General Article

HOW NOT TO BE SEEN: The Contribution of Similarity and Selective Ignoring to Sustained Inattentional Blindness

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When people attend to objects or events in a visual display, they often fail to notice an additional, unexpected, but fully visible object or event in the same display. This phenomenon is now known as inattentional blindness. *We present a new approach to the study of sustained inattentional blindness for dynamic events in order to explore the roles of similarity, distinctiveness, and attentional set in the detection of unexpected objects. In Experiment 1, we found that the similarity of an unexpected object to other objects in the display influences attentional capture: The more similar an unexpected object is to the attended items, and the greater its difference from the ignored items, the more likely it is that people will notice it. Experiment 2 explored whether this effect of similarity is driven by selective ignoring of irrelevant items or by selective focusing on attended items. The results of Experiment 3 suggest that the distinctiveness of the unexpected object alone cannot entirely account for the similarity effects found in the first two experiments; when attending to black items or white items in a dynamic display, nearly 30% of observers failed to notice a bright red cross move across the display, even though it had a unique color, luminance, shape, and motion trajectory and was visible for 5 s. Together, the results suggest that inattentional blindness for ongoing dynamic events depends both on the similarity of the unexpected object to the other objects in the display and on the observer's attentional set.*

The belief that in order to see something one simply needs to direct one's eyes toward it has received several empirical challenges over the past three decades (e.g., Mack & Rock, 1998; Neisser & Becklen, 1975; Simons & Chabris, 1999). In one early study, observers watched a videotape of a group of people in white shirts passing a basketball among themselves overlaid over a video of a group of people in black shirts doing the same, so that both videos appeared partially transparent. Observers attended to one of the two teams and pressed a key whenever that team made a pass. After 30 s, a woman carrying an umbrella (also overlaid and partially transparent) walked across the display, remaining visible for roughly 4 s as she moved from one side to the other. Strikingly, only 21% of naive observers reported seeing the woman (Neisser & Dube, 1978, cited in Neisser, 1979) even though she was visible to anyone not keeping track of passes. In another version of this task, the woman with the umbrella wore the same colored shirt as either the attended team or the ignored team. However, the similarity of the woman's appearance to that of the other players did not affect detection (Neisser, 1979).

Recently, Simons and Chabris (1999) replicated these selective-looking results, finding that 44% of observers missed the "umbrella woman." Furthermore, under similar conditions, when the unexpected object was a person in a gorilla suit rather than an umbrella woman, even more people (73%) missed it. Interestingly, the rate of noticing the gorilla depended on whether the observers attended to the team in white or the team in black. Those attending to the team in black noticed the black gorilla more often (58%) than those attending to the team in white (27%); in contrast to the results reported by Neisser (1979), the perceptual similarity between the unexpected event (the gorilla) and the ignored or attended teams did seem to make a difference.

A more recent series of studies used briefly presented static displays to explore the perception of unexpected objects (see Mack & Rock, 1998, for an overview). In these studies, observers viewed a briefly presented cross and tried to determine which of its arms was longest. After several trials, a *critical trial* occurred: An unexpected object (e.g., a small square) appeared alongside the cross. Immediately after the trial, observers were asked if they had seen anything other than the cross. These experiments revealed a large degree of *inattentional blindness*: Approximately 25% of observers failed to notice the unexpected object on the critical trial (Mack & Rock, 1998). Perhaps even more strikingly, when observers attended to a cross that was presented parafoveally (away from fixation) and the unexpected stimulus appeared at fixation,

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even more observers—approximately 75%—missed it. This finding suggests that observers may actively inhibit processing at fixation when they concentrate attention elsewhere in the display. Furthermore, unexpected objects with distinctive colors, motions, or orientations were no more likely to be noticed in this paradigm than were simple black shapes (Mack & Rock, 1998).

Findings of inattentional blindness seem to provide evidence against the notion that salient and distinctive stimuli automatically capture attention (e.g., Theeuwes, 1994). Instead, detection may be contingent on whether observers expect an object feature. The primary idea of this *contingent-capture* hypothesis (Folk, Remington, & Johnston, 1992) is that attentional capture depends on the observer's attentional set; when observers have an attentional set for a particular feature, only that feature will capture attention. If they do not expect that feature, it will not draw attention (e.g., if observers vigilantly expect a stimulus with a unique luminance, only stimuli with unique luminances—not unique motions or shapes—will capture attention). According to this view, the salience of a stimulus alone does not fully determine whether it captures attention.

