. There was no evidence of a speed-accuracy trade-off, because the accuracy data presented an identical pattern. These results were consistent with Goolsby and Suzuki (2001b), demonstrating the distractor-previewing effect with color stimuli.

We concluded that the equipment and procedure used in this experiment were valid for obtaining the distractor-previewing effect. In Experiment 2 we examined whether the distractor-previewing effect is restricted to color stimuli by introducing a visual search for the target face uniquely defined by its gender (sex).

Experiment 2: The distractor-previewing effect with faces

Experiment 2 examined whether the distractor-previewing effect can be obtained with faces, which are assumed to require achromatic shape processing rather than color processing (Perrett, Rolls, & Caan, 1982). We used the same procedure as in Experiment 1, except that male or female faces replaced the diamonds. If the distractor-previewing effect can be obtained with facial stimuli, then the reaction times to find the face in the distractor-previewing condition will be less than reaction times in the target-previewing condition.

Expt.	Stimuli and Sequence (response attribute)	Conditions	
		Distractor-previewing	Target-previewing
1	color (shape)	1.69	3.24
2	face (shape)	2.77	3.71
3A	motion (shape)	4.47	4.70
3B	motion (direction)	5.67	8.34
4A	word-->color (shape)	1.61	1.81
	color-->word (shape)	2.60	3.42
4B	word-->face (shape)	2.60	4.14
	face-->word (shape)	2.85	3.56
5	centre word-->color (shape)	2.37	3.03

Table 1. Error rates in Experiments 1-5 (%)

Method

Observers

Twelve naive paid observers participated. The observers' ages ranged from 18 to 24 years. All had normal or corrected-to-normal visual acuity. None were familiar with the persons whose faces were used as stimuli.

Apparatus and stimuli

The apparatus and stimuli were the identical to those used in Experiment 1, except that the display consisted of three achromatic faces. The facial images were created from digitized photographs of female and male faces using Photoshop 6.0 (Adobe Systems); the faces were equated in size (2.4° (V) × 1.8° (H)) and mean luminance (74.0 cd/m^2). When two or more same-sex faces were presented in a trial, those faces were all the same persons; a non-search trial contained only one person and a search trial contained two persons. A white horizontal "hair," subtending 0.1° × 0.4°, was superimposed either on the right or left side of each face (Figure 1B).

Procedure

The procedure was the same as in Experiment 1, except that the observers searched for an incongruent-sex face and indicated the side of the face with the "hair." Because faces of different individuals were used in the preview and search trials, it was likely that any preview effect obtained would primarily be due to processing the gender of the faces, rather than to the processing of spurious features specific to individual faces. All observers passively viewed the non-search display for 1005 ms. The preview duration was chosen such that it was appropriately equal to the mean response time for the search trials. (The same procedure was applied to Experiments 3A and 3B.)

Results

Figure 3B displays the mean reaction times of correct responses as a function of conditions. The reaction times in the distractor-previewing condition (1176 ms) were significantly less than those in the target-previewing condition (1251 ms), $t(11) = 4.37$, $p < .005$. Error rates were less than 5% (Table 1). There was no significant difference in error rates between the experimental conditions, $t(11) = 0.99$, *ns*.

Discussion

The pattern of results was similar to that of Experiment 1; the reaction time in the distractor-previewing condition was less than that for the target-previewing condition. This result clearly indicates that the distractor-previewing effect occurred when the stimuli were human faces. The effect was present even when the identities of faces were changed between the preview and search displays, suggesting that higher levels of stimulus representation, such as gender, can also produce this effect. However, this effect might be due to a few perceptual distinctions between males and females, such as eyebrow thickness, roundness of jaw, height of cheek bone, fullness of lips, etc. We investigated whether the distractor-previewing effect could be obtained solely through semantic activation in Experiment 4A and 4B.

Experiment 3A: The distractor-previewing effect with motion stimuli

Another interesting question is whether this effect can be obtained with stimuli defined by dynamic features. That is, in this experiment, the features that observers used to find the target was motion direction and the features that they used to respond to the target was the diamond shape. The purpose of Experiment 3A was to examine whether the distractor-previewing effect can be obtained with stimuli defined by coherent motion. The procedure was the same as in Experiment 1, except that the diamonds were defined by dots that moved coherently across frames.

Method

Observers

Ten naive paid observers and the authors (12 observers in total) participated in Experiment 3A. The observers' ages ranged from 20 to 32 years. All had normal or corrected-to-normal visual acuity.

Apparatus and stimuli

The apparatus and stimuli were identical to those used in Experiment 1, except for the following changes. The display consisted of random white dots, each of which was 1 pixel in size, and a red closed circle presented in the center of the display (the fixation point). The random dots occupied 31.3% of the display area (17.5° (V), 19.0° (H)). The three diamonds arranged as in Experiment 1 were defined by dots moving coherently either up or down by 4 pixels/50 ms against a static background of random dots. Each diamond subtended 2.6° × 2.6° in visual angle and was chipped out on either the right or left side by 0.44°.

