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Synergy of stimulus-driven salience and goal-directed prioritization: Evidence from the spatial blink

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In the spatial blink paradigm, participants search for a target of a designated color in a rapidly presented stream of letters at fixation. Target identification is typically impaired if a peripheral distractor appears shortly before the target, inducing a *spatial blink*, but impairment is observed only when the distractor also shares the sought-for color. Such results reveal an important top-down influence on the capture of attention. In the present experiments, we examined the influence of the bottom-up transients associated with the appearance and disappearance of distractors in the spatial blink paradigm. Onsets and offsets alone are incapable of inducing a spatial blink, but we found that the presence of such transients did enhance the effects of target-color-matched distractors. The results reveal important synergistic interactions between top-down and bottom-up factors involved in attentional capture.

The allocation of spatial attention is determined by the joint effects of stimulus-driven and goal-directed factors. Stimulus-driven selection occurs when attention is governed by stimulus salience. The abrupt onset of a new object is perhaps the prototypical example of stimulus-driven selection (Yantis, 1993; Yantis & Jonides, 1984, 1990). The onset of a new object captures attention not only during visual search, but also in a change detection task (Cole, Kentridge, & Heywood, 2004). Although part of the effect of an object onset may be due to the luminance transient associated with the event (Franconeri, Hollingworth, & Simons, 2005), new objects can capture attention even without a unique transient (Davoli, Suszko, & Abrams, 2007). In real-world scenes, the onset of new objects also yields prioritization even in the absence of a transient signal (Brockmole & Henderson, 2005). And finally, new objects often capture gaze when presented around the time of an eye movement (Theeuwes, Kramer, Hahn, & Irwin, 1998; Theeuwes, Kramer, Hahn, Irwin, & Zelinsky, 1999). Strong stimulus-driven capture is also caused in preexisting objects by the presence of an irrelevant feature singleton (Theeuwes, 2004), by the onset of motion (e.g., Abrams & Christ, 2003, 2005), or by the emergence of a new perceptual grouping (Christ & Abrams, 2006b).

Attention is also guided by goal-directed mechanisms in which attentional prioritization is determined by the particular goal at the moment. For example, Folk and colleagues found that uninformative precues captured attention if and only if they matched the target-defining feature (Folk, Remington, & Johnston, 1992; Folk, Remington, & Wright, 1994). Conversely, salient events, such as onsets and color or motion singletons, often fail to capture attention if they do not match the features that define the target (Bacon & Egeth, 1994; Gibson & Kelsey, 1998; Hillstrom & Yantis, 1994; Jonides & Yantis, 1988; Todd & Kramer, 1994). In addition, goal-directed selection can operate when a person has information about the likely spatial location of a target (Posner, 1980).

Although it appears that capture by onsets can sometimes be suppressed in some tasks if the onsets are inconsistent with top-down attentional control settings (Folk et al., 1992; Yantis & Jonides, 1990; but see Christ & Abrams, 2006a), some recently reported results have revealed important interactions between goal-directed and stimulus-driven selection (Ludwig & Gilchrist, 2002, 2003; Richard, Wright, & Ward, 2003). In particular, Ludwig and Gilchrist (2002) studied both onset capture and contingent capture in a saccadic and manual-pointing task. During the pointing task, Ludwig and Gilchrist (2002) presented a distractor that either did or did not match the target in color. Distractors appeared either with or without an abrupt onset. Ludwig and Gilchrist (2002) found that participants produced more inappropriate saccades to the color-matched distractors than to the color-unmatched ones, and more saccades were also made erroneously to distractors that abruptly onset. But most important, participants were most likely to fixate irrelevant onsets when they shared the target color. Error rates in that condition were more than the sum of the individual error rates for onset and color match alone. These results thus reveal an important interactive effect of top-down and bottom-up attentional mechanisms (Ludwig & Gilchrist, 2003).

Despite findings such as those just discussed, there has been relatively little work in which both top-down and

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bottom-up attentional factors have been manipulated simultaneously. In most studies, researchers have, instead, manipulated one type of attentional influence (e.g., top-down attentional set) while holding constant the level of the other (e.g., whether stimuli appeared via sudden onsets). In the present study, we were specifically interested in learning more about potential interactions between stimulus-driven orienting and goal-directed attentional prioritization. For this purpose, we modified a task that has been used extensively in studies of attention, and that permits the convenient manipulation of both top-down and bottom-up factors. The task is one in which the stimuli appear in a rapid serial visual presentation (RSVP).

One recent study employing an RSVP task did manipulate stimulus-driven and goal-directed factors. Lamy, Leber, and Egeth (2004) extended a task initially developed by Folk, Leber, and Egeth (2002). In the task, participants identified a uniquely colored target letter in a rapid stream of letters presented at fixation. Folk et al. (2002) showed that the participants were impaired in identifying the target at fixation if a distractor suddenly appeared in the periphery—but only if the distractor matched the target color. They called the impairment a *spatial blink*, akin to the attentional blink; however, unlike with the attentional blink, the distracting element in the spatial blink paradigm appeared in a location of the display known to be irrelevant to the task. Because the effect of the distractor was contingent upon the color match between target and distractor (mismatching colors did not impair performance), the effect serves as an example of contingent attentional capture. Importantly, because the participants could easily ignore the peripheral distractor if it did not match the target-defining color, it appears that stimulus-driven factors contributed minimally to the task.

In the subsequent study by Lamy et al. (2004), a stimulus-driven factor was manipulated in addition to the manipulation of top-down attentional set. Lamy et al. found that a color-matched distractor (a top-down influence) produced a larger spatial blink at a 100-msec distractor–target interval when it was a color singleton (a bottom-up influence) than did the same distractor when mixed with heterogeneously colored distractors. Thus, the spatial blink, initially presumed to reflect only goal-directed capture, may also depend somewhat on stimulus-driven factors.

Because the onset of new objects has often been regarded as a very powerful stimulus-driven factor (e.g., Christ & Abrams, 2006b; Enns, Austen, Di Lollo, Rauschenberger, & Yantis, 2001), and given the interactive effects reported to involve onsets and top-down control settings for color in some tasks (Ludwig & Gilchrist, 2003), we sought here to assess the contribution of onsets to the spatial blink. The previous work on the spatial blink has been unable to address this issue because the onset of the distractor has not been manipulated (Folk et al., 2002; Lamy et al., 2004; Serences et al., 2005). Indeed, in most of the previous studies on the spatial blink, the distractors were always introduced as new objects (Folk et al., 2002; Lamy et al., 2004). Thus, it is unknown whether the onset might have affected the magnitude of the spatial blink. The present study was designed to test the possibility that the spatial blink is caused, in part, by an interaction between the bottom-up influence of the onset of a color-matched distractor and the top-down effect of an attentional set for the target color. If such a result were to be found, it would be informative more generally regarding the extent to which bottom-up and top-down attentional influences can and do interact with one another.

EXPERIMENT 1A

Can the bottom-up activation caused by the abrupt onset of peripheral distractors contribute to the impairment produced when one distractor matches the target color during a feature search (the spatial blink)? Previous studies of the spatial blink could not address this question, because the distractor elements in those studies always underwent an abrupt onset (Folk et al., 2002; Lamy et al., 2004). In the present experiment, we included an *onset-and-offset condition* that replicated the original conditions studied by Folk et al. (2002), in which the peripheral distractors onset and then offset shortly before the target letter appeared at fixation. We also included a new condition, *color change*, in which placeholders for the distractors appeared in the display at the beginning of each trial and remained throughout each trial. In this case, there was no onset or offset accompanying the appearance of a color-matched distractor. If the spatial blink is caused by contingent capture per se, no difference in the magnitude of the spatial blink should exist between the color change and the onset-and-offset conditions. However, the spatial blink might be greatly reduced in the color change condition if the spatial blink depends on the bottom-up influence of an abrupt onset.

Method

Participants. Twenty undergraduate students from Washington University participated in an hour-long experiment for course credit. All had normal or corrected-to-normal visual acuity. No participants had experience in similar experiments.

Apparatus and Procedure. All the stimuli were presented on a 19-in. monitor with a 100-Hz refresh rate in a dimly lit room at a distance of 56 cm. The sequence of events on a trial is illustrated in Figure 1. Each trial began with a 500-msec presentation of a white fixation cross in the center of the screen, followed by the sequential presentation of 20 uppercase letters at the center. The letters were selected randomly without replacement from the English alphabet, with the exception of "I." The letters were 1.2º in width and 1.5º in height. Each letter was presented for 40 msec, followed by a 40-msec blank interval, yielding a stimulus onset asynchrony of 80 msec. One half of the participants were required to report the sole red letter in the sequence; the other half searched for the sole green letter as their target. Across trials, the target letter (in either red or green) appeared in the 11th through 14th frames of the letter sequence. The colors of the remaining letters were randomly chosen from three colors (gray, blue, or purple). The participants reported the target letter by pressing the corresponding key after each trial.

