

Should I Stay or Should I Go? Attentional Disengagement From Visually Unique and Unexpected Items at Fixation

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Distinctive aspects of a scene can capture attention even when they are irrelevant to one's goals. The authors address whether visually unique, unexpected, but task-irrelevant features also tend to hold attention. Observers searched through displays in which the color of each item was irrelevant. At the start of search, all objects changed color. Critically, the foveated item changed to an unexpected color (it was novel), became a color singleton (it was unique), or both. Saccade latency revealed the time required to disengage overt attention from this object. Singletons resulted in longer latencies, but only if they were unexpected. Conversely, unexpected items only delayed disengagement if they were singletons. Thus, the time spent overtly attending to an object is determined, at least in part, by task-irrelevant stimulus properties, but this depends on the confluence of expectation and visual salience.

Keywords: attention capture, eye movements, fixation duration, attention, novelty

When viewing a scene, observers volitionally deploy attention to regions of interest. However, unique, distinctive, or transient aspects of a scene, such as the abrupt onset of a new object, a unique color or shape, and certain types of motion, tend to attract observers' attention (e.g., see Chastain, Cheal, & Kuskova, 2002; Franconeri & Simons, 2003; Jonides & Yantis, 1988; Theeuwes, 1994). This prioritization often seems involuntary because it occurs unintentionally and despite explicit knowledge that these items are irrelevant to observers' goals. For example, in one standard attention capture task, observers view a search display containing one unique item (e.g., it suddenly appears or is a unique color), but this item's uniqueness is irrelevant because it is just as likely to be a distractor as it is to be a target (e.g., Jonides & Yantis, 1988). Despite this, set size effects in search time are absent on those occasions where the unique item is the search target, indicating that search begins with objects defined by unique features. Results like these have led researchers to argue that attention is therefore captured in these situations.

The attraction of attention toward unique items is not limited to covert shifts of spatial attention. Unique items in visual displays also tend to capture gaze. Although the guidance of the eyes through a scene is often an active process of interrogating scene regions to extract informative information relevant to one's goals

(e.g., Henderson, Brockmole, Castelano, & Mack, 2007; Mackworth & Morandi, 1967; Torralba, Oliva, Castelano, & Henderson, 2006; Yarbus, 1967), fixation placement is also, at least in part, influenced by stimulus-based low-level perceptual factors associated with objects in a scene (e.g., Itti & Koch, 2000; Koch & Ullman, 1985; Parkhurst, Law, & Neibur, 2002). For example, Theeuwes, Kramer, Hahn, and Irwin (1998) showed that while searching for a uniquely colored object in a visual display, the observer's eyes were involuntarily drawn to a suddenly appearing nontarget object before moving on to the desired target (see also Brockmole & Henderson, 2005a, 2005b, 2008). Further studies have shown that this *oculomotor capture* effect extends to color and luminance singletons as well, albeit at a somewhat lower rate (Irwin, Colcombe, Kramer, & Hahn, 2000). Thus, visually unique items can influence the allocation of attention within a visual display by influencing the eyes' scan pattern.

To date, attention and oculomotor capture research has strictly focused on cataloguing the sorts of features that attract attention irrespective of the observer's goals and intentions. However, by pursuing this theme, researchers in these areas have overlooked the fact that considerations of attention allocation should not be limited to where attention goes but also extend to how long it stays in any particular place. Taking fixation duration as a measure of the temporal extent of attention allocation at a particular location, the reading and scene processing literatures have shown that both low-level and cognitive factors influence how long attention dwells in one location before shifting to a new location. For example, fixation on a word is influenced by its lexical properties (e.g., frequency and length), its predictability in the sentence, and its semantic ambiguity (for reviews, see Liversedge & Findlay, 2000; Rayner, 1998). Similarly, fixations on objects are affected by visual factors such as contrast as well as semantic factors such as object-scene consistency (for reviews, see Henderson, 2003, 2007; Henderson & Hollingworth, 1999). All of these demonstrations, however, pertain to situations where the information influencing fixation duration is task relevant.

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The purpose of the experiments reported here was to directly address, for the first time, the extent to which visually unique but task-irrelevant features within the scope of attention tend to hold attention. Phrased another way, once attended, does an object's visual distinctiveness affect the ease with which attention can be disengaged? In this article, we confine our answer to this question to overt aspects of visual attention—those that are coupled with the locus of gaze within a display. Although it is certainly true that the scope of attention can include areas away from fixation and can be decoupled from fixation, it is also true that the locus and duration of gaze are important hallmarks of attention allocation (see Irwin, 2004, for extensive review and discussion). Thus, we more precisely addressed whether a fixated object's visual distinctiveness affects the ease with which gaze can be moved to a new location. In all prior oculomotor capture research, the influence of irrelevant visual distinctiveness on dwell time has been confounded with reflexive shifts of spatial attention toward the unique object as well as competing saccades programmed to move toward the search target. For example, fixations on the capture-inducing item are atypically brief (Theeuwes et al., 1998), but this is because a preprogrammed saccade to the target is interrupted before it can be executed, not because unique features of the onset affect the time spent fixating that object. It is therefore unknown whether the kinds of task-irrelevant features that attract gaze (and attention) also tend to hold gaze (and attention) when these competing factors are controlled.