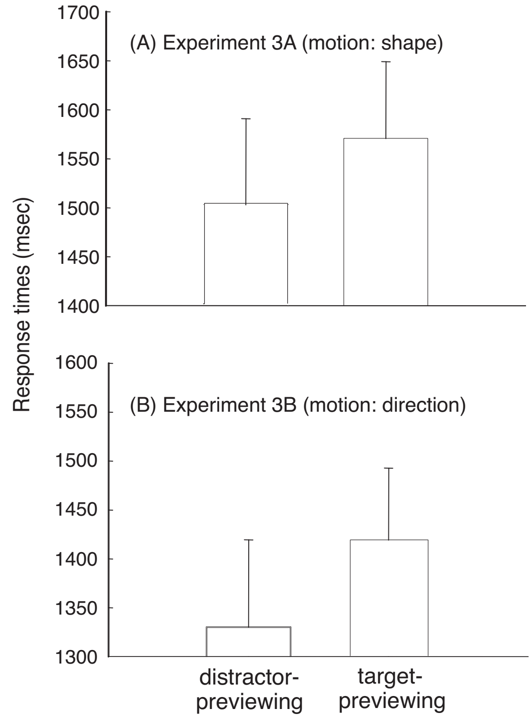

Figure 4. (A). Mean reaction times for the shape discrimination of the diamond defined by dots moving coherently toward an incongruent direction in the distractor-previewing and target-previewing conditions of Experiment 3A. (B). Mean reaction times to determine the direction toward which the incongruent-speed dots move in the distractor-previewing and target-previewing conditions of Experiment 3B. Bars on the figures indicate the *SEM*.

Procedure

The procedure was the same as in Experiment 1, except that the observers pressed a button to indicate which side of the diamond (whose internal dots moved towards an incongruent direction) was chipped out. All observers passively viewed the non-search display for 1146 ms, except the authors, who viewed the display for 1005 ms. The duration of the non-search trial was calculated as in Experiment 2.

Results

Figure 4A presents the mean reaction times of correct responses as a function of experimental conditions. The reaction times in the distractor-previewing condition (1503 ms) were significantly less than those in the target-previewing condition (1570 ms), $t(11) = 2.61$, $p < .05$. The error rates were less than 5% (Table 1). There was no significant difference in error rates between the experimental conditions, $t(11) = 0.21$, *ns*.

Discussion

Reaction times in the distractor-previewing condition were less than in the target-previewing condition, indicating that the distractor-previewing effect occurs within motion-based search. All of our experiments so far used shape as the response attribute. To determine whether the distractor-previewing effect depended on the use of shape as the response attribute, we used motion direction as the response attribute in the next experiment.

Experiment 3B

This experiment examined whether the distractor-previewing effect occurs when the response-defining attribute is not shape but motion direction. That is, in this experiment, the features that observers used to find the target was motion speed and the features that they used to respond to the target was motion direction. The display was the same as in Experiment 3A, except that the stimuli were circles defined by the moving dots rather than diamonds.

Method

Observers

Thirteen naive paid observers and the authors (15 participants) participated in Experiment 3B. The observers' ages ranged from 19 to 32 years. All had normal or corrected-to-normal visual acuity.

Apparatus and stimuli

The apparatus and stimuli were identical to those used in Experiment 3A, except that the display consisted of three circles, each 1.3° in diameter, defined by dots moving coherently toward either the right or the left by 2 or 4 pixels/50 ms.

Procedure

The procedure was the same as in Experiment 3A, except that the target was a circle containing internal dots moving at an incongruent speed (a "fast" circle among "slow" circles or vice versa). The task of the observers was to indicate the direction of coherent motion (right or left) in the target circle. All observers passively viewed the non-search display for 959 ms, except for the authors, who viewed it for 1146 ms. The duration of the non-search trial was calculated as in Experiment 2.

Results

Figure 4B presents the mean reaction times of correct responses as a function of conditions. The reaction times in the distractor-previewing condition (1330 ms) were significantly less than those in the target-previewing condition (1419 ms), $t(14) = 2.24$, $p < .05$. Error rates were less than 10% (Table 1). There was no significant difference in error rates between the experimental conditions, $t(14) = 1.70$, *ns*.

Discussion

Even when the response-defining attribute of the stimuli is motion direction, the distractor-previewing effect may be found. The results suggest that the distractor-previewing effect is not restricted to a phenomenon that occurs with static stimuli but occurs with dynamic stimuli. This implies that not only the ventral but also the dorsal stream of the visual pathway may be involved in this phenomenon (e.g., Mishkin, Underleider, & Macko, 1983; but see also Sereno & Maunsell, 1998).

Our results confirmed and extended the robustness of the distractor-previewing effect, which can occur with both static and dynamic stimuli. The results of Experiment 2 imply, in particular, that a higher cognitive component, such as semantic activation, might also elicit this effect. The effect obtained in Experiment 2, however, might be attributed to perceptual components, because the stimuli used in that experiment were facial images with sex-specific perceptual features. We used word stimuli in our next experiment to investigate whether abstract semantic activation alone can elicit the distractor-previewing effect.