In the *onset-and-offset* condition, one of the letters in the 8th through 15th frames, randomly chosen with equal chance, was surrounded by four pound signs (#) whose inner edges appeared 4.2º above, below, to the right of, and to the left of the center of the letter. On one third of the trials, all of the pound signs were gray; on the other trials, one of the pound signs was either red or green (equally likely) and the other three were gray. The onset-and-offset condition was a replication of Experiment 2 in Folk et al.'s (2002) study. In the color change condition, four pound signs were presented at the same locations as those just noted in every frame of the trial. All of

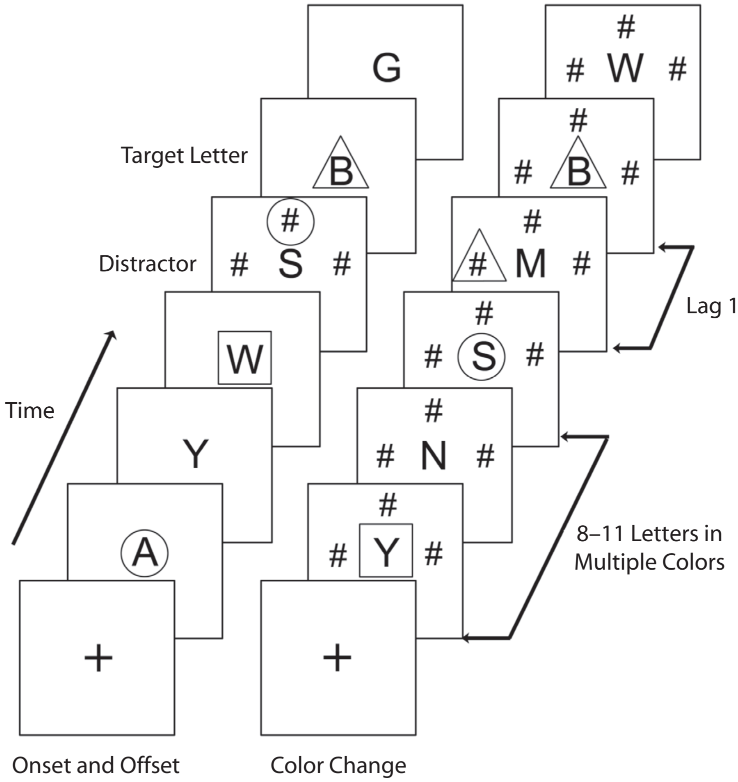

Figure 1. Schematic representation of the procedure in the onset-and-offset and color change conditions in Experiments 1A and 1B. The shapes surrounding the symbols designate stimuli of different colors and did not appear in the actual experiment. Each frame was presented for 40 msec and was followed by a blank interval of 40 msec.

the pound signs were initially gray. On one third of the trials, they remained gray. However, on the other two thirds of the trials, one of the pound signs changed color to either red or green (equally likely) in one of the frames between the 8th and 15th frames (and then back to gray again in the subsequent frames). Thus, both conditions included trials that contained a distractor display that included a color singleton that either matched the target color or did not. But only in the onset-and-offset condition did the colored distractor undergo an abrupt onset. The frame containing the colored distractor could appear from three frames before that containing the target (distractor–target lag of 3) to one frame after the target (lag of -1).

Design. The two conditions (color change and onset-and-offset) were presented to each participant in separate blocks, in a counterbalanced order. Each trial was in one of three distractor conditions: (1) The four pound signs could be all gray (*gray*); (2) one pound sign could match the target in color (*color matched*); or (3) one pound sign was the complementary, nontarget color (*color unmatched*). Each block contained 20 replications of each combination of three distractor conditions and five distractor–target lags, for a total of 300 trials. The participants first performed one block of 15 trials in each condition for practice. They then completed the test trials. After every 100 trials, they received a brief break. Half of the participants were assigned red as their target color.

Results and Discussion

The accuracy of target identification is plotted in Figure 2 as a function of distractor–target lag and the distractor condition. The two distractor conditions are plotted in separate panels. First, we found a main effect of lag,[1] with lower accuracy as lag increased [$F(4,76) = 7.56$, $p < .001$, $\eta_p^2 = .285$]. Next, there was a main effect of distractor condition, with accuracy lowest in the color-matched condition [$F(2,38) = 45.193$, $p < .001$, $\eta_p^2 = .704$]. The effects of lag and distractor condition interacted [$F(8,152) = 9.634$, $p < .001$, $\eta_p^2 = .336$], reflecting the fact that the impairment caused by the color-matched distractors occurred only for the longer lags. This is the pattern indicative of the spatial blink. Most important, the interaction between lag and distractor condition depended on the placeholder condition, yielding a three-way interaction between those factors [$F(8,152) = 5.938$, $p < .001$, $\eta_p^2 = .238$]. This interaction reflects the fact that the impairment caused by the color-matched distractors (at the longer lags) was greater in the onset-and-offset condition than in the color change condition, as can be seen in Figure 2.

In addition, there was still a significant spatial blink in the color change condition even in the absence of abrupt onset and offset of the distractors. This can be confirmed by a main effect of distractor condition in the color change condition [$F(2,38) = 21.004$, $p < .001$, $\eta_p^2 = .525$], as well as an interaction between lag and distractor condition [$F(8,152) = 2.215$, $p < .05$, $\eta_p^2 = .104$], reflecting the increased effect of the color-matched distractor at longer lags.

In order to more clearly quantify the impairment caused by the distractors in this and subsequent experiments, we computed a *spatial blink index* (SBI) by subtracting accuracy in the color-matched distractor condition from the

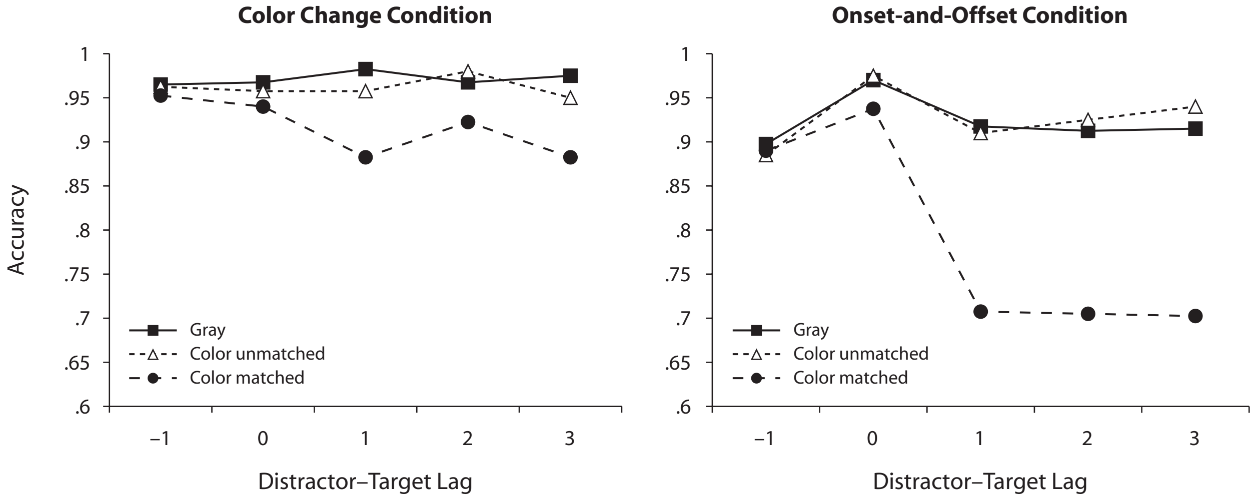

Figure 2. Accuracy of target identification in Experiment 1A.

Table 1
Spatial Blink Index From Experiment 1A

	Lag				
Condition	−1	0	1	2	3
Color change	1.1	2.3	8.8	5.1	8.0
Onset and offset	0.1	3.5	20.6	21.4	22.5

average accuracy of color-unmatched and gray distractors at each lag. The SBI for all combinations of lags and conditions is shown in Table 1 in units of percentage of accuracy reduction. The SBI shows our main findings. First, there was a substantial spatial blink in the onset-and offset condition, replicating the results in Folk et al. (2002). This result is revealed by the reduction in target identification accuracy at the longer lags. Second, there is also a small but consistent spatial blink in the color change condition, despite the absence of abrupt onset or offset of the distractors in that condition. Thus, it appears that the spatial blink caused by the color-matched distractor was enhanced by the presence of an abrupt onset and offset.

