

New perceptual objects that capture attention produce inhibition of return

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New perceptual objects are known to capture attention. We show that such attentional capture is similar to that produced by peripheral luminance changes, as opposed to symbolic central cues, in that it produces inhibition of return. Two experiments employed equiluminant texture changes that attracted attention, producing an initial attentional benefit (in detection and discrimination) followed by inhibition of return. However, when the display was altered so that the texture change did not define a new object, no facilitation or inhibition was observed. The results bolster recent claims of the importance of new perceptual objects and extend our understanding of the effect of such objects on attention.

People are unable to fully process all of the details of a complex visual scene, so they must first select some stimuli to subject to further detailed processing. This selection of important elements in the environment is guided by visual attention. At least two different means are thought to be available for the allocation of attention. First, an automatic or *exogenous* mechanism may cause one to reorient attention to important stimuli in the environment due to the presence of some special stimulus features (a sudden onset, for example; see the discussion that follows). Second, a voluntary or *endogenous* mechanism may allow one to move attention centrally, guided from within. Researchers have identified a number of important differences between these two ways of orienting attention, providing support for the claim that they represent the operation of distinct mental mechanisms (e.g., Klein, 1994; Posner & Cohen, 1984; Riggio & Kirsner, 1997; for reviews of these and related issues, see Egeth & Yantis, 1997, and Yantis, 1996, 1998).

Yantis and Jonides (1984) studied questions about the features of a stimulus necessary for it to capture attention. They had subjects search for target letters in displays that also contained distractors. Targets that appeared suddenly in the display were more readily identified than targets that were revealed by the removal of camouflaging elements that had already been present. Yantis and Jonides concluded that the sudden onsets in the former situation automatically attracted the subject's attention, presumably via exogenous attentional orienting mechanisms. Recent work by Yantis and Hillstrom (1994) extended those results, examining events that did not involve a luminance change. In their study, newly presented stimuli that were defined by equiluminant (with the background) depth, texture, or motion differences were also shown to cap-

ture attention. This finding led Yantis and his colleagues to suggest that any new perceptual object, including but not limited to those defined by a luminance change, will automatically capture attention (but see Gibson, 1996a, 1996b, and Yantis & Jonides, 1996, for a recent debate on this issue).

The suggestion that a new object can capture attention, even in the absence of an abrupt luminance change, leads to an important question about the underlying attentional mechanisms. Specifically, although it has been shown that attention can be captured by either an abrupt onset (Yantis & Jonides, 1984) or by the appearance of a new object without a luminance change (Yantis & Hillstrom, 1994), it is not clear that the attention so captured is the same in each case. In other words, are the attentional mechanisms that are engaged by the appearance of a new object the same as those that are engaged by an exogenous attentional cue defined by a luminance change? This question is the focus of the present study.

In order to answer this question, we made use of an attentional phenomenon that has been extensively studied with exogenous cues. The phenomenon is inhibition of return, in which subjects are slower to respond to an event at a recently attended location than to one at an unattended location (Abrams & Dobkin, 1994; Maylor, 1985; Maylor & Hockey, 1985; Posner & Cohen, 1984; Rafal, Calabresi, Brennan, & Sciolto, 1989; Tipper, Weaver, Jerreat, & Burak, 1994). The inhibition is typically manifested late relative to the attention cue, and it is always preceded by an early period of facilitation, characterized by enhanced responses at the cued location immediately following the cue. Inhibition of return has been demonstrated in a number of different experimental settings but has been found almost exclusively in situations in which attention has been cued exogenously.¹ Other forms of cuing attention, such as with symbolic, central (endogenous) cues, although effective in redirecting attention, have not been found to produce inhibition at the cued location (Posner & Cohen, 1984; Rafal et al., 1989). Thus, allocating attention to a location is not sufficient to produce inhibi-

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tion of return there. And because of that, inhibition of return may be an effective diagnostic tool for dissociating different types of attentional allocation.

The purpose of the present study was to determine whether the appearance of a new object that is equiluminant with the background would result in inhibition of return to a subsequent target in the same location. If it did, that would bolster claims that the appearance of a new perceptual object marks an important perceptual event (see, e.g., Yantis & Hillstrom, 1994), summoning attentional resources as effectively (or at least in a similar way) as a peripheral luminance change. Such a result would also bear on models of inhibition of return—further specifying the conditions necessary to produce the phenomenon. Of course, it is possible that a new object summons attention by activating the same attention system as that activated by endogenous cues. In that case, we would expect not to find inhibition of return to the location of a new object.