Our general methodological approach was to examine the speed with which overt attention can be disengaged from a unique object that appears within the focus of attention (i.e., at fixation). While their eye movements were recorded, observers engaged in a visual search task in which they were first presented with a preview display of 6 circles concentrically arranged around a central circle (see Figure 1). While observers fixated on the center circle, all circles changed color and search targets (which required fixation to be identified) were revealed in the peripheral circles. Thus, the color change indicated to observers the availability of the search array and cued them to shift gaze from the center circle to the peripheral circles to start their search. Critically, on some trials, all of the circles in the display turned the same color (congruent trials). On other trials, the center circle was a different color

relative to homogeneously colored peripheral circles, and, as a result, the central circle constituted a color singleton (incongruent trials). Although color changes indicated the start of search, the congruency of the central and peripheral colors was task irrelevant as all color changes, regardless of their exact values, indicated the availability of the search array (in fact, the task could be accomplished even if observers were unable to perceive the color of the center circle). The primary dependent variable was the elapsed time between the onset of the search array and the flight of the eyes away from the center circle (i.e., saccade latency), which is the most direct and sensitive measure of the time needed to disengage overt attention from the critical object. If visual distinctiveness at fixation, despite its task irrelevance, obligatorily demands additional processing, it should hinder one's ability to disengage attention from the center circle. As a consequence, the saccade latency of the eye movement traveling away from the center circle should be inflated in the incongruent condition relative to the congruent condition.

From the existing literature on attention and oculomotor capture, there are two possible general mechanisms by which visually distinctive objects attract attention, but the conditions under which each occurs have been matters of some debate. Some researchers have argued that attention is captured in an entirely stimulus-driven fashion (Theeuwes, 1994; Yantis, 1993; Yantis & Hillstrom, 1994). Under this argument, attention capture arises by the within-trial distinctiveness of an object irrespective of expectations or top-down attention control settings. Other researchers, however, have argued that attention capture results from default attention sets, strategies, or across-trial expectations (e.g., Bacon & Egeth, 1994; Folk, Remington, & Johnston, 1992). As a way of extending this debate to the consideration of attentional disengagement, across four experiments, we assessed whether one's ability to disengage overt attention from a unique object (in this case, a color singleton) is influenced by within-trial distinctiveness (bottom-up influence), across-trial novelty (top-down influence), or both.

Experiment 1

In Experiment 1, unique visual features were defined with respect to their immediate perceptual context. The frequencies of congruent and incongruent trials were equated so that observers would not derive perceptual expectations pertaining to the frequency or likelihood of a unique stimulus appearing in the display. Our goal in this experiment, therefore, was to examine whether visual uniqueness can delay any subsequent attempt to disengage overt attention from the distinctive object in a bottom-up manner.

Method

Participants. Eight students at the University of Edinburgh participated in Experiment 1. In this and all subsequent experiments, participants reported normal color vision and normal or corrected-to-normal visual acuity. Each participant was paid £5 (approximately \$9.30) for his or her participation in one 40-min session.

Stimuli. Displays consisted of 7 circles (diameter = 2.7°, outline thickness = 0.03°) on a gray background. One circle was located at the center of the screen. Six circles were equidistantly spaced around an imaginary circle with a diameter of 6.1° an-

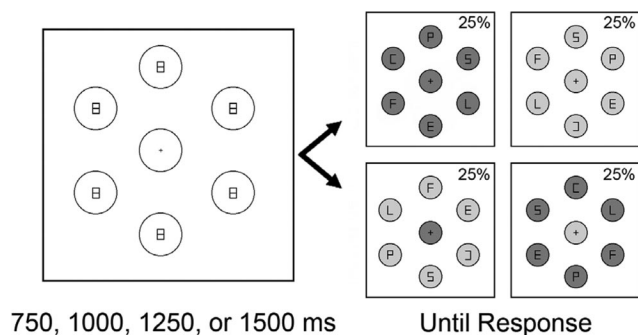


Figure 1. Schematic illustration of the procedure used in Experiment 1. In the initial premask array, the circles were gray. In the search array, the circles were red (denoted by dark gray shading) or blue (denoted by light gray shading). Stimuli are not drawn to scale. Variants of this procedure were used in Experiments 2–4.

chored to the screen center (see Figure 1). On each trial, the six outer circles could be located at clock positions of 1, 3, 5, 7, 9, and 11 o'clock or 2, 4, 6, 8, 10, and 12 o'clock. Each circle had a black outline and the area within this outline was gray, red, or blue. Small black figure-eight premasks initially appeared in each outer circle (0.21°). Search items were formed by removing line segments from each premask to form the letters *C*, *E*, *F*, *L*, *P*, and *S*. The *C* was either presented in its normal orientation or mirror reversed about the vertical axis. These items were small enough to require foveation to identify. A black fixation cross was located at the center of the screen and was visible throughout the trial (0.6°).