EXPERIMENT 1B

Experiment 1A revealed a smaller effect of a color-matched distractor in the color change condition, as compared with the onset-and-offset condition. However, in that experiment, each placeholder condition was studied in a separate block. This leaves open the possibility that the observers might have adopted different strategies for performing the task in the two conditions. If that occurred, the difference that we observed might have been due, in whole or in part, to a difference in strategies. To test that possibility, we repeated the conditions studied in Experiment 1A, but we mixed color change and onset-and-offset trials within each block.

Method

Participants. Sixteen undergraduate students from Washington University participated in a 50-min experimental session for course credit. All had normal or corrected-to-normal visual acuity and color vision. No participants had experience in similar experiments.

Apparatus, Procedure, and Design. This experiment was identical to Experiment 1A, with two minor changes. First, trials in the color change condition were randomly mixed with those in the onset-and-offset condition. Second, here we studied only four lags, rather than five, between the distractor and the target. Lags from zero to three were included here.

The participants took 24 trials as practice. Then they served in four blocks, each containing 120 trials that were randomly chosen from the collection of 480 trials, without replacement. A short break was given to the participants after each block.

Results and Discussion

The accuracy of letter identification is plotted in Figure 3 as a function of distractor condition and distractor–target lag. The results are very similar to those in Experiment 1A. We again found a main effect of lag, with lower accuracy at longer lags [$F(3,45) = 11.019$, $p < .001$, $\eta_p^2 = .423$]. And again, only the color-matched distractor captured attention, demonstrated by a significant main effect of distractor condition [$F(2,30) = 75.092$, $p < .001$, $\eta_p^2 = .834$] and a two-way interaction between lag and distractor condition [$F(6,90) = 5.754$, $p < .001$, $\eta_p^2 = .277$]. As in Experiment 1A, the spatial blink in the onset-and-offset condition was considerably larger than that in the color change condition, as evidenced by a significant three-way interaction between distractor condition, lag, and placeholder condition [$F(6,90) = 3.221$, $p < .01$, $\eta_p^2 = .177$]. Considering only the color change condition, we observed a significant spatial blink, as indicated by main effects of distractor condition [$F(2,30) = 39.196$, $p < .001$, $\eta_p^2 = .723$] and lag [$F(3,45) = 5.713$, $p < .005$, $\eta_p^2 = .276$]. The interaction between those factors did not

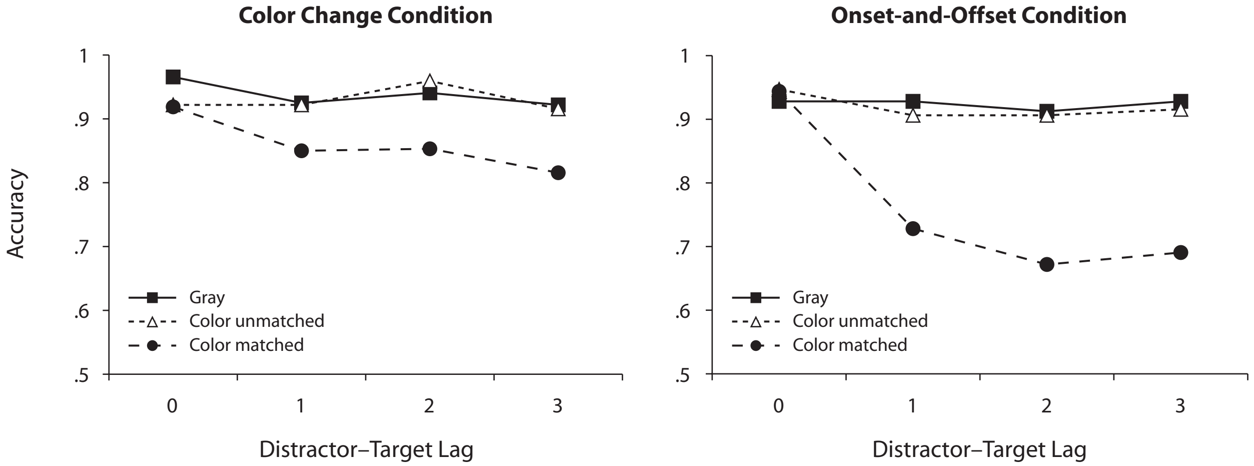

Figure 3. Accuracy of letter identification in Experiment 1B.

Table 2
Spatial Blink Index From Experiment 1B

	Lag			
Condition	0	1	2	3
Color change	2.5	7.3	9.7	10.3
Onset and offset	−0.6	18.9	23.8	23.1

attain significance [$F(6,90) = 1.798, p > .05, \eta_p^2 = .107$], perhaps due to insufficient power here.

The SBI from Experiment 1B is shown in Table 2. Again, the impairment in letter identification extended from lag 1 to lag 3 in both conditions. But the impairment in the color change condition was again much smaller than that in the onset-and-offset condition. The present results show that the smaller impairment in the color change condition cannot be attributed to a difference in strategies used by the participants. Instead, the transients associated with the onset and/or offset appear to have enhanced the ability of the color-matched distractor to capture attention.

EXPERIMENT 2

The results from Experiments 1A and 1B are consistent with our hypothesis that the spatial blink reported by Folk et al. (2002) was caused, in part, by the contingent capture of attention by the distractor that matched the target color (the color-matched condition here) and, in part, by the transient events associated with appearance of new objects (the distractor) in the onset-and-offset condition. This conclusion follows from our finding of a substantially greater spatial blink in the onset-and-offset condition than in the color change condition. What is unknown, however, is whether the additional impairment can be attributed only to the onset, only to the offset, or to a combination of both. To resolve that issue was the focus of the present experiment.

It is worth noting that, on the basis of the results of Experiments 1A and 1B, we can rule out the possibility that onsets and/or offsets alone, without a target–colored item, are capable of producing a spatial blink, because the gray distractor condition (as well as the color-unmatched condition) led to very little impairment in target identification: Accuracy was quite high with gray distractors and did not depend on lag. Instead, it seems as if the onsets or the offsets enhanced the effects of the color-matched distractor.

There is still some debate regarding the relative strengths of attentional capture produced by onsets as opposed to offsets. Some previous studies have shown that offsets might be as efficient as onsets in capturing attention (Pratt & McAuliffe, 2001; Watson & Humphreys, 1995). But other researchers have found that onsets exert a more powerful effect (Cole, Kentridge, Gellatly, & Heywood, 2003). In the case of the spatial blink, onsets and offsets have not been compared, and that was the purpose of the present experiment.

Method

Participants. Sixteen undergraduate students from Washington University participated in a 50-min experimental session for credit. All had normal or corrected-to-normal visual acuity and color vision. No participants had experience in similar experiments.

Apparatus, Procedure, and Design. The experiment was similar to Experiment 1A, with two exceptions. First, instead of five possible distractor–target lags, as in Experiment 1A, the lag between the distractor and the target here was either 0 or 2 frames. Second, we added two new placeholder conditions (onset-only and offset-only), in addition to the color change and onset-and-offset conditions previously studied in Experiment 1A. The two additional conditions are shown in Figure 4. In the offset-only condition, the placeholders (four gray pound signs) were presented from the beginning of the trial until the frame immediately before presentation of the colored distractor. After the appearance of the distractor, all of the pound signs disappeared. In the onset-only condition, there were no initial placeholders. Instead, the distractor appeared abruptly, as it had in the onset-and-offset condition in Experiment 1A. However, beginning with the frame after the distractor,

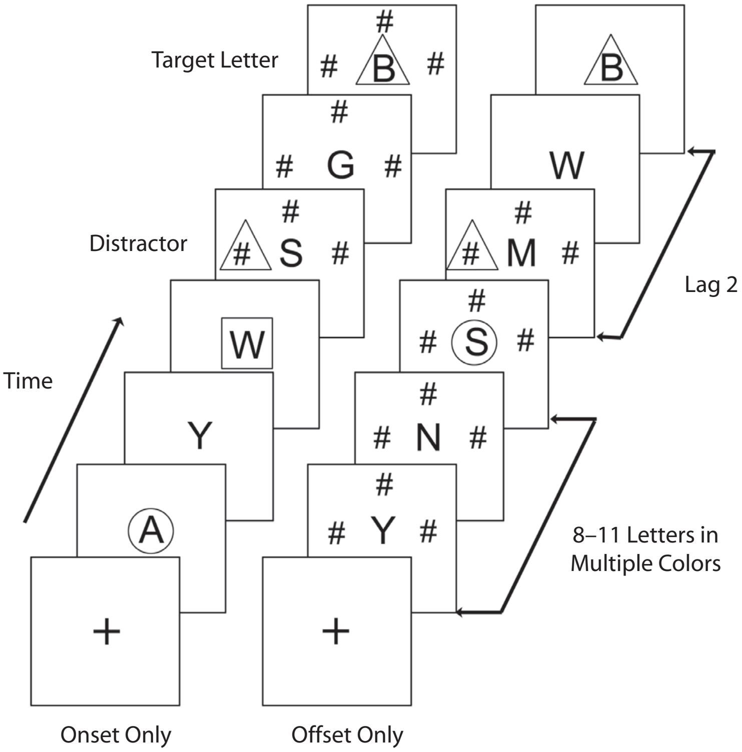

Figure 4. Schematic representation of the procedure in the onset-only and offset-only conditions in Experiment 2. The shapes surrounding the symbols designate stimuli of different colors and did not appear in the actual experiment. Each frame was presented for 40 msec and was followed by a blank interval of 40 msec.

four gray pound sign placeholders were displayed for the remainder of the trial. The onset-and-offset and color change conditions were exactly the same as those in Experiment 1A. In each of the conditions, one third of the trials contained only gray distractors, one third contained one distractor whose color matched the target color (red or green) in one of the frames between the 8th and the 15th frames, and one third contained a colored distractor that was not the target color (green or red).