Studies of inattentional blindness and attentional capture have largely been limited to brief, static displays. This approach has helped to elucidate the role of stimulus salience in capturing attention, but it is suboptimal for exploring attentional capture under more naturalistic viewing conditions. After all, these computer displays are motionless and fleeting, qualities quite different from those in people's daily visual experience of a sustained and dynamic world. Yet the complex, naturalistic videos used in selective-looking studies also are not optimal for a systematic exploration of the role of similarity between the unexpected object and the other objects in the display because they do not allow the same degree of control over the appearance of the display.

The current article presents the first of a series of studies that combine the dynamic nature of the selective-looking paradigm (Neisser, 1979; Simons & Chabris, 1999) with the rigerous control of the static inattentional blindness paradigm (Mack & Rock, 1998). Participants selectively attended to certain shapes moving about a computer display, while the colors and luminances of these shapes (and of additional unexpected shapes) were carefully controlled and varied. Using this sustained inattentional blindness task, we addressed three main issues. In Experiment 1, we explored whether the similarity of the unexpected object to the other objects in the display influences attentional capture. In Experiment 2, we considered whether the effects of similarity on inattentional blindness are driven by selective focusing on attended items or selective ignoring of irrelevant items. Finally, in Experiment 3, we considered whether sustained inattentional blindness would occur at a greater rate than in the previous experiments if the unexpected object differed on several dimensions from all other objects in the display.

EXPERIMENT 1

Method

Participants

One hundred forty-five observers were tested individually in exchange for candy. Data from 17 observers were subsequently excluded because of previous knowledge of inattentional blindness or related research (8), failure to see the unexpected event in the full-attention trial (3), computer error (1), experimenter error (2), visual impairment (1), failure to understand instructions (1), and ambiguity of response (1). The remaining 128 observers (75 male, 53 female; mean age = 20.8 years) were equally distributed across the eight experimental conditions (described in the next section).

Materials and procedure

Stimuli were presented using custom software written with Micro M-L's Vision Shell C libraries (http://www.mlink.net/~ml) on a Macintosh G3 PowerBook with a 14.1-in. active matrix display. Head position was not fixed, and observers sat at a comfortable distance from the display (on average, approximately 35 cm). All of the events on each trial took place against a gray 12.7- × 15.5-cm display window (luminance = 32.1 cd/m^2) with a small blue fixation point located at its center. (Note that luminance values are approximate and vary slightly with the orientation of the monitor relative to the viewer. All luminance measurements were made from the same orientation.) Within this window, four black (luminance = 1.2 cd/m^2) and four white (luminance = 88.0 cd/m^2) *L* and *T* shapes (1-cm × 1-cm block letters) all moved independently on random paths at a variable rate ranging from 2 to 5 cm/s. As they moved, the objects could occlude each other, and each black and white shape periodically "bounced" off the edges of the display window. Each trial lasted for a total of 15 s, and each observer completed five trials.

Observers were instructed to fixate on the central point and to keep a silent tally of the total number of times either white or black shapes bounced off the edges of the display window during each 15-s trial. We emphasized that they should count only the bounces of the attended shapes (e.g., black but not white). Half the observers attended to the white shapes and half attended to the black shapes. Following each trial, observers indicated the number of bounces they had seen, in response to a prompt from the computer.

The sequence of trials in this experiment was modeled after previous inattentional blindness experiments (Mack & Rock, 1998). The first two trials contained no unexpected event. Five seconds into the third trial (the critical trial), a cross with the same horizontal and vertical extent as the *L*s and *T*s unexpectedly entered from the right side of the display, moved horizontally on a linear path across the center of the screen, passed behind the fixation point, and exited the left side of the display.

During these trials, the cross was visible for 5 s. The luminance of the cross varied across conditions, ranging from white (luminance = 88.0 cd/m^2), to light gray (luminance = 49.3 cd/m^2), to dark gray (luminance = 19.2 cd/m^2), to black (luminance = 1.5 cd/m^2). Thus, the experiment was a 2 (luminance of attended items: black vs. white) × 4 (luminance of unexpected cross: black vs. dark gray vs. light gray vs. white) between-subjects design. Because observers were not forewarned about the cross, its appearance was unexpected. (See Fig. 1 for an illustration of the display. QuickTime versions of some of these displays are available on the World Wide Web on the demonstrations page of http://www.wjh.harvard.edu/~viscog/lab/.)

After the critical trial, observers were given a printed questionnaire, on which they were asked to report whether they had seen anything unusual on the screen. They were then asked to report (or guess, if they had not seen the object) the details of the object, including color, shape, and path of motion (see the appendix for the exact wording of all the questions). Observers then completed a fourth trial on which the cross again appeared. Although they were not explicitly told to look for the cross, the questionnaire after the previous trial alerted them to the possibility that an additional object might appear. Therefore, this trial tested perception under *divided-attention* conditions. After completing this trial, observers filled out a second questionnaire, identical to the first.