Experiment 4A: The distractor-previewing effect with meaning

We examined whether the distractor-previewing effect occurs with words, which produce a more abstract semantic activation than that elicited by images of faces. In addition to the display of colored diamonds, as in Experiment 1, we included displays of outlined diamonds, each of which contained a color-name word (i.e., "green" or "red"). If the reaction times in color search trials are speeded by previewing words labeling the distractor color (compared to previewing words labeling the target color), such a result will suggest that activation of color through abstract semantic activation can produce the distractor-color previewing effect.

Method

Observers

Ten naive paid observers and the authors, 12 observers in all, participated in Experiment 4A. The observers' ages ranged from 19 to 32 years. All had normal or corrected-to-normal visual acuity and normal color vision, based on self-report.

Apparatus and stimuli

The apparatus and stimuli were identical to those used in Experiment 1, except for the following changes. Three outlined diamonds, each of which contained a Japanese color-name word meaning "green" or "red," were inserted into the sequence of the stimulus displays of color diamonds, as they appeared in Experiment 1. Each outlined diamond was formed by a white, 2-pixel thick line, and its word was also white. Both the color diamond and outlined diamond were subtended 2.6° × 2.6° in visual angle and were chipped out on either the right or left side by 0.44°. The internal word representing "red" or "green" in Japanese hiragana subtended 0.5° × 1.0°.

Procedure

The procedure was the same as in Experiment 1, except that the target was an incongruent diamond defined either by color or by the word that constituted the color's name. The colored diamond and the diamond with the color-name word never appeared together in the same trial. The observers indicated which side of the target diamond was chipped. There were two types of display sequence. One was the word—>color sequence, in which a current color search trial was preceded by a word non-search trial. The other was the color—>word sequence, in which a current word search trial was preceded by a color non-search trial. Both sequences were randomly presented, and there were five blocks of 128 experimental trials, or a total of 640 trials, which was double that of Experiment 1. The non-search display remained on the screen for 1000 ms. This duration of the non-search trial was determined from the time that it took observers to appropriately read the words.

Results and discussion

Figure 5A displays the mean reaction times of correct responses as a function of conditions in the word—>color sequence. The reaction times in the distractor-previewing condition (613 ms) were significantly less than those in the target-previewing condition (643 ms), $t(11) = 4.41$, $p < .005$. Error rates were less than 5% (Table 1). There was no significant difference in error rates between the experimental conditions, $t(11) = 0.31$, *ns*.

Figure 5B also displays the mean reaction times of correct responses as a function of conditions in the color—>word sequence. Although the reaction times in the distractor-previewing condition (1122 ms) were less than those in the target-previewing condition (1135 ms), there was no significant difference between the conditions, $t(11) = 0.89$, ns. Error rates were less than 5 % (Table 1). There was no significant difference in error rates between the experimental conditions, $t(11) = 1.07$, *ns*.

The pattern of the results was asymmetric across conditions. Only in the word—>color sequence were reaction times in the distractor-previewing condition less than in the target-previewing condition, suggesting that the distractor-previewing effect can be obtained through distractor-color activation induced by previewing words labeling the distractor color. Reaction times were not different among experimental conditions in the color—>word sequence condition. In our next experiment, we investigated the generality of abstract semantic activation by replicating the distractor-previewing effect with images of human faces and identifying word labels.

Experiment 4B

This experiment replicated Experiment 4A by using images of faces and the words identifying their sex (i.e., "male" or "female"). Experiment 2 demonstrated that the distractor-previewing effect is found when using images of faces that require sex identification; thus, if abstract semantic activation of sexual identity takes place when previewing a word, then we should find the distractor-previewing effect.

Method

Observers

Twelve naive paid observers participated. The observers' ages ranged from 19 to 32 years. All had normal or corrected-to-normal visual acuity. None of them were familiar with the persons whose faces were used as stimuli.

Apparatus and stimuli

The apparatus and stimuli were identical to those used in Experiment 4A, except for the following changes. The face images replaced the color diamonds, and the outlined ellipses containing words representing sex (i.e., "male" or "female") replaced the outlined diamonds. The outlined

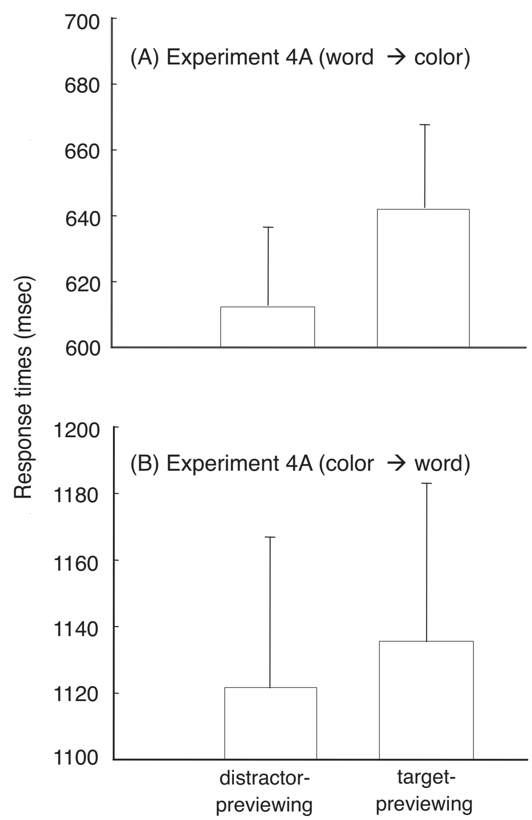

Figure 5. Mean reaction times for the shape discrimination of a target defined by the incongruent-color (A) or incongruent color word (B) in the distractor-previewing and target-previewing conditions of Experiment 4A. Bars on the figures indicate the *SEM*.

ellipse was created by a white, 2-pixel thick line, and its internal word was also white. Both the facial image and outlined ellipse were of the same size as the facial image in Experiment 2, and a white "hair" was superimposed on either the right side or the left side of the face. The internal words for "male" or "female" subtended 0.5° × 1.5°, and they were written in Japanese.