The participants took 24 randomly selected trials as practice. Then they participated in one block in each of the four placeholder conditions, each containing 120 trials. Placeholder condition order was counterbalanced across participants. A short break was given to the participants midway through the session.

Results and Discussion

The accuracy of letter identification is plotted in Figure 5 as a function of distractor–target lag and the distractor condition. A main effect of distractor condition shows that the color-matched distractor caused the largest impairment [$F(2,30) = 16.912$, $p < .001$, $\eta_p^2 = .530$]. The significant two-way interaction between lag and distractor condition [$F(2,30) = 16.268$, $p < .001$, $\eta_p^2 = .520$] shows that the impairment occurred mostly at the longer lag (lag 2). Most important, the impairment caused by a color-matched distractor differed across the four placeholder conditions, with the impairment appearing smallest in the color change condition. This is indicated by a significant three-way interaction [$F(6,90) = 5.626$, $p < .001$, $\eta_p^2 = .273$].

We also analyzed each condition separately to learn more about the effects of the distractors. Impairment in letter identification caused by the color-matched distractor was found strongly in three of the four placeholder conditions: onset-and-offset, offset-only, and onset-only. For the onset-and-offset condition, the largest impairment caused by a color-matched distractor (the SBI at lag 2 was 32.2%) was confirmed by a main effect of distractor condition [$F(2,30) = 23.089$, $p < .001$, $\eta_p^2 = .606$]. The SBI is shown in Table 3. At lag 2, the SBI in the onset-and-offset condition was 32.2%. A main effect of lag [$F(1,15) = 24.802$, $p < .001$, $\eta_p^2 = .623$] and an interaction between lag and distractor condition [$F(2,30) = 24.128$, $p < .001$, $\eta_p^2 = .617$] indicated that impairment occurred mostly at lag 2. For the onset-only condition (the SBI at lag 2 was 20.2%), the main effect of distractor condition was also significant [$F(2,30) = 11.562$, $p < .001$, $\eta_p^2 = .435$]. The main effect of lag [$F(1,15) = 6.295$, $p < .05$, $\eta_p^2 = .296$] and the interaction between lag and distractor condition [$F(2,30) = 9.658$, $p < .005$, $\eta_p^2 = .392$] indicated that impairment occurred mostly at lag 2. The pattern of results in the offset-only condition (the SBI at lag 2 was 21.1%) was the same as that in the onset-only condition: Main effects of distractor condition and lag and their interaction were significant [$F(2,30) = 12.180$, $p < .001$, $\eta_p^2 = .448$; $F(1,15) = 9.558$, $p < .01$, $\eta_p^2 = .389$; $F(2,30) = 12.769$, $p < .001$, $\eta_p^2 = .460$, respectively]. In the color change condition, we found the smallest impairment caused by the color-matched distractor (SBI at lag 2 was 8.1%), which was only marginally significant [$F(2,30) = 3.040$,

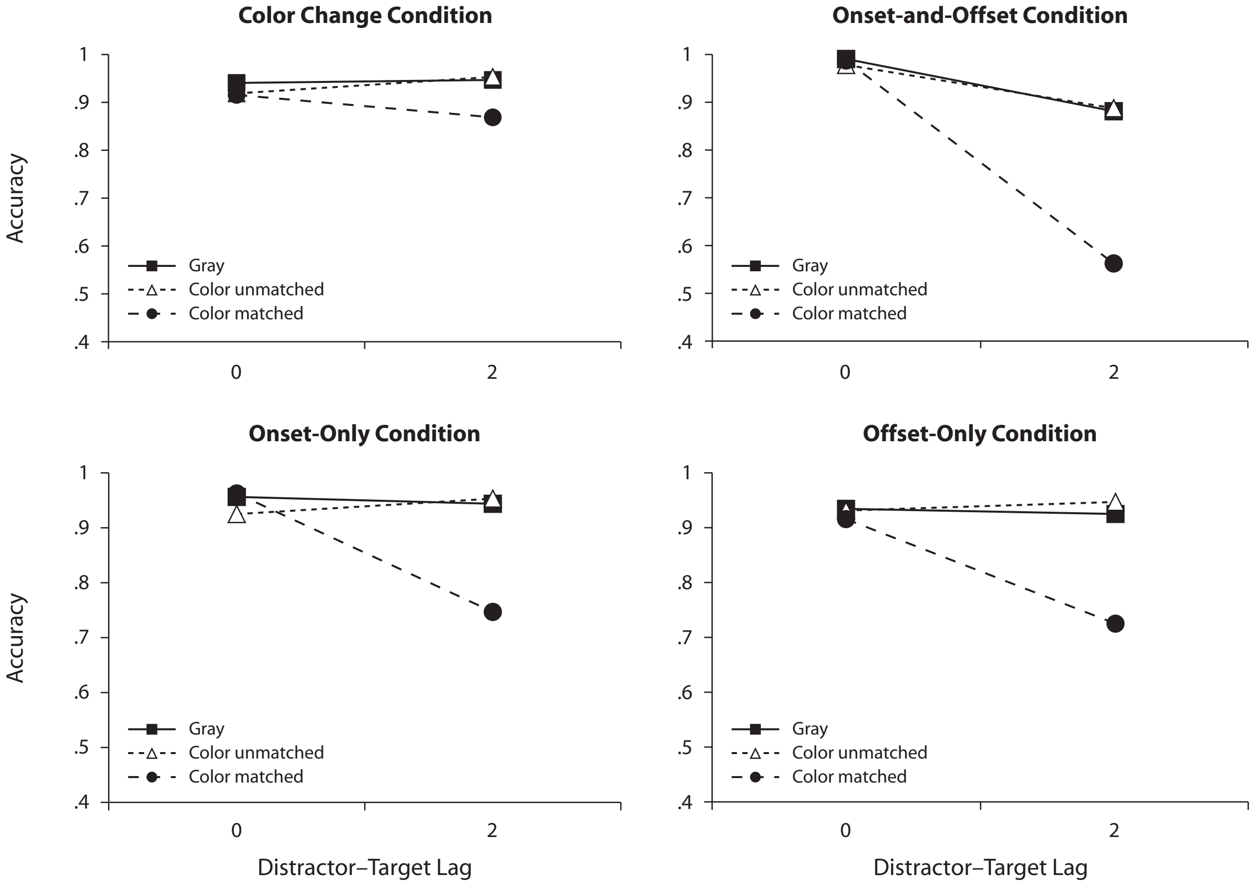

Figure 5. Accuracy of letter identification in Experiment 2.

Table 3
Spatial Blink Index From Experiment 2

Condition	Lag 0	Lag 2
Color change	1.4	8.1
Onset and offset	−0.3	32.2
Onset only	−2.2	20.2
Offset only	1.7	21.1

$p = .063$, $\eta_p^2 = .169$]. The effect of lag and the interaction were not significant in this condition.

To compare the magnitude of the spatial blink between conditions, we conducted additional tests on the SBIs at lag 2. The spatial blink in the onset-and-offset condition was higher than that in the color change, onset-only, and offset-only conditions ($p < .001$, $p < .05$, and $p < .05$, respectively). The intermediate spatial blink magnitudes observed in the onset-only and offset-only conditions were not different from each other ($p > .05$). Finally, the spatial blink in the color change condition was significantly lower than those in the onset-and-offset, onset-only and offset-only conditions ($p < .001$, $p < .05$, and $p < .01$, respectively).