On the fifth trial, observers were told: “On this trial, the instructions are slightly different. As before, keep your eyes fixated on the fixation point, but this time don’t count the bounces any of the shapes make. Simply watch the display.” Because observers did not have to count bounces, they could devote full attention to the formerly unexpected object. After this *full-attention* trial, they completed a questionnaire identical to the first two. Because observers should have seen the object in the full-attention trial (Mack & Rock, 1998), we used this trial as a control to ensure that they could understand and follow task instructions. Accordingly, 3 observers who failed to see the cross on this trial were replaced, and their data were excluded from the analyses.

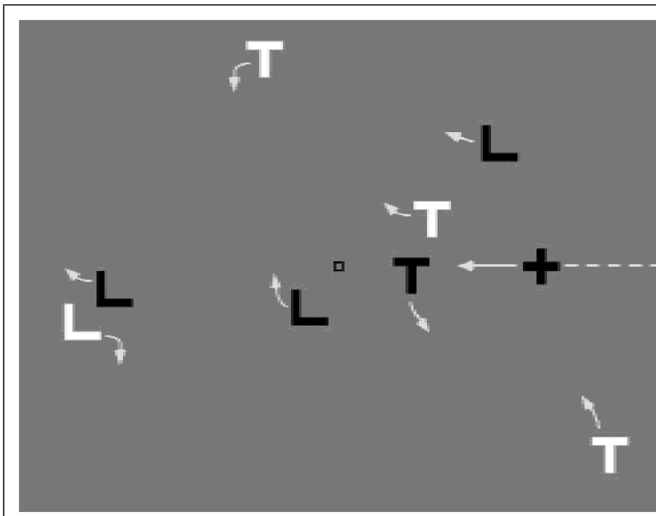

Fig. 1. Still frame from a single critical trial with a black unexpected object. Arrows and a dashed line have been added to indicate the direction of motion at this moment. The cross always moved in a straight line from right to left across the display, whereas the other objects moved independently on random, nonlinear paths.

After completing all five trials, observers answered follow-up questions designed to gather demographic information and to determine if they had been familiar with this or other related experiments (e.g., Simons & Chabris, 1999) prior to participation. If they spontaneously mentioned experiments from the selective-looking or inattentional blindness literatures, they were considered to be familiar with the paradigm, and their data were excluded from the analyses (because we wanted observers to have no prior expectation that another object might appear). Participating in the experiment took 5 to 10 min, and observers were debriefed afterward.

Results

Previous research on selective looking produced conflicting results for the effect of similarity on detection of an unexpected object. The original selective-looking studies (Neisser, 1979) found that observers were no more likely to see the unexpected object when it was similar to the attended items than when it was similar to the ignored items. This finding suggests that detection depends on the observer’s expectations (and possibly the salience of the unexpected event), but not on the physical similarity of the unexpected object to the other items in the display. In contrast, more recent findings (Simons & Chabris, 1999) suggest that observers should be more likely to notice unexpected objects when they are similar to the attended items than when they are dissimilar.

Our results demonstrate a substantial role for visual similarity in detection: When the unexpected cross was more similar in luminance to the attended items, a greater number of observers noticed its appearance on the critical trial (see Fig. 2). Observers were regarded as having seen the unexpected object if they answered “yes” when asked if they had seen anything on the critical trial that had not been present before and if they were able to describe its color, motion, or shape (see the appendix). Nearly everyone who claimed to have seen something was able to describe one of these features. Across all conditions in this experiment, only 3 participants who claimed to have seen something were actually coded as having failed to see the unexpected cross, because of their inadequate descriptions. Reversing the coding for these observers did not substantially alter the results. The differences in noticing rates across the luminance conditions were reliable for observers attending to white, $\chi^2(3, N = 64) = 27.87, p < .001$, and for observers attending to black, $\chi^2(3, N = 64) = 35.74, p < .001$. The overall effect of similarity was also reliable when combined across all observers, $\chi^2(3, N = 128) = 56.72, p < .001$. This effect was evident on the divided-attention trial as well:

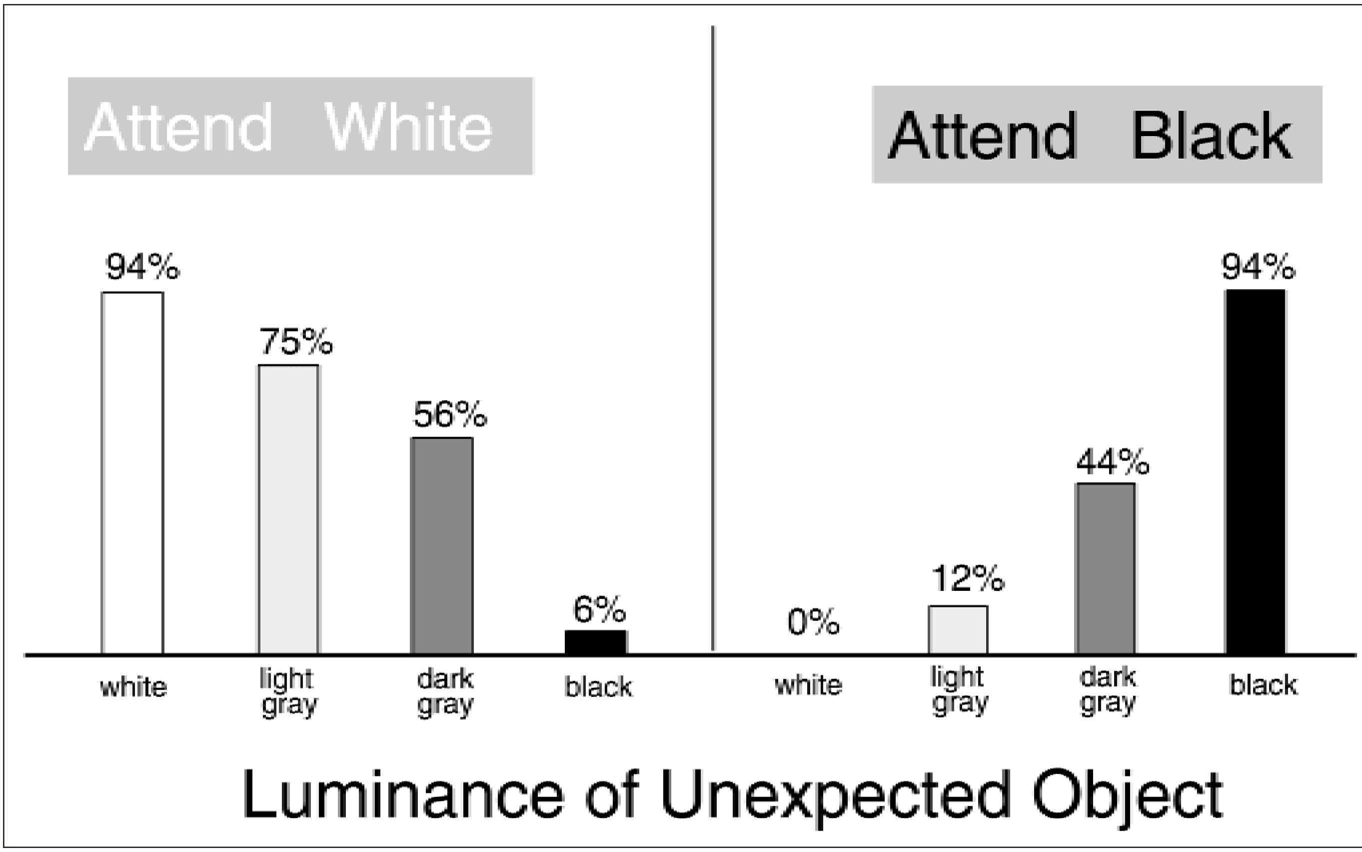

Fig. 2. Percentage of observers in each condition who noticed the unexpected object on the critical trial in Experiment 1.

attending white, $\chi^2(3, N = 64) = 14.90, p < .001$; attending black, $\chi^2(3, N = 64) = 21.17, p < .001$; overall, $\chi^2(3, N = 128) = 35.41, p < .001$. The results of the critical and divided-attention trials for all eight conditions are reported in Table 1.

Error rates in the primary counting task were calculated for each participant by taking the absolute value of the difference between each count and the actual number of bounces on that trial and then dividing that difference by the number of actual bounces on that trial. Thus, the average of these error rates represents the percentage error relative to the total number of actual bounces. Accuracy in the counting task on the critical trial, averaged across all conditions, did not differ significantly between observers who noticed the unexpected stimulus (mean error = 22.0%, *SD* = 15.6%) and those who did not (mean error = 18.4%, *SD* = 12.4%), $t(124) = 1.44, p = .15$. (Accuracy data from 2 subjects were not included in this analysis because of computer error during data collection.) In other words, observers who noticed the unexpected object on the critical trial were no more or less accurate than those who did not. There was also no difference in accuracy rate between noticers and nonnoticers on the second trial, during which no unexpected object appeared (mean error for noticers = 14.9%, *SD* = 11.5%; mean error for nonnoticers = 16.0%, *SD* = 11.8%), $t(124) = 0.511, p = .610$. Thus, group differences in the ability to perform the primary task cannot account for differences in rates of noticing the unexpected object.