Procedure

The procedure was the same as in Experiment 4A, except that the target was an incongruent face defined either by the sex of the actual facial image or by words in an ellipse identifying its sex. The face and word images never appeared together in the same trial. The observers were to indicate the location (right or left side of the face) of the target "hair." There were two types of display sequence. One was the word—>face sequence, in which a current face search trial was preceded by a word non-search trial. The other was the face—>word sequence, in which a current word search trial was preceded by a face non-search trial. The non-search display remained on the screen for 1000 ms, as in Experiment 4A.

Results and discussion

Figure 6A presents the mean reaction times of correct responses as a function of conditions in the word—>face sequence. The reaction times in the distractor-previewing condition (1235 ms) were significantly less than those in the target-previewing condition (1275 ms), $t(11) = 2.32$, $p < .05$. Error rates were less than 5% (Table 1). There was no significant difference in error rates between the experimental conditions, $t(11) = 1.22$, *ns*.

Figure 6B also presents the mean reaction times of correct responses as a function of conditions in the face—>word sequence. Although the reaction times in the distractor-previewing condition (1436 ms) were less than those in the target-previewing condition (1462 ms), the difference was not significant, $t(11) = 1.61$, ns. Error rates were less than 5% (Table 1). There was no significant difference in error rates between the experimental conditions, $t(11) = 0.48$, *ns*.

The asymmetric pattern of the results was similar to that of Experiment 4A; in the word—>face sequence, the distractor previewing effect occurred as expected, while in the face—>word sequence, the trend was not statistically significant. This experiment replicated Experiment 4A, and the results support our hypothesis that abstract semantic activation produces the distractor-previewing effect with these stimuli.

Experiment 5

It seems clear that the distractor-previewing effect is not limited to color stimuli and can be obtained when the target/distractor is a face, stimulus motion (motion direction and speed), or words. These parallel results, observed across a variety of stimulus attributes, imply that the distractor-previewing effect observed in this study exhibits characteristics similar to those found by Goolsby and Suzuki (2001b). Goolsby et al. (2004) found that when the preview display did not look like the search display, the distractor-previewing effect was eliminated, suggesting that task-relevant adaptation is necessary to obtain the distractor-previewing effect with color. Thus, if we alter the stimuli so as not to provide task-relevant adaptation, as in Goolsby et al. (2004), the effect should not occur. In the present experiment, we tested this by presenting observers with one word, either "green" or "red," presented in the center of the screen as a preview display. The observers' task was, again, to search for an incongruently colored diamond among the distractors presented on the periphery of the screen, and to report which side was missing a corner.

Method

Thirteen naive paid observers and one of the authors (AA) (a total of 14 observers) participated. The observers' ages ranged from 19 to 25 years. All had normal or corrected-to-normal visual acuity and normal color vision, based on self-report.

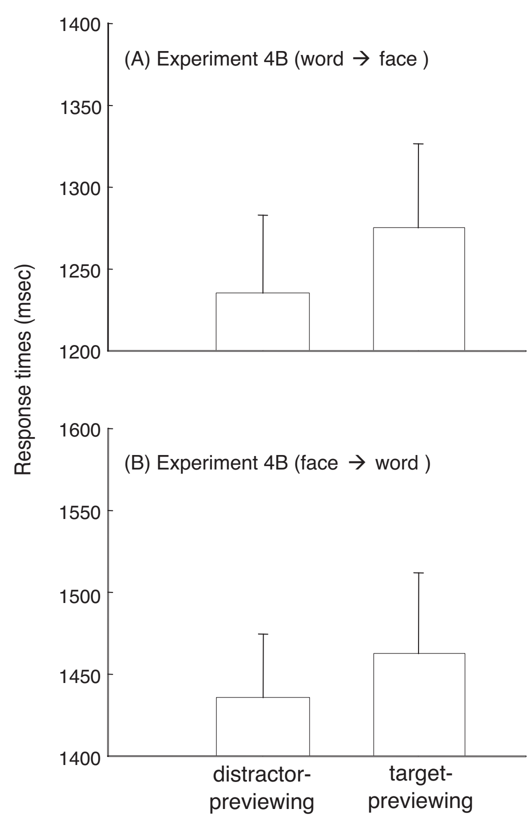

Figure 6. Mean reaction times to discriminate a target defined by a white bar on the side of an incongruent-sex face (A) or incongruent-sex word (B) in the distractor-previewing and target-previewing condition of Experiment 4B. Bars on the figures indicate the *SEM*.