In the present experiment, we replicated the result of Experiments 1A and 1B, finding a larger spatial blink in the onset-and-offset condition than in the color change condition. In addition, we demonstrated an intermediate spatial blink in both the onset-only and the offset-only conditions.[2] These results suggest that both the onset of the distractors and the offset of the distractors may contribute to the spatial blink.

EXPERIMENT 3A

The results from Experiments 1 and 2 suggest that the onsets and offsets of the distractors enhanced the strength of attentional capture when a distractor matched the target color. As a result, we observed greater spatial blink magnitudes in the onset-only, offset-only, and onset-and-offset conditions than in the color change condition. We assume that at least some of the benefit of the onset transient in the onset-only and onset-and-offset conditions was due to the fact that the distractors, when they appeared, were perceived to be new objects in the display, and new objects are known to attract attention (Enns et al., 2001; Yantis &

Hillstrom, 1994; Yantis & Jonides, 1996). However, an alternative possibility exists. It is, instead, possible that the continuous presence of placeholders before and after the distractor in the color change condition served to mask or otherwise reduce the salience of the distractor display there, and not merely to cause the distractors to appear to be old objects. According to this explanation, there is a reduced spatial blink in the color change condition because the distractor is simply less noticeable there, being masked by the placeholders in the earlier and/or later frames. Furthermore, the onset-only and offset-only conditions would also be subject to distractor masking, although to a lesser extent than the color change condition, thus explaining the intermediate level of interference that we observed in those conditions.

As was just noted, we assume that the benefit of the transients in the onset-and-offset condition may have been due, at least partially, to the fact that the distractors there were perceived to be new objects, whereas, in the color change condition, the presence of placeholders prior to the distractor frame did not support the same interpretation. Given that, we sought here to create a condition in which a target-colored distractor could be presented under one condition in which it could be perceived to be an old object and under another condition in which it would be perceived to be a new object, but in neither case would there be any prior placeholder that might mask the distractor display. We accomplished that by using induced motion of the placeholders in order to create the impression that some of the distractors were present from earlier in the trial (we call this the old-object condition), whereas others were new objects that had just appeared in the display (new-object condition). Importantly, because of the induced motion, in neither case did a distractor appear in a location that had been occupied by a placeholder in an earlier frame. If masking, rather than the absence of onset and offset, explains the reduced spatial blink in the color change condition earlier, no reduction in the spatial blink should occur in the comparable condition (old-object) in the present experiment. However, if the old-object condition still has a smaller spatial blink than the new-object condition, that would suggest that the status of a distractor as a new object enhances its ability to capture attention in this paradigm.

Method

Participants. Sixteen undergraduate students from Washington University participated in a 30-min experimental session for course credit. All had normal or corrected-to-normal visual acuity and color vision. The participants had no experience in any similar experiments.

Apparatus and Procedure. The general procedure is illustrated in Figure 6. Each trial began with a 500-msec presentation of a white fixation cross in the center of the screen, followed by the sequential presentation of 23 letters. Across trials, the target letter appeared in the 13th through 15th frames of the letter sequence. As in the earlier experiments, the distractor display contained four pound signs—aligned above, below, to the left, and to the right of the central stream. In the present experiment, two placeholders appeared in the display 2 frames before the distractors appeared. The placeholders moved from frame to frame, yielding convincing apparent motion and causing two of the four placeholders to appear to be old objects and two to appear to be new objects. For example, in Figure 6, the distractors in panel A that are vertically aligned would appear to be old objects because of their locations in the sequence of moving placeholders there, whereas the horizontally aligned placeholders would be perceived to be new objects when they appeared. In panel B of Figure 6, although the distractor frame is identical to that in panel A, the locations of the moving placeholders are different, causing the horizontally aligned placeholders to appear to be old objects there. Either the four pound signs in the distractor display were all gray (*gray distractor* condition) or there was a single red- or green-colored distractor that matched (*color-matched* condition) or did not match (*color-unmatched* condition) the designated target color.

The placeholders initially appeared with their inner edges (1) 4.2º above and to the left of the central letter and (2) 4.2º below and to the right of it. The four pound signs in the distractor frame had their inner edges 4.2º away from the central letter, as in the earlier experiments. After the distractor frame, there were two additional frames showing the two gray placeholders, moving away from the distractor location.

Design. We studied two placeholder conditions (new-object and old-object), three distractor conditions (gray, color-unmatched, and color-matched), and two distractor–target lags (0 or 2). Twenty-four replications for each combination of the two placeholder conditions, three distractor conditions, and two lags produced a total of 288 trials. Four blocks each contained 72 trials, which were randomly selected from the trial bank without replacement. Half of the trials involved clockwise movement of the placeholders in the display. The

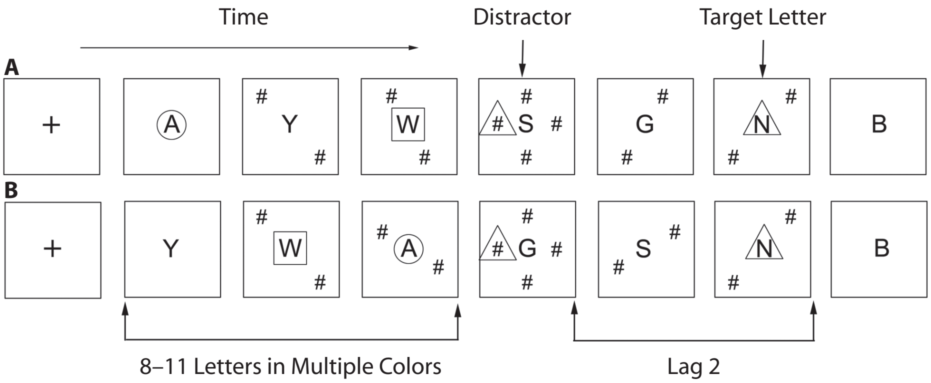

Figure 6. Schematic illustration of the procedure in Experiment 3A. (A) Onset-and-offset condition, with a clockwise apparent motion in the horizontal direction. (B) Color change condition, with a counterclockwise apparent motion in the vertical direction. The shapes surrounding the symbols designate stimuli of different colors and did not appear in the actual experiment. Each frame was presented for 40 msec and was followed by a blank interval of 40 msec.

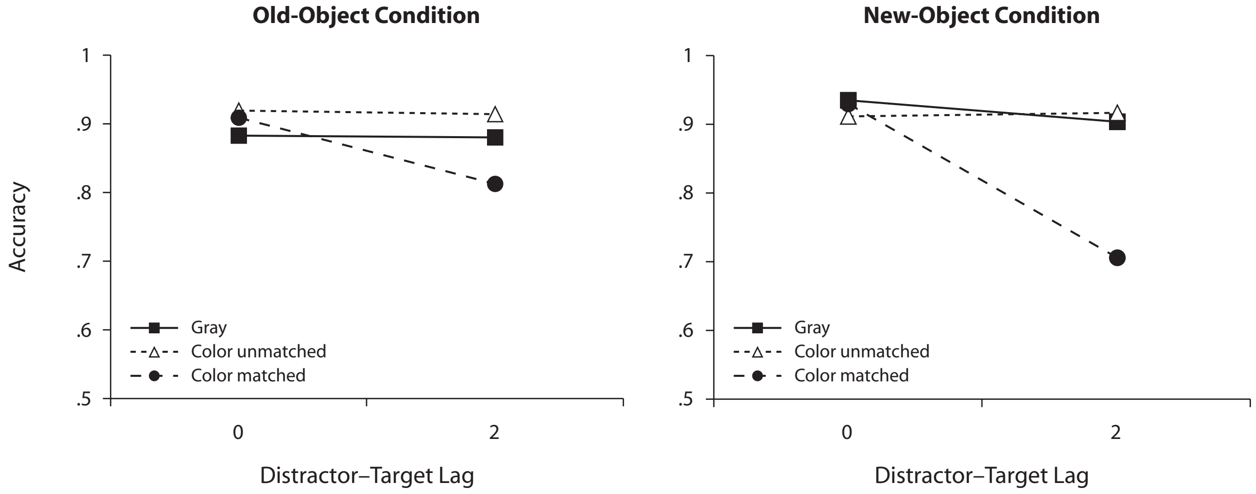

Figure 7. Accuracy of letter identification in Experiment 3A.

Table 4
Spatial Blink Index From Experiment 3A

Condition	Lag 0	Lag 2
Old object	−0.8	8.5
New object	−0.7	20.4

participants took 24 randomly selected trials as practice before they were exposed to the four blocks of test trials. A short break was given to the participants after two blocks.