EXPERIMENT 1

The purpose of Experiment 1 was twofold. First, we sought to investigate whether the presentation of a new equiluminant perceptual object would produce inhibition of return. Second, we also examined whether attention would be captured by a new object in a task that did not involve a visual search. To accomplish these goals, we employed a cued detection task (Posner, 1980; Posner, Nissen, & Ogden, 1978), in which the peripheral cue on each trial was composed of a texture change on an equiluminant background. The cue was uninformative with respect to the location of a subsequent target. On some trials, the target to be detected was presented immediately (200-msec cue–target stimulus onset asynchrony [SOA]) after the offset of the cue. If the appearance of a new (equiluminant) object automatically captures attention in this task, subjects should be faster to detect targets at the cued location relative to those at the uncued location. If the attention that is captured by the new object (the cue) is like that engaged when a peripheral flash is presented, there should also be inhibition of return, as evidenced by slower responses to a target appearing at the cued location a short time after the cue. In order to determine this, other trials included a longer cue–target SOA (950 msec).

Method

Subjects. Ten Washington University undergraduates participated in a single 1-h session. They all had normal, uncorrected vision. They were paid \$6 for participation.

Apparatus and Procedure. Subjects were seated 38 cm from a video monitor in a dimly illuminated, sound-isolated room. Subjects' heads were kept steady by a chinrest.

The order of events on each trial is shown in the left panel of Figure 1. At the beginning of each trial, a texture-pattern rectangle (500×400 pixels, $29^\circ \times 23.3^\circ$) was presented at the center of the display monitor (640×480 pixels, $37^\circ \times 27.9^\circ$). This rectangle served as the background of the display and remained visible throughout the trial. The texture pattern consisted of parallel black lines oriented at either 45° or

135° angles on a gray background. The pattern was generated using repeated 4×4 pixel grids in which the pixels along one of the diagonals were black. At the same time that the background pattern appeared, a plus sign was presented at the center of the background (0°). After 1,000 msec, the cue, consisting of a new object—defined by a texture difference—appeared for 200 msec centered 7° to the right or the left of center. The cue was a box ($1^\circ \times 1^\circ$) with no border, filled with the background texture rotated 90° . A target box was presented either at the same time as the offset of the cue (200-msec SOA) or after a delay of 750 msec (950-msec SOA). The target was a smaller ($0.75^\circ \times 0.6^\circ$) gray box either at the same (cued) location as the texture cue or at the opposite (uncued) location. Catch trials, in which no target was presented, were also included. Subjects were instructed to remain fixated on the central plus sign and to make a simple keypress as soon as they detected the target box. They understood that the cue did not predict the location of the target. The target remained on the screen until a response was made.

Design. Subjects served in eight blocks of 36 trials. Five of the subjects were presented background composed of lines oriented at 45° and 5 were presented the 135° background. Sixteen trials in each block were cued trials, 16 were uncued trials, and 4 were catch trials. Left and right targets were equally likely.

Results

The mean keypress latencies in each condition are shown in Figure 2. The latencies were analyzed with a 2 (cue condition) \times 2 (SOA) \times 2 (target location) analysis of variance (ANOVA). Subjects were faster on the long (950-msec) than on the short (200-msec) SOA trials [$F(1,9) = 26.5, p < .001$]. There was a significant interaction between SOA and cue condition [$F(1,9) = 10.8, p < .01$]. No other main effects or interactions were found. The latencies for the short- and long-SOA trials were analyzed with separate 2 (cue condition) \times 2 (target location) ANOVAs. At the short SOA, latencies were 11 msec faster on the cued trials than on the uncued trials [$F(1,9) = 10.3, p < .05$]. At the long SOA, subjects were 13 msec slower on the cued than on the uncued trials [$F(1,9) = 5.1, p < .05$]. Target location had no effect at either SOA [$F_s(1,19) < 1.8, p_s > .3$]. Analyses of the errors revealed no main effects or interactions. The overall error rate for the experimental trials was 2.6%, and the false alarm rate for catch trials was 5.9%.

Discussion

At the short SOA, subjects were faster to respond to targets appearing in locations at which a new equiluminant object had appeared. This occurred even though the object was uninformative with respect to the target location. These findings replicate those of Yantis and Hillstrom (1994)—that new perceptual objects automatically capture attention. Furthermore, we obtained the result using a detection task instead of a discrimination task, which has been studied previously. More importantly, the new object produced inhibition of return: At the long SOA, subjects were slower to respond to targets appearing in the location at which the equiluminant object had appeared (compared with the other location). Thus, the appearance of a new object produces inhibition of return, as does a peripheral luminance change (but not a centrally directed movement of attention), suggesting that both engage similar endogenous attentional mechanisms.