The apparatus, stimuli, and procedure were identical to those used in Experiment 1, except for the following changes. In the non-search trial, only one Japanese color-name word (without the diamond shape) was presented in the center of the screen. The observers' task was to indicate the missing corner of an incongruently colored diamond in the search trial, after previewing a color-name word in a non-search trial. The non-search display remained on the screen for 1000 ms, as in Experiment 4A.

Results and discussion

Figure 7 presents the mean reaction times of correct responses as a function of conditions. There was no significant difference in reaction times between the distractor-previewing (572 ms) and target-previewing conditions (566 ms), $t(13) = 1.11$, *ns*. Error rates were less than 5% (Table 1). There were no significant differences in error rates between the experimental conditions, $t(13) = 0.84$, *ns*.

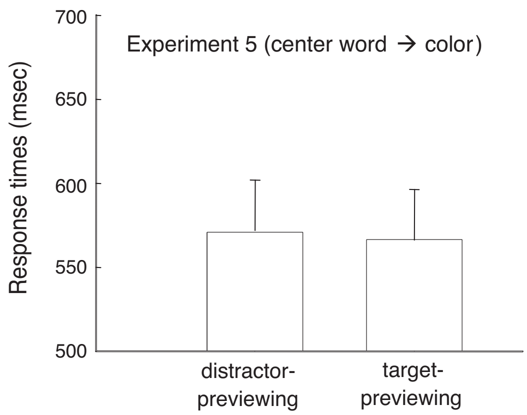

Figure 7. Mean reaction times for the shape discrimination of an incongruent-color diamond, after previewing one color-word presented in the center, for both the distractor-previewing and target-previewing conditions of Experiment 5. Bars on the figures indicate the *SEM*.

In this experiment, we demonstrated conditions under which the distractor-previewing effect was eliminated. The effect produced by previewing a word that emerged in Experiment 4A did not occur when a single color-name was presented in the center of the display. This suggests that the distractor-previewing effect with words occurs only when semantic activation is accompanied by task relevancy. The importance of task relevancy has also been demonstrated by Goolsby et al. (2004). Their overall results suggested that the distractor-color previewing effect on color-based visual search occurred only when a preview trial displayed colored items in a search relevant context (e.g., the presence of multiple items away from the point of fixation). Thus, the distractor-color previewing effect was eliminated when only a single item was presented at the fixation point, and when the colored items were strongly grouped into a single unit centered at the fixation point. The former result parallels our result in this experiment, suggesting that the distractor-color previewing effect we demonstrated here using color names share a common mechanism with the effects reported in a series of studies by Goolsby and colleagues colored images.

General discussion

We used different types of stimuli to determine the characteristics of stimuli that do and do not produce the distractor-previewing effect (Goolsby & Suzuki, 2001b). In Experiment 1, we observed the distractor-previewing effect with color stimuli and replicated Goolsby and Suzuki (2001b). Experiment 2 showed that the distractor-previewing effect is not limited to color and can be obtained with achromatic complex stimuli such as faces. The results of Experiment 2 also indicate that this effect might be due to semantic activation rather than, exclusively, to image-based adaptation, as the results cannot be explained on the basis of processing features that are specific to individual faces.

Experiment 3 extended conditions for obtaining the distractor-previewing effect; the effect was observed with motion stimuli, regardless of whether the response-defining attribute was stimulus shape or motion direction. The distractor-previewing effect is thus a robust phenomenon observed with color, face, motion, and word stimuli, and is independent of the visual processing pathways.

Experiment 4 tested the potential involvement of semantic activation in the distractor-previewing effect. Results indicated that abstract semantic activation could elicit the effect by previewing words. We conclude that higher cognitive component, such as abstract semantic activation, and not only perceptual adaptation, can facilitate visual search when that search is preceded by a preview display consisting of items containing distractor names. In Experiment 4A, the distractor-previewing effect was obtained only in the word—>color sequence. This asymmetric pattern is similar to the Stroop effect (Stroop, 1935), where word identification affects color identification, but not vice versa. It is assumed that this reflects the automatic activation of meaning elicited by word stimuli. Although image color does not induce lexical activation, color name automatically induces spreading semantic activation of color (MacLeod, 1991; Posner & Snyder, 1975). Thus, in the word—>color display sequence, strong semantic activation was induced (and affected color search in our study), while in the color—>word sequence, color probably failed to produce lexical (or orthographic) activation, and did not affect word search. This could also explain the results of Experiment 4B, in which face stimuli were used, indicating that strong semantic activation is required for certain tasks.

These results imply that a higher level process(es) might be a source of the distractor-previewing effect, as Goolsby et al. (2004) suggested. The effect in our studies was obtained only when the preview items was in a search relevant context, indicating that the global-form-contingent color preview effect is not due solely to bottom-up, stimulus-based adaptation. We conclude that some expressions of the distractor-previewing effect are not image-based phenomena, as demonstrated in Experiments 2, 4A, and 4B, in which semantic activation of color or gender was sufficient to elicit the effect.

In Experiment 5, we examined whether the distractor-previewing effect with semantic activation, and the previewing effect obtained with color, share similar underlying mechanisms. To date, task-relevant adaptation has been necessary to obtain the effect with color (Goolsby et al., 2004), and the present results indicate that this is the case with words as well. We suggest that the distractor-previewing effect with perceptual adaptation, and the effect with semantic activation, might share a common underlying mechanism(s); it is important for future studies to determine these contributing processes.