For observers who noticed the cross on the critical trial, accuracy in counting on the critical trial was lower than on the previous (second) trial, $t(59) = 3.02, p = .004$. There was no such decrease in accuracy among observers who did not notice

Table 1. *Percentage of observers noticing the unexpected object in the critical and divided-attention trials in Experiment 1*

Luminance of unexpected cross	Trial type: Critical	Divided-attention
Attending white, ignoring black		
White	94	94
Light gray	75	94
Dark gray	56	75
Black	6	44
Attending black, ignoring white		
White	0	31
Light gray	12	62
Dark gray	44	88
Black	94	100

Note. $n = 16$ per condition.

the cross, $t(65) = 1.40$, $p = .17$. However, the relative difference in error rates between the second and critical trials did not differ significantly for noticers versus nonnoticers, $t(124) = 1.62$, $p = .11$. The decrease in accuracy on the critical trial for those who noticed the cross can likely be attributed to the fact that they noticed. That is, because accuracy was comparable for noticers and nonnoticers on the second trial, lower accuracy on the primary task did not determine whether the cross was detected. Instead, detection of the cross on the critical trial apparently reduced accuracy on the primary task. The slight, but nonsignificant reduction in counting performance among nonnoticers might be taken to imply implicit detection of the cross, an intriguing possibility in need of further study.

Discussion

The visual similarity between the attended objects and the unexpected object dramatically affected the probability of detection. When the unexpected item had the same luminance as the attended items, almost all observers saw it. When it had the same luminance as the ignored items, almost nobody saw it. Even at intermediate luminances, the more similar the unexpected object to the attended items—and the more different from the ignored items—the more likely it was to be detected. These findings refute models in which visual similarity plays little role in determining what will be noticed (Neisser, 1976).

It is unclear, however, which similarity comparison drives the effect: similarity to the attended set or dissimilarity from the ignored set. Perhaps observers notice only those objects that are similar to the attended items, filtering out any items that are different from them. If so, observers should fail to notice any objects that are different from the attended set. Alternatively, observers may selectively ignore items in the display that resemble the unattended set of items (Duncan & Humphreys, 1989; Watson & Humphreys, 1997, 1998). In this case, observers should fail to notice any objects that are similar to the unattended items, but they still might notice other irrelevant stimuli in the display. Both of these explanations are entirely consistent with the results of Experiment 1. Accordingly, Experiment 2 was a preliminary attempt to discriminate between them.

EXPERIMENT 2

In Experiment 1, the luminance of the unexpected object varied along a continuum between that of the attended items and that of the ignored items. Consequently, any increase in the similarity to the attended items entailed an equivalent decrease in the similarity to the ignored items. In Experiment 2, we again used a luminance continuum, but the attended items were always at the center of the continuum, with the ignored items at one of the ends. In this case, the unexpected object was either (a) different in luminance from the attended items and of the same luminance as the ignored items or (b) different in luminance from the attended items but on the opposite end of the luminance continuum from the ignored items. If detection depends on the similarity of the unexpected object to the attended items, then similarity to the ignored items would have no effect on detection in this experiment; observers would be just as likely to notice the unexpected object when its luminance was similar to the ignored items as when it was different from the ignored items, because it was comparably similar to the attended items in each case. For example, if the attended items were gray and the ignored items were black, observers would be just as likely to notice a black unexpected object as a white unexpected object because the two would be comparably different from the gray attended items. Alternatively, if detection depends on the difference of the unexpected object from the ignored items, detection would be greater when the luminance of the unexpected object was different from the luminance of the ignored items than when it was the same as the luminance of the ignored items. For example, with gray attended and black ignored items, observers would be more likely to notice a white unexpected object than a black one.

Method

Participants

Seventy-four observers were tested individually in exchange for candy. Data from 10 observers were subsequently excluded because of computer error (3), previous knowledge of inattentional blindness research (3), failure to notice the unexpected event on the full-attention trial (3), and ambiguous responses (1). The remaining 64 observers (42 male, 22 female; mean age = 19.1 years) were equally distributed across four conditions (described in the next section).