EXPERIMENT 2

One potential limitation of the preceding experiment is that it is possible that there were some local luminance

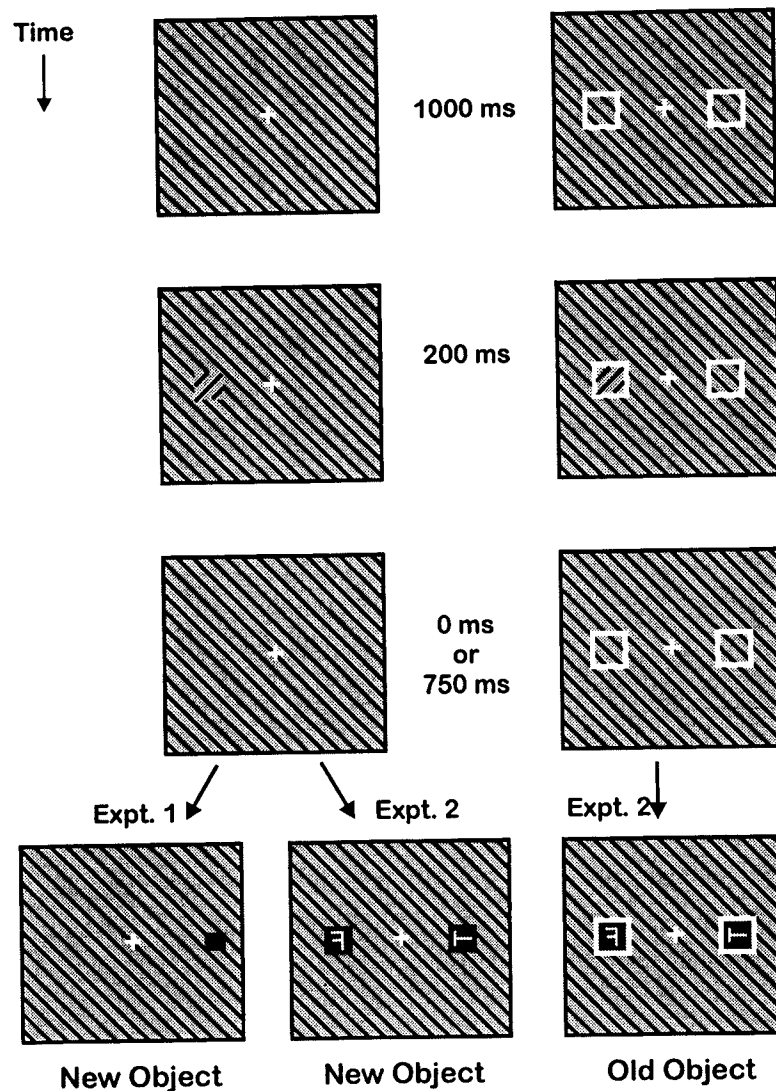


Figure 1. Sequence of events on each trial of Experiment 1 (left side) and Experiment 2 (middle and right sides). In Experiment 1, a texture change defined a new perceptual object (new object), and subjects performed a detection task. In Experiment 2, the texture change either defined a new perceptual object (new object) or, when box placeholders were already present, it did not (old object), and subjects performed a discrimination task.

changes near the edges of (or elsewhere in) the new object when the texture changed. If that happened, the luminance changes might be responsible for the facilitation and inhibition that we observed, and not the appearance of a new object per se. In order to rule out this possibility, we repeated Experiment 1 but included an additional condition. In the new condition, box outlines were present throughout the trial around the locations in which the texture cue could occur. Hence, the texture change would not constitute the appearance of a new object (since the box outlines already defined the objects), and we refer to this as the "old-object condition." If the appearance of a new object caused the results of Experiment 1, similar results should not be observed in the old-object condition

here. However, any local luminance changes would still occur even with the outline box. If such luminance changes were responsible for the results of Experiment 1, the same results should occur here regardless of whether the box outline is present or absent.

We also made one other change in the method. In Experiment 1, we studied a detection task, in which subjects simply had to detect the appearance of the target. However, it has been argued (e.g., Stelmach, Campsal, & Herdman, 1997) that detection tasks do not require focused visual attention. As a result, the attentional mechanisms tapped using a detection task may be quite different from those studied when discrimination tasks are employed. Hence, we used a discrimination task here in which sub-