An alternative explanation of the distractor-previewing effect is that it might be due to response inhibition. For example, imagine a search trial with a red target and two green distractors. In the distractor-previewing condition, the response required for the discriminating feature of the current target (e.g., red color) is not inhibited in the search trial because the preceding distractor-preview trial contains only green items. On the other hand, in the target-previewing condition, the response to the red target might be inhibited in the search trials, and result in slower reaction times, because the preceding target preview trial contained red items. Contrary to this prediction, Goolsby et al. (2004) found that a distractor-color preview speeded search (while a target-color preview slowed search) relative to an achromatic preview. Furthermore, Goolsby et al. (2004) found that the distractor-previewing effect was not eliminated, even when observers responded to the preview display, suggesting that the distractor-previewing effect cannot be explained in terms of stimulus-response pairings.

Similar phenomena

The notion that a higher level of processing, such as semantic activation, may contribute to the distractor-previewing effect under certain conditions leads us to consider two phenomena that are similar to the distractor-previewing effect. In this section, we will consider whether each of those two phenomena shares a common mechanism with the distractor-previewing effect. First, demonstrating the familiarity effect in a visual search task (Wang, Cavanagh, & Green, 1994), observers were able to search faster and more efficiently for an unfamiliar target among familiar distractors than for a familiar target among unfamiliar distractors. So, in the distractor-previewing condition, the familiarity of current distractors increases temporarily, due to the perceptual adaptation or semantic activation created by viewing the distractors on the preceding trial. In the same way, current-target familiarity increases by viewing it as a stimulus in the target-previewing trial. In short, in the distractor-previewing condition, observers view "familiar" distractors (familiarised in a preceding trial) in search trials, while in the target-previewing condition, they view a "familiar" target. Wang et al. (1994) argued that this pattern of results is consistent with Treisman's (1985) explanation of an asymmetrical familiarity effect, such that familiar items are coded as standards and unfamiliar items are coded as deviations from standards. Because standards elicit less activity, as compared to deviations, as Treisman (1985) has suggested, the visual search for a deviation from standard distractors is facilitated. Therefore, the reaction time in the distractor-previewing condition (i.e., unfamiliar target among familiar distractors) will be less than that in the target-previewing condition, which is the distractor-previewing effect.

We should, however, be cautious in defining familiarity. Although Wang et al. (1994) defined familiarity in terms of the observer's extant knowledge, the stimuli in our experiments (i.e., red and green diamonds) were likely equally familiar to the observers, and so the familiarity explanation holds only if the familiarity of the colored diamonds is assumed to increase or decrease on a trial-by-trial basis. We can distinguish the familiarity effect from the distractor-previewing effect, in that the former is due to a long-term adaptation process, while the latter is due to short-term adaptation. Future experiments should investigate whether the long-term familiarity effect shares a mechanism(s) in common with the short-term distractor-previewing effect.

Negative priming, defined as slow responses to stimuli that have previously been ignored (Tipper, 1985), might also be related to the distractor-previewing effect. Milliken, Joordens, Merikle, and Seiffert (1998) presented a probe display that consisted of two differently colored (green and red) superimposed words, preceded by a preview that contained one of the words in the probe display (all presented in the center of the screen). The observer's task was to view the preview displays passively and to name aloud the red word in the probe displays. The preview words were either the target word in the probe displays (the target repeated condition) or the distractor word (the distractor repeated condition). Their results showed faster responses to the target in the distractor repeated condition than in the target repeated condition.

It is premature, though, to regard the distractor-previewing effect reported by Goolsby and his colleagues, and in the present study, as same phenomenon as the distractor repetition effect reported by Milliken et al. It is important to note that Milliken et al. (1998) showed that selection of a probe among other items was critical to obtain the effect of distractor repetition. When their probe display contained a single target without any distractors, there was no repetition effect. This is consistent with other negative priming studies, which show the effect of distractor-repetition occurs only when selection of a probe was involved (Lowe, 1979; Moore, 1994; Tipper & Cranston, 1985). We have shown that, unlike for the distractor repetition effect, there is no need for selection during the probe display to obtain the distractor-previewing effect (i.e., the distractor-previewing effect occurs even when the probe display contained only one item to be responded to) (Ariga, Lleras, & Kawahara, 2004). Therefore, we can draw a line between the distractor-repetition effect and the distractor-previewing effect.

Analysis of the priming of pop-out

The non-search trials and search trials were randomly intermixed throughout Experiments 1-3 in the present study. Some search trials were immediately preceded by a search trial, either under the condition that a specific target-distractor combination was repeated (repeated condition) or that a target-distractor combination was reversed (reversed condition). According to Maljkovic and Nakayama (1994), observers can detect the odd-ball target in a current trial more rapidly in the repeated condition than in the reversed condition, an effect that was labeled the priming of pop-out. Because this priming effect has been observed with stimuli defined by color and by spatial frequency (Maljkovic & Nakayama, 1994), we thought that it would be an interesting development if the effect was found with the variety of target-defining features used in Experiment 1 (color), 2 (faces), 3A (motion direction), and 3B (motion speed). We conducted analyses to determine whether stimuli that elicit the distractor-previewing effect also produced a Maljkovic-Nakayama-type priming effect.