Results

The accuracy of letter identification is plotted in Figure 7 as a function of distractor condition and distractor–target lag. As can be seen in the figure, a spatial blink induced by a color-matched distractor occurred. This is revealed by main effects of distractor condition and lag [$F(2,30) = 18.054, p < .001, \eta_p^2 = .546$; $F(1,15) = 23.95, p < .001, \eta_p^2 = .615$, respectively] and a significant two-way interaction between lag and distractor condition [$F(2,30) = 15.059, p < .001, \eta_p^2 = .501$]. The spatial blink also differed dramatically between the placeholder conditions (i.e., new-object vs. old-object), as was revealed by a significant three-way interaction between placeholder condition, distractor condition, and lag [$F(2,30) = 3.741, p < .05, \eta_p^2 = 0.2$].

We also analyzed the old-object and new-object conditions separately. In both conditions we observed main effects of distractor condition [$F(2,30) = 5.221, p < .05, \eta_p^2 = .258$; $F(2,30) = 22.968, p < .001, \eta_p^2 = .605$, for old-object and new-object, respectively] and distractor–target lag [$F(1,15) = 10.274, p < .01, \eta_p^2 = .407$; $F(1,15) = 19.115, p < .005, \eta_p^2 = .560$] and an interaction between the two [$F(2,30) = 4.763, p < .05, \eta_p^2 = .241$; $F(2,30) = 13.708, p < .001, \eta_p^2 = .478$]. This pattern indicates an impairment in target letter identification at lag 2, and only for color-matched distractors in each placeholder condition. The SBIs are shown in Table 4, which reveals a smaller spatial blink in the old-object than in the new-object condition. In the old-object condition, the SBI at lag 2 was 8.5%, whereas it was 20.4% in the new-object condition. (These values are different from each other, as revealed by the three-way interaction noted earlier.)

Discussion

In the present experiment, we manipulated the newness of the distractors by the location of placeholders prior to the distractor display, as in the earlier experiments. However, here, unlike in the earlier experiments, the placeholders did not appear in exactly the same locations as the distractors. Instead, they moved across the display, causing some distractors to appear to be old objects as a result of the convincing apparent motion. As a result, the distractors themselves would have been less likely to have been masked by the placeholders in the present experiment, as compared with the earlier ones. Despite this change, we again observed a much greater spatial blink when a color-matched distractor appeared in a new object, as opposed to an old one. This result reveals that bottom-up factors can enhance the magnitude of the spatial blink and is consistent with many previous studies showing that new objects can attract attention (Enns et al., 2001; Yantis & Hillstrom, 1994; Yantis & Jonides, 1996).

EXPERIMENT 3B

Experiment 3A was designed to rule out an alternative explanation for the reduced spatial blink in the color change condition in Experiments 1 and 2. According to that explanation, distractors not accompanied by an onset and offset in the earlier experiments were simply less salient because they were masked by the preexisting placeholders. We attempted to eliminate that possibility in Experiment 3A by using placeholders that were moving on the display and never appeared in exactly the same locations as the distractors. However, it is still possible that the placeholders there may have produced a small amount of masking—and that masking may have affected the distractors in the old-object condition more than it did those in the new-object condition. There are two reasons to believe so. First, there is some evidence that even objects in nearby locations can produce masking (Kahneman, 1967). Second, in Experiment 3A, the placeholders were somewhat closer to the old-object distractor locations than to the new-object locations in both the frame immediately before the distractors appeared and the frame immediately after the distractors. Thus, if there was any masking caused by the placeholders, the effect would have been greater in the old-object condition.

In order to rule out the possibility of greater masking in the old-object condition, we replicated Experiment 3A with a minor but important change. In the present experiment, we set the placeholders in the frames immediately before and after the distractor to be equidistant from both the old-object and the new-object distractor locations. We also made the placeholders in the two initial and final frames (i.e., two frames before and two frames after the distractor frame) *closer* to the *new-object* distractor locations. Thus, if masking is affecting the salience of the distractors, there should be greater masking affecting the new-object distractors here. If a reduced spatial blink in the old-object conditions earlier was caused by masking, we should find a very different pattern in the present experiment.

Method

Participants. Thirty undergraduate students from Washington University participated in a 30-min experimental session for course credit. All had normal or corrected-to-normal visual acuity and color vision. The participants had no experience in any similar experiments.

Apparatus and Procedure. The general procedure was the same as that in Experiment 3A. The only change here involved the locations of the placeholders. The five frames of the trial sequence that contained placeholders or distractors are shown in Figure 8. Here, in the frames immediately before and immediately after the distractor frame, the placeholders were in the corners of an imaginary 8.4º square upon which the distractor elements were placed. As a result, the placeholders in these frames were equidistant from the locations at which the old-object and new-object distractors were presented. In the first and last frames, the placeholders were placed an additional 4.2º in the periphery—along the line that they traversed in the apparent motion sequence. As a result, they were actually somewhat closer to the new-object distractor location than to the old-object location in these frames.

Design. The design was identical to that in Experiment 3A.

Results

The accuracy of letter identification is plotted in Figure 9 as a function of distractor condition and distractor–target lag. A spatial blink induced by the color-matched distractor still occurred, indicated by main effects of distractor condition and lag [$F(2,58) = 47.662$, $p < .001$, $\eta_p^2 = .622$; $F(1,29) = 15.784$, $p < .001$, $\eta_p^2 = .352$, respectively] and a significant interaction between distractor condition and lag

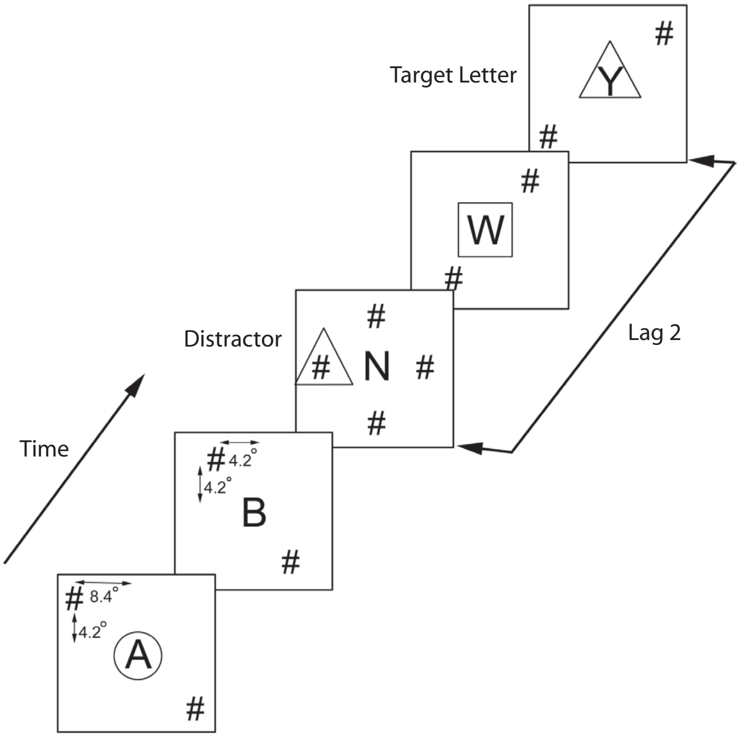

Figure 8. Schematic illustration of the procedure in Experiment 3B. The shapes surrounding the symbols designate stimuli of different colors and did not appear in the actual experiment. Each frame was presented for 40 msec and was followed by a blank interval of 40 msec.

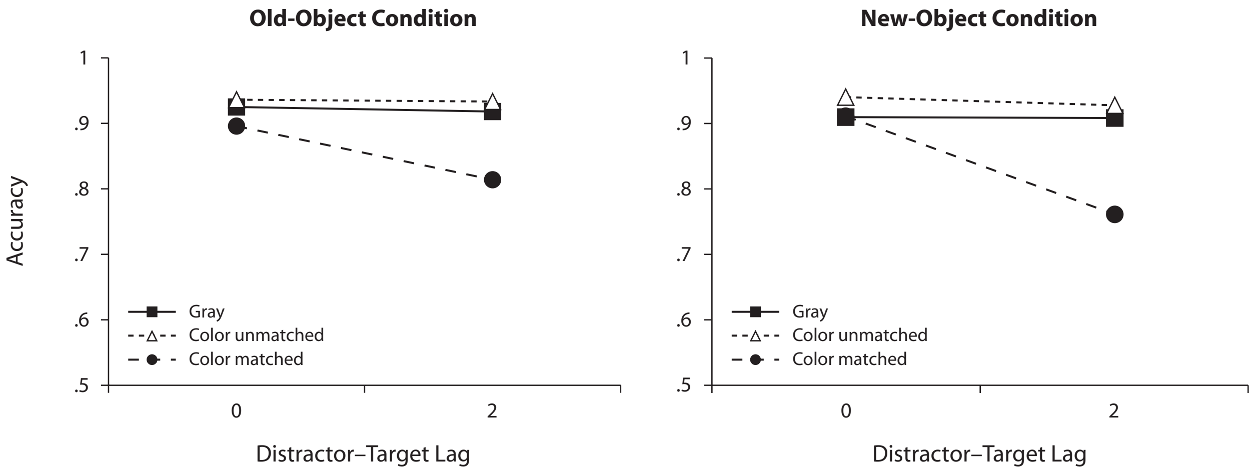

Figure 9. Accuracy of letter identification in Experiment 3B.