Materials and procedure

The materials used in Experiment 2 were identical to those of Experiment 1, except for two details. First, the background of the display window was aquamarine (luminance = 10.2 cd/m^2), rather than gray. This allowed for the second difference: The attended items were gray (32.1 cd/m^2), approximately halfway between black and white. Accompanying the gray attended shapes was either a set of black distractor shapes or a set of white distractor shapes with the same luminance values as in Experiment 1. On the critical, divided-attention, and full-attention trials, either a white or a black cross passed through the display in exactly the same manner as in Experiment 1. Thus, the design was a 2 (luminance of unattended items: black or white) × 2 (luminance of unexpected cross: black or white) matrix in which the unexpected object's luminance was either identical to that of the ignored items or maximally different from that of the ignored items. (In both cases, the unexpected object differed in luminance from the attended items because the luminance of the attended items was between these extremes.)

Results

The results revealed a large effect of similarity to the ignored items. Fewer observers detected the unexpected cross on the critical trial when it was similar to the unattended items than when it was different from them: ignoring white, $\chi^2(1, N = 32) = 12.70$, $p < .001$; ignoring black, $\chi^2(1, N = 32) = 24.89$, $p < .001$; overall effect, combining across ignored luminance, $\chi^2(1, N = 64) = 36.57$, $p < .001$ (see Fig. 3). Only 6% of observers noticed the unexpected object when it had the same luminance as the ignored items, whereas 81% of observers noticed it when it had a different luminance, even though in both cases, its luminance was different from that of the attended items (2 participants who responded that they had seen something were coded as not having seen the cross, because of their inadequate descriptions).

This effect was present but less evident on the divided-attention trial: ignoring white, $\chi^2(1, N = 32) = 1.18$, $p = .28$; ignoring black, Fisher Exact Test, $p = .09$; overall effect, combining across ignored luminance, $\chi^2(1, N = 64) = 3.48$, $p = .062$. Even though observers knew an unexpected object might appear, they still were somewhat less likely to see it when it had the same luminance as the unattended items. The data from the critical and divided-attention trials for all four conditions are reported in Table 2.

Discussion

These preliminary results suggest that selective ignoring contributes to rates of inattentional blindness in this paradigm. Noticing rates were substantially greater when the unexpected object differed from the ignored items than when it was similar to them. However, there are at least two alternative explanations for this result. One is that observers may have performed the task by relying on the linear separability of the display into light items and dark items (e.g., Bauer, Jolicoeur, & Cowan, 1996). For example, if the ignored items were white, observers could establish a luminance threshold, selectively attending to all objects darker than that threshold while ignoring all objects lighter than it. In this case, an unexpected black object would fall onto the darker side of the continuum and would be noticed, whereas a white item would fall onto the ignored side of the continuum and would be missed. Further experiments are needed to explore the possibility of this alternative mechanism, perhaps by varying the similarity of the unexpected object to the ignored items along a dimension orthogonal to that defining the difference between the attended and ignored items.

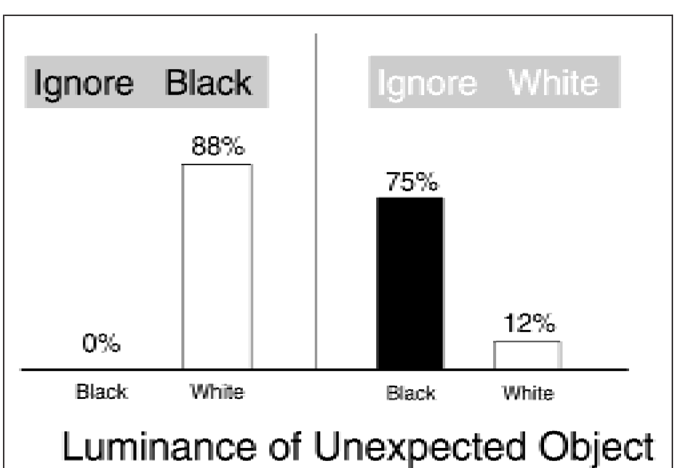

Fig. 3. Percentage of observers in each condition who noticed the unexpected object on the critical trial in Experiment 2.

Table 2. *Percentage of observers noticing the unexpected object in the critical and divided-attention trials in Experiment 2*

Luminance of unexpected cross	Trial type: Critical	Trial type: Divided-attention
Attending gray, ignoring white		
White	12	50
Black	75	69
Attending gray, ignoring black		
White	88	88
Black	0	62

Note. $n = 16$ per condition.

Another plausible alternative explanation for this result is that the unexpected object was simply more distinctive because it had a unique luminance value (e.g., it was the only white item when the other items were gray or black). The distinctiveness of the item might have drawn attention, increasing the probability of detection. Although the linear-separability and active-ignoring hypotheses are difficult to disentangle, our data provide some evidence against a strong form of the distinctiveness explanation. First, note that the gray items in Experiment 1 were also unique in luminance, yet they were not always noticed. Second, the shape and path of motion of the unexpected object in all conditions were different from the shape and path of all other items in the display, yet in several conditions, almost no observers noticed the unexpected object.