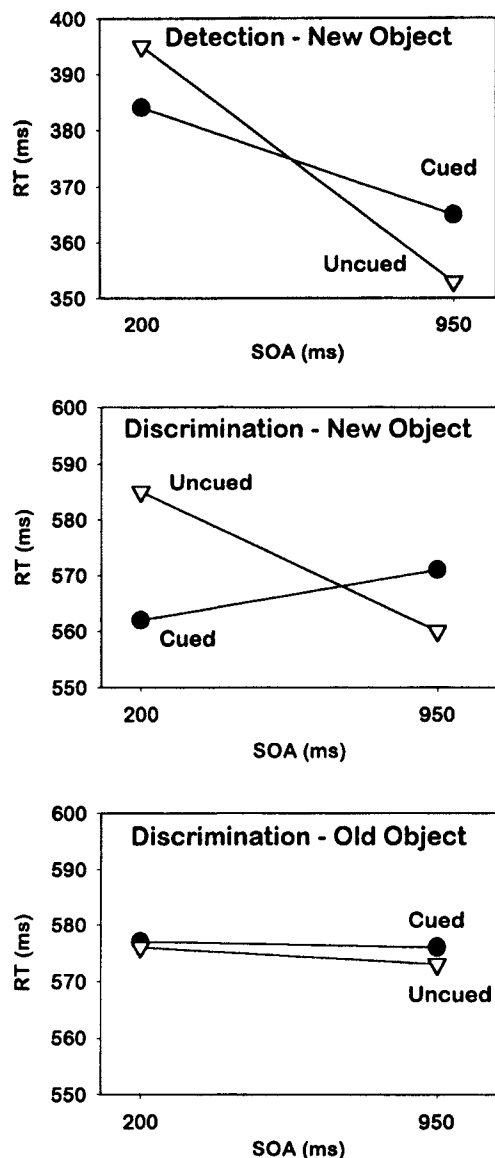


Figure 2. Mean latencies for detection (Experiment 1, top panel) and discrimination (Experiment 2, middle and bottom panels) as a function of the interval between the cue and the target (stimulus onset asynchrony [SOA]) and cueing. RT, reaction time.

jects were required to discriminate the identity of a target letter (T or L) in the presence of a distractor (a reversed F). This type of task has been used to demonstrate inhibition of return to peripheral cues in other studies (Pratt, 1995).

Method

Subjects. Twenty Washington University undergraduates participated in a single 1-h session. They all had normal, uncorrected vision. They were paid \$6 for participation.

Apparatus and Procedure. The order of events on each trial is shown in Figure 1. The apparatus and procedure were the same as in Experiment 1 with the following changes. On some trials (old object trials),

two placeholders composed of white box outlines were presented at the same time as the fixation point, and these remained visible throughout the trial.² The boxes were positioned so that when the cue (i.e., the change in background texture) was presented, it exactly filled the interior of one of the boxes. On the other trials (new object trials), no box placeholders were presented. This condition was exactly the same as that studied in Experiment 1. The target display consisted of two characters rotated 0°, 90°, 180°, or 270°. One of these was always a reversed F, and the other was either a T or an L. They were presented on gray squares located to the right and the left of fixation (within the placeholders on the old-object trials). Subjects were instructed to decide which target letter was present and to press the “z” key if it was T and the “/” key if it was an L.

Design. The design was the same as in Experiment 1, with the following exceptions. Subjects served in 12 blocks of 32 trials. Six of the blocks consisted of new-object trials and six of old-object trials. Half of the subjects served in all of the old-object blocks first, and the other half served in the new-object blocks first. The orientations of the characters in the target display were chosen randomly on every trial and T and L targets were equally likely.

Results

The mean keypress latencies in each condition are shown in Figure 2. Keypress latencies and errors were analyzed separately for the old- and new-object conditions. Data were subjected to a 2 (cue condition) \times 2 (SOA) \times 2 (target identity, T vs. L) ANOVA.

New-object trials. There was a significant interaction between SOA and cue condition [$F(1,19) = 17.8, p < .001$]. At the short SOA, latencies on the cued trials were 23 msec faster than on the uncued trials [$F(1,19) = 15.6, p < .01$]. At the long SOA, the latencies for uncued trials were 9 msec faster than those for cued trials [$F(1,19) = 5.2, p < .05$]. This is the same pattern as that seen in Experiment 1. Analyses of the error rates also revealed a main effect of cue condition [$F(1,19) = 5.1, p < .05$] and an interaction between SOA and cue condition [$F(1,19) = 36.5, p < .0001$]. Overall, subjects made more errors on uncued trials than on cued trials. Separate analyses revealed that they made fewer errors on the cued than on the uncued trials at the short SOA [10.4% vs. 17.4%, $F(1,19) = 21.5, p < .001$] and fewer errors on the uncued than on the cued trial at the long SOA [14.1% vs. 11.25%, $F(1,19) = 10.75, p < .01$]. Hence a tradeoff between speed and accuracy cannot account for the results.