Table 5
Spatial Blink Index From Experiment 3B

Condition	Lag 0	Lag 2
Old object	3.5	11.2
New object	1.4	15.7

[$F(2,58) = 17.055$, $p < .001$, $\eta^2_p = .37$]. More important, although there was no main effect of placeholder condition [$F(1,29) = 3.736$, $p > .05$, $\eta^2_p = .114$], we found a significant three-way interaction [involving distractor condition, lag, and placeholder condition; $F(2,58) = 3.256$, $p < .05$, $\eta^2_p = .101$], which clearly shows that the spatial blink differed between the two placeholder conditions, with a greater impairment in the new-object condition.

In separate analyses of the two placeholder conditions, we found a small impairment caused by a color-matched distractor in the old-object condition, confirmed by a main effect of distractor condition [$F(2,58) = 31.224$, $p < .001$, $\eta^2_p = .518$; the SBI at lag 2 was 11.2%]. We also found a main effect of distractor–target lag [$F(1,29) = 6.277$, $p < .05$, $\eta^2_p = .178$] and an interaction between distractor condition and lag [$F(2,58) = 5.827$, $p < .01$, $\eta^2_p = .167$], indicating that the impairment occurred primarily at lag 2. In the new-object condition, however, a slightly greater impairment was induced by a color-matched distractor (the SBI at lag 2 was 15.7%). This was confirmed by main effects of distractor condition and distractor–target lag [$F(2,58) = 30.681$, $p < .001$, $\eta^2_p = .514$; $F(1,29) = 20.905$, $p < .001$, $\eta^2_p = .419$, respectively] and an interaction between distractor condition and lag [$F(2,58) = 18.773$, $p < .001$, $\eta^2_p = .393$]. The SBIs from the experiment are shown in Table 5.

Discussion

If the placeholders that we used here (and in Experiment 3A) continued to mask the distractors, the color-matched distractor in the new-object condition in the present experiment should have suffered more than that in the old-object condition. Nevertheless, we again found a reduced spatial blink in the old-object condition.[3] This result replicates the pattern in Experiment 3A and provides further support for the conclusion that the transient effects of new-object appearance can enhance the magnitude of the spatial blink.

EXPERIMENT 4

Experiments 1, 2, and 3 consistently showed that the mere onset of four distractors did not impair the letter identification as long as none of the distractors was the target color (the gray and color-unmatched conditions studied earlier). Thus, onset alone was insufficient to produce attentional capture independently, consistent with several studies of the top-down control over attention (Folk et al., 1992; Theeuwes, 1991; Yantis & Jonides, 1990; but see Christ & Abrams, 2006a). However, an alternative explanation is available for the inability of the distractors in the gray and color-unmatched conditions to capture attention. According to this explanation, participants tend to move their fixation and, presumably, attention to the center of gravity of a configuration of multiple objects during search (Zelinsky, Rao, Hayhoe, & Ballard, 1997). The symmetric configuration of distractors in our earlier experiments might have caused observers to attend to its center of gravity, which exactly overlapped the location of the letter stream. This might be why the onset of four gray or color-unmatched elements in the periphery did not capture attention.

In the present experiment, we tested the aforementioned possibility by presenting only a single distractor in the periphery of the display. If abrupt onset of a single distractor is sufficient to capture attention, a spatial blink (impairment in letter identification) should exist no matter what color the distractor has.

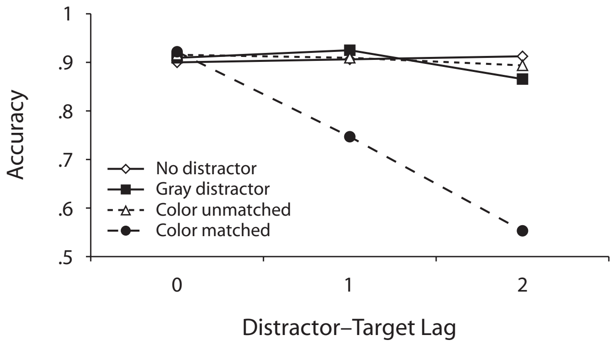

Figure 10. Accuracy of letter identification in Experiment 4.

Method

Participants. Twenty undergraduate students from Washington University participated in a 30-min experimental session for credit. All had normal or corrected-to-normal visual acuity and color vision. No participants had experience in similar experiments.

Apparatus, Procedure, and Design. The procedure and design here were similar to those of the onset-and-offset condition in Experiment 1A, with several exceptions. The main difference was that here, only a single distractor (a gray, green, or red pound sign) was presented. The distractor appeared on 75% of the trials, with equal numbers of each type of distractor. On 25% of the trials, there was no distractor. When the single distractor appeared, it could occupy any one of the four possible locations in the periphery. We studied distractor–target lags from 0 to 2.

Results and Discussion

The accuracy of letter identification is plotted in Figure 10 as a function of distractor condition and distractor–target lag. A significant main effect of distractor condition [$F(3,45) = 18.504$, $p < .001$, $\eta_p^2 = .552$] indicates that an impairment of letter identification occurred in the present experiment. In addition, the main effect of distractor–target lag [$F(2,30) = 9.792$, $p < .005$, $\eta_p^2 = .395$] and a two-way interaction [$F(6,90) = 11.464$, $p < .001$, $\eta_p^2 = .433$] further confirm that impairment occurred at the longer lag.

As can be seen in Figure 10, only the color-matched distractor impaired the identification of the target letter. Multiple comparisons showed that only the color-matched distractor resulted in a significantly lower accuracy, as compared with that of no distractor at lag 1 ($p < .05$) and lag 2 ($p < .001$). There was no decline in accuracy for color-unmatched or gray distractors, as compared with no distractor (all *p*s $> .05$). Therefore, the onset and offset of a color-unmatched distractor is insufficient to produce attentional capture in this paradigm. Only the color-matched distractor could independently capture attention. This is essentially the same conclusion as that drawn from Folk et al.'s (2002) original study with the onset of multiple symmetric distractors.

GENERAL DISCUSSION

Summary of the Results

Previous work can be interpreted as indicating a primarily top-down effect of distractors on attention in the spatial blink paradigm (Folk et al., 2002). The reason for this conclusion is that sudden onsets (and offsets) of distractors in the periphery did not disrupt target identification if the distractors did not match the target color but were disruptive if the distractors matched the target color. Nevertheless, Lamy et al. (2004) showed that a bottom-up factor (the presence of color singletons) can, indeed, interact with the effects of the color-matched distractor.

In the present study, we extended the investigation of potential interactive effects of top-down and bottom-up factors in the spatial blink paradigm. Here, we evaluated the contribution of the bottom-up factors of onset and offset to the spatial blink. Experiments 1A and 1B showed much larger impairments in target letter identification when an irrelevant distractor matched to the target color suddenly appeared and disappeared in the periphery (the onset-and-offset condition), as compared with the same distractor when it was revealed by a change from gray to the target color (the color change condition). That result indicates that the magnitude of the spatial blink is enhanced by the presence of onsets and/or offsets. The reduced spatial blink in the absence of onsets and offsets might have occurred due to visual masking of the changing-color distractors (in the color change condition) in Experiment 1. To address that possibility, Experiments 3A and 3B used distractors that could be considered either new objects in the display or old objects, yet we used a method that eliminated the possibility of a differential effect of masking of the two types of distractors. The results again showed a larger spatial blink in the new-object condition (a conceptual counterpart to the onset-and-offset condition in Experiment 1) than in the old-object condition (a conceptual counterpart to the color change condition in Experiment 1). The results of Experiments 1 and 3 clearly show that goal-driven attentional selection (an attentional set for the target-defining color) and stimulus-driven selection (caused by the sudden appearance of a new distractor) have a synergistic effect on visual attention (as revealed by the change in the spatial blink). This is consistent with previous findings from others that have revealed synergistic effects of stimulus-driven salience and goal-driven priority in cuing and visual search paradigms (Lamy et al., 2004; Ludwig & Gilchrist, 2002, 2003).