EXPERIMENT 3

In order to explore the distinctiveness hypothesis further, we conducted a third experiment in which observers attended or ignored white and black items against a gray background and the unexpected object was a red cross. The shape of the unexpected object was made even more distinctive by using circles and squares as the attended and ignored items, rather than *L*s and *T*s. If the distinctiveness and salience of the unexpected object determine noticing, then it would be reasonable to expect that the red cross would be noticed more than the distinctive items in Experiment 2.[1]

Method

Participants

Thirty-three observers were tested individually in exchange for candy. Data from 1 observer were subsequently excluded because the observer had previously heard of inattentional blindness. The remaining 32 observers (18 male, 14 female; mean age = 23.6 years) were equally divided into the two experimental conditions (described in the next section).

Materials and procedure

The materials and procedures were identical to those of Experiment 1 except that the attended objects were circles and squares rather than *L*s and *T*s, and the unexpected object was a red cross (luminance = 14.1 cd/m^2). Thus, the unexpected object differed even more from the other objects in the display than in the previous experiments, in both shape and color. As in Experiment 1, participants attended to either the black or white items in the display.

Results and Discussion

If the results of Experiment 2 were due to the distinctiveness of the unexpected object, then the red cross should have been detected more consistently. Yet only 72% of observers noticed the red cross on the critical trial (only 1 participant who claimed to have seen something was coded as not having seen the cross, because of an inadequate description). The proportion of observers noticing the cross did not differ substantially between those attending to the white items (75%) and those attending to the black items (69%), $\chi^2(1, N = 32) = 0.15$, $p = .69$. More important, even though the red cross was more distinctive than the unique items in Experiment 2, it was actually noticed somewhat less often, $\chi^2(1, N = 64) = 0.78$, $p = .38$, combining across conditions in both experiments. Thus, the high noticing rates in Experiment 2 when the unexpected object was different from the ignored items should not be attributed entirely to the distinctiveness of the unexpected object.

1. An alternative possibility is that differences in the degree of distinctiveness will have no effect on detection rate once items have passed a sufficient threshold of distinctiveness. This possibility needs to be addressed in future research.

GENERAL DISCUSSION

As in previous research on selective looking and inattentional blindness, our observers often failed to notice an unexpected event. Across all conditions, only 50% of observers noticed the unexpected object on the critical trial, even though the object was visible and in motion for 5 s and was easily perceived by observers who were not otherwise engaged. Even when the unexpected object was a red cross, unique in color, shape, type of motion, and luminance, 28% of observers did not notice it. These findings support the conclusion from work with complex video displays (Simons & Chabris, 1999) that inattentional blindness can occur for sustained and highly salient events, provided that observers are engaged in a selective-looking task.

One of our main goals in the experiments reported here was to examine the role of visual similarity in selective attention by combining the dynamic nature of the selective-looking paradigm with the rigorous control of the static inattentional blindness paradigm. Although visual similarity accounted for most of the variation in detection across conditions, an attentional set may still be "tuned" to the particular dimensions that differentiate the attended and ignored items. The unexpected object was always different from both the attended and the ignored items on feature dimensions other than luminance, but these distinctive features did not appear to capture attention; in some conditions, almost no subjects noticed the unexpected object even though it was distinctive on these other dimensions. Hence, observers may have developed an attentional set for luminance, ignoring other, irrelevant dimensions (see Folk et al., 1992), with the result being that only the luminance dimension affected the likelihood of attentional capture. Future studies could explore this possibility by using different dimensions (e.g., shape, texture, color) to distinguish between attended and unattended items. If the attentional-set hypothesis is correct, detection in these studies should be determined by these other properties, and luminance differences should have little effect. Even if visual similarity plays an important role, it may be important only with respect to the dimension observers use to distinguish the attended from the ignored items in the display.

Note that a more precise definition of attentional set might include the nature of the critical target events and not just the dimension defining the difference between attended and ignored objects. Because observers were asked to notice any time one of the target objects contacted the sides of the display window, target events were defined spatially (by the boundaries of the window) and by the direction changes that occurred with each bounce. Hence, observers might have selected which objects to attend to by using luminance differences, but they likely also attended to the spatial and motion characteristics of the objects. Spatial proximity does appear to play a role in detecting unexpected objects in this paradigm (Most, Simons, Scholl, & Chabris, 2000).