The results revealed that the Maljkovic-Nakayama-type priming effect was observed with color (635 ms) (SE = 24.41) for the repeated condition versus 682 ms (SE = 23.37) for the reversed condition, $t(11) = 6.57$, $p < .001$, and motion speed (1430 ms) (SE = 81.58) for the repeated condition versus 1516 ms (SE = 83.07) for the reversed condition, $t(14) = 4.53$, $p < .001$. However, there was no significant effect of the expected priming effect with face (1243 ms) (SE = 57.59) for the repeated condition versus 1274 ms (SE = 56.18) for the reversed condition, $t(11) = 1.85$, *ns*, and motion direction (1536 ms) (SE = 76.46) for the repeated condition versus 1571 ms (SE = 70.43) for the reversed condition, $t(11) = 1.19$, *ns*. In short, both the distractor-previewing effect and the priming of pop-out occurred with color and motion speed stimuli, whereas face and motion direction stimuli elicited only the distractor-previewing effect. These results indicated that obtaining the Maljkovic-Nakayama-type priming effect was not necessary to obtain the distractor-previewing effect.

The final issue that needs to be discussed is the relationship between the distractor-previewing effect and the priming effect due to distractors that Maljkovic and Nakayama (1994) reported. They showed a cumulative effect of repeating trials which contained consistent color of the distractors across trials. The reaction times to the odd-color target in the current search trial became shorter as the trials that consisted of the same color of distractors were repeated. To determine the boundary condition of the distractor-previewing effect, we need to compare it with the distractor-priming effect. Therefore, we examined whether the amount of the distractor-previewing effect would increase as the same preview trials cumulated. Although we believe that this subsidiary analysis would provide important information about the difference/similarity between the distractor-priming effect and the distractor-previewing effect, there are a few things to keep in mind. First, most of the repetitive preview trials retrieved from our data were at most two-successive preview trials in which the same distractor colors were repeated, whereas the experiment in Maljkovic and Nakayama had six preceding trials. This difference was because our procedure was designed to maximize the number of trials for the distractor-preview and the target-preview conditions. Second, the number of samples of two successive trials was very few (at most about 10 trials per unpracticed observer) in our experiment. On the contrary, the reaction times were averaged from several hundreds of trials per practiced observer in Maljkovic and Nakayama's study.

The cumulative distractor-previewing effect was obtained only in Experiment 1. The amount of distractor-priming effect in two-successive preview trials was larger (138 ms, 591 ms for the distractor-previewing condition, and 729 ms for the target-previewing condition) than those in one preview trial (70 ms, 611 ms, and 681 ms), $t(11) = 2.95$, $p < .05$ (Figure 8).

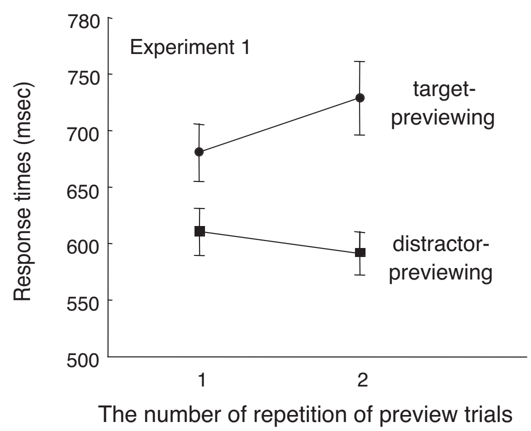

Figure 8. Mean reaction times in Experiment 1 for distractor- and target-previewing conditions, plotted as a function of the number of repetition of preview trials (1 preview trial vs. 2 preview trials). Bars on the figures indicate the *SEM*.

Importantly, the increase in the distractor-priming effect was mainly due to the delayed response in the target-previewing condition, $t(11) = 2.89$, $p < .01$, rather than the faster response in the distractor-previewing condition, $t(11) = 1.15$, *ns*. The same analysis conducted for other experiments did not reveal significant cumulative distractor-priming effect; 115 ms for two-successive preview trials (1172 ms) (SE = 59.60) for the distractor-previewing condition and 1287 ms (SE = 70.73) for the target-previewing condition versus 72 ms for one preview trial (1177 ms) (SE = 50.36) and 1249 ms (SE = 44.02), $t(11) = 0.98$, *ns*

(Experiment 2); 44 ms (1487 ms) (*SE* = 78.64), and 1531 ms (*SE* = 61.84) versus 49 ms (1538 ms) (*SE* = 84.12) and 1587 ms (*SE* = 75.77), $t(11) = 0.06$, *ns* (Experiment 3A); -30 ms (1271 ms) (*SE* = 113.43) and 1241 ms (*SE* = 75.33) versus 89 ms (1326 ms) (*SE* = 85.52) and 1415 ms (*SE* = 75.43), $t(14) = 0.63$, *ns* (Experiment 3B); 34 ms (612 ms) (*SE* = 35.11) and 646 ms (*SE* = 32.41) versus 29 ms (612 ms) (*SE* = 21.45) and 641 ms (*SE* = 25.61), $t(11) = 0.09$, *ns* (Experiment 4A); 54 ms (1217 ms) (*SE* = 59.05) and 1271 ms (*SE* = 55.51) versus 40 ms (1236 ms) (*SE* = 45.50) and 1276 ms (*SE* = 49.42), $t(11) = 0.36$, *ns* (Experiment 4B). Thus, we suggest that the distractor-previewing effect observed in this study was a different phenomenon from the distractor-priming effect reported by Maljkovic and Nakayama.