In Experiment 2, we examined the separate contributions of onsets, as opposed to offsets. We found there that the onset-only condition produced almost the same amount of spatial blink as the offset-only condition. Nevertheless, it might be inappropriate to conclude that onsets and offsets have equivalent effects, because perception of the distractor is likely to have been affected by backward masking from the placeholder in the onset condition and forward masking in the offset condition, and the present data are not sufficient to allow us to compute the precise magnitude of the masking in both cases.

Experiment 4 pursued two possible alternative explanations for the failure of nontarget-color distractors to capture attention in the spatial blink paradigm. Such a failure to capture was observed in our Experiments 1–3, as well as in the work of others (e.g., Folk et al., 2002). It is possible that either the presence of multiple onsets or the symmetric configuration of the multiple distractors in those experiments rendered the distractors ineffective. The results from Experiment 4 ruled out both of the alternative explanations, because only a color-matched distractor caused a spatial blink when a single distractor appeared abruptly in the periphery. Thus, the mere bottom-up activation produced by the onset and offset of distractors is not sufficient to attract attention in the spatial blink paradigm when the distractor color does not match that of the target. The ability to ignore onsets is consistent with previous findings that onset capture can be overridden by top-down control under conditions of spatial certainty (Theeuwes, 1991; Yantis & Jonides, 1990; but see Christ & Abrams, 2006a).

Spatial Control Setting and Onset Capture

Our results clearly revealed that an irrelevant distractor that matches the target color can cause involuntary covert orienting but that the onset of a color singleton was insufficient to capture attention. At first glance, our results seem inconsistent with some previous findings indicating that an onset can cause involuntary shifts of attention even when it is completely irrelevant to the task (Ludwig & Gilchrist, 2002, 2003; Theeuwes, 1994). The discrepancy may be due to the difference in tasks. All of the aforementioned studies employed a visual search task with multiple possible target locations, whereas targets in the spatial blink task always appeared at fixation. The increased spatial certainty, along with fixation at the target location in the present study, might have suppressed the effects of onset capture.

However, our results do not necessarily indicate that a spatial blink would never be induced by a salient distractor that did not match the target color. Theeuwes (2004) showed that a salient but task-irrelevant feature singleton failed to capture attention in visual search when visual noise in the scene was high. However, the same irrelevant feature singleton could penetrate top-down control and produce attentional capture when it was salient enough. Thus, it remains possible that a spatial blink could be caused by a color-unmatched distractor if it was highly salient. Nevertheless, it is clear from the present experiments (as well as those in Folk et al., 2002) that a distractor that is sufficiently salient to disrupt performance when matched to the target color had no effect on performance when not matched to the target color.

Synergy Between Stimulus-Driven Salience and Goal-Driven Priority

Our results suggest a synergism between top-down attentional control and stimulus-driven attentional capture. This is consistent with a previous finding (Lamy et al., 2004) that showed a synergetic effect between top-down control (target-defining color) and stimulus-driven salience (a salient color singleton). The present study extended the findings of Lamy et al. and showed that another stimulus-driven factor, onset and offset signals, could boost the contingent capture effect of a color-matched distractor too (indexed by larger spatial blink). But how the onset and offset signals modulate the magnitude of the spatial blink is still unknown. There are two possible explanations. One possibility is that the effect of onset and offset is contingent upon top-down control (Folk et al., 1992). In particular, the top-down control setting could work as a filter, only passing activation that was produced by a bottom-up signal relevant to the task goal. As a result, onset and offset signals could enhance the spatial blink, but only when the distractor matched the target color.

An alternative possibility is that onset and offset signals always add saliency to stimuli in a scene but top-down control modulates the salience and, hence, the attentional priority. The onset and offset signals thus were suppressed by top-down control when the distractors did not match target color. Thus, color-unmatched distractors never induced a spatial blink. However, when a color-matched distractor appeared abruptly in the periphery, the onset and offset signals were enhanced by the top-down control, resulting in a larger spatial blink.

Although both explanations could account for our results, we prefer the latter one, for several reasons. First, Lamy and colleagues showed that irrelevant feature singletons that did not match the top-down control setting caused inhibition at the singleton's location in a feature search task (Lamy & Egeth, 2003; Lamy et al., 2004). No inhibition should be observed if the effect of an irrelevant singleton is contingent upon the top-down control setting. Second, in some cases, if a stimulus is salient enough, it can penetrate top-down control and capture attention involuntarily (Bacon & Egeth, 1994; Theeuwes, 2004).

But how the visual system coordinates salient bottom-up signals and goal-directed priority is largely unknown. Theeuwes (1995) proposed that early stages of visual processing are purely stimulus driven and cannot be modulated by top-down control. Kim and Cave (1999) believed that top-down control was usually negligible during preattentive processing (less than 100 msec) but that it could influence preattentive stages after extensive practice. Serences and Yantis (2006) suggested that the visual processing at each level past the retina was influenced by both stimulus-driven salience and goal-directed priority: Low levels of the visual cortex are dominated by stimulus-driven salience, whereas the goal-directed influence becomes progressively larger in higher levels of the visual system. By using a similar spatial blink task, Serences et al. (2005) were able to identify the temporoparietal junction and the ventral frontal cortex (TPJ and VFC) as the key brain regions involved in coordinating top-down (voluntary) control settings with salient bottom-up signals from the visual scene. However, their conclusion may apply only to stimulus-driven salience from a feature singleton, rather than from a transient event such as an onset, because placeholders in the periphery were present in their study at all times. Whether the TPJ and VFC are critical for all kinds of coordination between top-down control settings and bottom-up salience needs further testing.

Whatever the underlying mechanism, it is clear that bottom-up signals and top-down control work together in guiding visual attention. Our results, along with those of many other studies (Lamy & Egeth, 2003; Lamy et al., 2004; Ludwig & Gilchrist, 2002, 2003; Serences et al., 2005), provide converging evidence for a synergism that may be essential for survival. Only when equipped with a balance between top-down control and bottom-up salience are people able to focus on an ongoing task without ignoring ecologically salient events in scenes.

AUTHOR NOTE

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NOTES

1. The magnitude of the spatial blink was approximately constant from lag 1 to lag 3 (corresponding to intervals of 80–240 msec) in the present experiment. Although some researchers have reported greater spatial blink magnitudes at lag 2 than at other lags (Folk et al., 2002, corresponding to a 168-msec delay; Lamy et al., 2004, 200 msec), others have found that the spatial blink effect peaked at lag 1 (Leblanc & Jolicœur, 2005, 117 msec) and decreased as lag increased. It is possible that these differences are due to unique visual properties of the stimuli, such as the eccentricity and size of the distractors. For example, the distractors in the present study were larger and closer to fixation than were those in Folk et al. (2002). Given the differences in the time course of the spatial blink across studies, we do not believe that these differences alter the interpretation of the effects reported.

2. It might be expected that the SBI in the onset-and-offset condition would be equal to the sum of the SBIs in the onset-only and offset-only conditions. But an inspection of Table 3 reveals that the sum of SBIs in the onset-only and offset-only conditions ($20.2 + 21.1 = 41.3$) exceeds that in the onset-and-offset condition (32.2). Presumably, however, the spatial blinks in the onset-only and the offset-only conditions have attentional components in common, and as a result, the sum of their effects would overestimate the effect that might be expected in a single condition that contained both onsets and offsets. An estimate of the component shared by the onset-only and offset-only conditions is provided by the magnitude of capture caused only by the contingent capture of a color-matched distractor. Indeed, such a color-matched distractor was included in both the onset-only and the offset-only conditions. An estimate of the impact of the color-matched distractor on the spatial blink can come from the magnitude of the blink in the color change condition, which included only the effects of a color-matched distractor. As can be seen in Table 3, the sum of the SBIs in the onset-only and offset-only conditions minus that in the color change condition (because that component is presumably included twice in the earlier sum; $41.3 - 8.1 = 33.2$) is very close to the figure from the onset-and-offset condition alone (32.2).

3. In theory, it is possible that the interaction between distractor condition, lag, and placeholder condition shown in Figure 9 might be due to either an increased spatial blink at lag 2 in the new-object condition (as compared with the old-object condition; the explanation that we have offered) or to a decreased spatial blink at lag 0 in the new-object condition (as compared with the old-object condition). In order to distinguish between these possibilities, we compared the SBI in the new-object condition with that in the old-object condition at the two lags separately. The comparison revealed that the SBI in the new-object condition was indeed significantly larger than the SBI in the old-object condition at lag 2 [$F(1,29) = 4.331$, $p < .05$, $\eta_p^2 = .13$]. Furthermore, the SBI in the new-object condition did not differ from that in the old-object condition at lag 0 [$F(1,29) = 1.067$, $p > .05$, $\eta_p^2 = .035$]. This pattern of results indicates that the new-object condition did produce a spatial blink larger than that in the old-object condition at lag 2.

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