The finding that variation along the dimension relevant to task performance led to variation in detection rates is largely consistent with a version of the contingent-capture hypothesis (Folk et al., 1992; Folk, Remington, & Johnston, 1993; Folk, Remington, & Wright, 1994). Much, if not most, of the variability in noticing was dependent on the luminance of the unexpected object—the one dimension that was critical to the primary task—and not on its distinctive shape and path of motion. Thus, observers seemed to have an attentional set for luminance. However, our findings are in some ways inconsistent with this hypothesis. For example, the contingent-capture hypothesis might predict that if noticing were contingent on an attentional set for luminance, then any item with a unique luminance value should be noticed. Yet in Experiment 1, observers were more likely to notice items that were similar to the attended items than to notice items that were unique in the display (e.g., the gray cross). The contingent-capture hypothesis might alternatively posit that observers form an attentional set limited to the specific luminance value of the attended items. For example, they could form an attentional set for black items. Accordingly, only black unexpected items would be noticed (Folk & Remington, 1998). However, our observers did sometimes notice gray items, and their noticing rates were related to the similarity of the unexpected object to the attended objects. (It is possible that this version of the contingent-capture hypothesis could be modified to include an effect of similarity according to which detection might decline as the difference between the unexpected object and the attended items increased.) Finally, note that evidence for contingent capture comes from the finding that an irrelevant, but anticipated item can influence performance on another task (e.g., it can slow or speed response times). However, findings of such implicit effects do not lead to clear predictions for the conscious detection of unexpected stimuli (Simons, 2000).

The current dynamic and sustained inattentional blindness task may be well suited to the study of attentional capture (Simons, 2000). In fact, because it is dynamic and sustained, it may better approximate the capture of attention under natural viewing conditions than brief, static displays do. Typically, observers focus attention on those elements of a scene necessary to achieve an explicit goal. Natural scenes are visible for extended periods, and goals are rarely accomplished in a matter of milliseconds. Yet most studies of attentional capture rely on briefly presented displays. In contrast, in our task observers are actively engaged in a dynamic task for many seconds, and the critical object can be visible for at least 5 s without detection. Another advantage of this paradigm is that the critical object is both unattended and unexpected, whereas in other capture paradigms, the object is expected.

In summary, our data reveal a striking effect of visual similarity in attentional capture by an unexpected object. The more similar the unexpected object is to the attended objects, and the greater its difference from the ignored items, the greater the likelihood that it will be seen. Evidence from Experiments 2 and 3 suggests that this effect of similarity may be driven partially, if not largely, by selective ignoring of irrelevant stimuli (cf. Watson & Humphreys, 1997, 1998). Although these results illustrate the importance of visual similarity, the observer's attentional set still influences detection: Variations along the dimension that differentiated relevant from irrelevant stimuli affected the likelihood of detection, but other salient differences between the unexpected object and the other objects in the display (e.g., shape and type of motion) did not seem to capture attention. Top-down processes may serve to "tune" the observer's attentional set to the critical feature dimension while diminishing attention to other features. Future studies will explore this possibility by manipulating the dimension distinguishing relevant from irrelevant information and by explicitly manipulating the irrelevant dimensions.

Acknowledgments—We thank Danielle Hobeika, Jason Freidenfelds, and Beata Ziolkowska for helping collect data; Adriane Seiffert and Arni Kristjansson for informative discussions; and Jim Enns, Ray Klein, Ron Rensink, and an anonymous reviewer for many helpful suggestions and comments on an earlier version of this article. We also thank M. Python for inspiring the title. Daniel J. Simons was supported by a Sloan Research Fellowship and by a grant from the Clarke/Cooke fund at Harvard University. Brian Scholl was supported by Grant No. F32-MH12 483-01 from the National Institute of Mental Health.

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(Received 10/10/99; Revision accepted 4/27/00)

APPENDIX

The following questions were asked after critical, divided-attention, and full-attention trials. Note that for Experiment 2, the word "gray" replaced either the word "black" or the word "white" in the first question. Participants answered each question in sequence and were not allowed to see any question before answering the previous ones. Question 5 was included to provide pilot data for future experiments. The results from this question were not used in the current analyses.

1. On the last trial, did you see anything other than the black and white L's and T's (anything that had not been present on the first two trials)?
2. If you did see something on the last trial that had not been present during the first two trials, please describe it.
3. If you did see something on the last trial that had not been present during the first two trials, what color was it? If you did not see something, please guess. (Please indicate whether you did see something or are guessing)
4. If you did see something during the last trial that had not been present in the first two trials, please draw an arrow on the "screen" below showing the direction in which it was moving. If you did not see something, please guess. (Please indicate whether you did see something or are guessing)
5. If you did see something during the last trial that had not been present during the first two trials, please circle the shape of the object below. If you did not see anything, please guess. (Please indicate whether you did see something or are guessing)