Old-object trials. Analyses of the latencies and error rates revealed a main effect of type of target for both dependent measures. Subjects responded more quickly [$F(1,19) = 5.6, p < .05$] and made more errors [18.5% vs. 14.7%, $F(1,19) = 4.5, p < .05$] when the target was an L than when it was a T. No other main effects or interactions were found [$F_s(1,19) < 1$ (latencies), $F_s(1,19) < 1.2, p_s > .28$ (errors)], except for a marginal main effect of cueing on errors [16.6% errors on cued trials vs. 17.7% on uncued trials, $F(1,19) = 3.3, p = .08$]. That effect, however, was unrelated to the absence of an interaction involving the latencies.

Discussion

When the texture change constituted the appearance of a new object (i.e., in the new-object condition), it attracted the subject's attention,

yielding, at a short SOA, enhanced discrimination at the location at which the new object had appeared. At the long SOA, the facilitation was replaced by inhibition—subjects were slower to perform the discrimination at the previously cued location. This pattern replicates that obtained in Experiment 1, except that we used a discrimination task here and a detection task in Experiment 1. When placeholders were added to the display (i.e., the old-object condition), rendering the texture change meaningless except for the possibility of some previously undetected luminance changes, there was no effect of cued location. This manipulation effectively eliminated the possibility that such changes were present and were responsible for the results observed in Experiment 1.

GENERAL DISCUSSION

When attention was attracted by the appearance of a new equiluminant object, there was a period of inhibition of return following the longer SOA. During this period, subjects were slower to make detection (Experiment 1) or discrimination (Experiment 2) judgments for stimuli appearing in the location in which the new object had appeared. The fact that inhibition of return is generated by exogenous, peripheral cues and not endogenous, central cues, suggests that a new perceptual object engages the visual attention system in a manner similar to that engaged by peripheral cues. Such a result bolsters claims of the importance of new perceptual objects.

In addition to inhibition of return at the long SOA, we also found that the appearance of a new perceptual object facilitated detection performance at the short SOA (in Experiment 1; discrimination was facilitated in Experiment 2). The presence of facilitation in a detection task extends the results of Yantis and Hillstrom (1994) to a situation that does not involve visual search and further strengthens the case that new objects represent important events that have high attentional priority.

Our results are also relevant to a better understanding of inhibition of return. In most previous studies of inhibition of return, attention has been attracted to the periphery initially by an exogenous cue involving a luminance change (e.g., Abrams & Dobkin, 1994; Posner & Cohen, 1984; Tipper et al., 1994; but see note 1).³ However, it is not clear whether the inhibition in those studies was triggered by the luminance changes or by the appearance of a new perceptual object. The present results demonstrate that the appearance of a new perceptual object is sufficient to yield inhibition of return. The occurrence of inhibition of return in the absence of a peripheral luminance change is consistent with the findings of Rafal et al. (1989). They showed that a prepared but then canceled eye movement was sufficient to yield inhibition of return. Rafal et al. concluded that both a peripheral luminance change and preparation of an eye movement produce inhibition of return because both of these events involve activation of the oculomotor system. It remains to be seen whether the appearance of a new perceptual object yields inhibition of return because it also produces similar oculomotor activation.

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NOTES

1. There are two possible exceptions to this, in which inhibition of return has been demonstrated in the absence of an exogenous cue. First, Rafal et al. (1989) demonstrated that preparing an eye movement to a location, even if the movement is never produced, was sufficient to yield inhibition of return at the intended target location. Presumably, exogenous cues and prepared eye movements yield inhibition of return because they both engage the oculomotor system. However, this result has yet to be replicated. Second, Law, Pratt, and Abrams (1995) found inhibition of return when subjects judged the color of objects presented at fixation. In that situation, the inhibition was for an attribute other than spatial location, so it could conceivably involve different types of orienting mechanisms altogether.

2. The box placeholders were present on the display for 1,000 msec before the cue appeared, a duration sufficiently long to prevent forward masking by the placeholders (Di Lollo, 1980). Thus, any local luminance changes that may have accounted for the results in the new-object condition or in Experiment 1 would also have the same effect in the old-object condition.

3. Kwak and Egeth (1992) studied a similar situation in which uninformative, equiluminant texture changes were presented prior to the presentation of a target. They found inhibition of return to the location

of the cue. However, in their experiment the targets were also defined by equiluminant texture changes. Thus, subjects were actively searching for such events, causing them to adopt an appropriate attentional set (Folk, Remington, & Johnston, 1992). Their result is therefore not likely to be due to automatic capture of attention, but instead could reflect top-down processing related to the defining stimulus attributes.

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