Summary

The purpose of this study was to explore the boundary conditions for the distractor-previewing effect. The study showed that the distractor-previewing effect is not limited to color stimuli, but is a robust phenomenon that can also be observed with other stimuli— faces, motion, and words. The most interesting aspect of the results is that the effect occurred with the abstract semantic activation elicited by using word stimuli. We also found that the previewing effect with semantic activation demonstrated a property similar to that exhibited in the effect with color, in terms of the task relevancy. The question of whether the distractor-previewing effect obtained with the stimuli that we used and that obtained with color stimuli shares common mechanisms awaits further investigation.

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References

Ariga, A., Lleras, A., & Kawahara, J. (2004, May). *Task relevance and response suppression in the distractor previewing effect*. Poster presented at the meeting of the Vision Sciences Society (VSS), Sarasota, FL.

Bravo, M. J., & Nakayama, K. (1992). The role of attention in different visual-search tasks. *Perception and Psychophysics*, *51*, 465-472. [PubMed]

Goolsby, B. A., Grabowecky, M., & Suzuki, S. (2004). *Adaptation of color salience contingent upon global form coding and task relevance*. Manuscript submitted for publication.

Goolsby, B. A., & Suzuki, S. (2001a). Understanding priming of color-singleton search: Roles of attention at encoding and 'retrieval'. *Perception and Psychophysics*, *63*, 929-944. [PubMed]

Goolsby, B. A., & Suzuki, S. (2001b, November). *Color priming and adaptation in color-singleton search*. Presentation delivered at the meeting of the Object Perception Attention and Memory (OPAM), Orlando, FL.

Goolsby, B. A., & Suzuki, S. (2002). The distracter-color adaptation effect in color-singleton search: What color representation is being adapted? [Abstract] *Journal of Vision*, *2(7)*, 537a, http://www.journalofvision.org/2/7/537/, doi:10.1167/2.7.537.

Humphreys, G. W., Quinlan, P. T., & Riddoch, M. J. (1989). Grouping processes in visual search: Effects with single- and combined-feature targets. *Journal of Experimental Psychology: General*, *118*, 258-279. [PubMed]

Lowe, D. G. (1979). Strategies, context and the mechanisms of response inhibition. *Memory and Cognition*, *7*, 382-389.

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An Integrative Review. *Psychological Bulletin*, *109*, 163-203. [PubMed]

Maljkovic, V., & Nakayama, K. (1994). Priming of pop-out: I. Role of features. *Memory and Cognition*, *22*, 657-672. [PubMed]

Milliken, B., Joordens, S., Merikle, P. M., & Seiffert, A. E. (1998). Selective attention: A re-evaluation of the implications of negative priming. *Psychological Review*, *105*, 203-229. [PubMed]

Mishkin, M., Ungerleider, L. G., & Macko, K. A. (1983). Object vision and spatial vision: Two cortical pathways. *Trends in Neurosciences*, *6*, 414-417.

Moore, C. M. (1994). Negative priming depends on probe-trial conflict: Where has all the inhibition gone? *Perception and Psychophysics*, *56*, 133-147. [PubMed]

Perrett, D. I., Rolls, E. T., & Caan, W. (1982). Visual neurons responsive to face in the monkey temporal cortex. *Experimental Brain Research*, *47*, 329-342. [PubMed]

Posner, M. I., & Snyder, C. R. R. (1975). Attention and cognitive control. In R. L. Solso (Ed.), *Information processing and cognition: The Loyola symposium* (pp. 55-85). Hillsdale, NJ: Erlbaum.

Sereno, A. B., & Maunsell, J. H. R. (1998). Shape selectivity in primate lateral intraparietal cortex. *Nature*, *395*, 500-503. [PubMed]

Stroop, J. R. (1935). Studies of inference in serial verbal reactions. *Journal of Experimental Psychology*, *18*, 643-662.

Tipper, S. P. (1985). The negative priming effect: Inhibitory effects of ignored primes. *Quarterly Journal of Experimental Psychology*, *37A*, 571-590. [PubMed]

Tipper, S. P., & Cranston, M. (1985). Selective attention and priming: Inhibitory and facilitatory effects of ignored primes. *Quarterly Journal of Experimental Psychology*, *37A*, 591-611. [PubMed]

Treisman, A. (1985). Preattentive processing in vision. *Computer Vision, Graphics, and Image Processing*, *31*, 156-177.

Treisman, A., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology*, *12*, 97-136. [PubMed]

Wang, Q., Cavanagh, P., & Green, M. (1994). Familiarity and pop-out in visual search. *Perception and Psychophysics*, *56*, 495-500. [PubMed]