Apparatus. Displays were presented on a 21-in. CRT monitor with a resolution of 1024×768 pixels and a screen refresh rate of 120 Hz. Throughout each trial, the spatial position of each participant's right eye was sampled at a rate of 1000 Hz by an EyeLink 1000 eye tracking system (SR Research, Ltd., Mississauga, Ontario, Canada) running in pupil and corneal-reflection mode, which resulted in an average spatial accuracy of 0.15° . An eye movement was classified as a saccade if its amplitude exceeded 0.2° and either (a) its velocity exceeded $30^\circ/\text{sec}$ or (b) its acceleration exceeded $9,500^\circ/\text{sec}^2$. Participants viewed the display from a distance of 81 cm. A chin rest and forehead rest stabilized head position and kept viewing distance constant. A Microsoft video game controller was used to collect responses.

Design and procedure. Participants were instructed to find the *C* in the search display as quickly as possible and to categorize it as normal or mirror reversed by pushing one of two buttons on the game controller. The experiment began with a calibration of the eye tracker. A drift correction was applied to the output of the tracker at the start of every trial, and recalibration was performed when necessary throughout the experiment. Each trial began with a fixation cross at the center of the screen. Observers initiated the *premask display* by pressing a button on the game pad. This display consisted of seven gray circles. Each outer circle contained a figure-eight premask and the center circle contained a fixation point. Participants were instructed not to begin search during the premask display. If eye position did not remain within 2° of the center of the screen (i.e., if search began) while the premask screen was visible, the trial was terminated and a message was presented indicating that the participant had initiated search too soon. After 750, 1,000, 1,250, or 1,500 ms, the *search display* appeared (this variable delay was used to discourage anticipatory eye movements). The search display was formed when all circles changed color to either blue or red and line segments were removed from each premask to reveal the search letters. Only at this point in time were participants allowed to initiate search.

On half of all search displays, the color of the center circle matched the color of the outer circles (red center circle and red surrounding circles or blue center circle and blue surrounding circles). Thus, the center circle color was congruent with the color of the outer circles containing the search stimuli. On the other half of the search displays, the color of the center circle was incongruent with the outer circles (red center circle and blue surrounding circles or blue center circle and red surrounding circles). Trials were equally divided between congruent and incongruent trials of each color combination (i.e., red center and red surround, blue center and blue surround, red center and blue surround, blue center and red surround).

Participants completed three blocks of 128 trials for a total of 384 trials. Trials were equally divided between each of the four congruent and incongruent color combinations. The stimulus onset asynchrony between the premask screen and the search display was counterbalanced. The configuration of the display (whether search items appeared at clock positions 1, 3, 5, 7, 9, and 11 o'clock or 2, 4, 6, 8, 10, and 12 o'clock) was randomly determined on each trial, as were the target identity (*C* or backward *C*), the target position, and the position of each distractor letter.

Results and Discussion

The first 20 trials were considered practice and were not analyzed. In addition, 17% of trials were aborted prematurely because of online detection of saccades or blinks during the premask display. Trials were further excluded from the analysis if (a) the first eye movement did not start within 1.35° of the fixation cross (5% of trials), (b) the first eye movement did not cross an invisible boundary halfway between the center and peripheral circles (6% of trials), or (c) the latency of the first eye movement was less than 100 ms (2% of trials). This trim resulted in a total of 25% of incongruent trials and 26% of congruent trial being discarded, $t(7) = 0.40$, $p = .70$. These stringent trial inclusion criteria were used to reduce variance by excluding trials on which multiple saccades were executed prior to search and on which saccades to the search array were anticipatory. Note that even after this trim, an average of 288 trials per participant were entered into the analysis, and that the trim did not differentially discard trials from the congruent and incongruent conditions.

On the acceptable trials, target discrimination accuracy was near ceiling and did not differ between conditions (for incongruent trials, $M = 96\%$, $SD = .05$; for congruent trials, $M = 97\%$, $SD = .03$), $t(7) = 0.86$, $p = .42$. Analyses focused on the saccadic latency of the first eye movement executed after the presentation of the search array. To determine whether an irrelevant but unique item at fixation reflexively holds attention, we compared saccade latency when the center circle was a color singleton with saccade latency when this item was a nonsingleton. Latencies were almost identical in the incongruent ($M = 275$ ms, $SD = 28$) and congruent conditions ($M = 276$ ms, $SD = 34$). A paired-samples *t* test demonstrated that this 1-ms difference was not reliable, $t(7) = 0.12$, $p = .91$. To determine whether a quickly dissipating singleton effect might have been observed early in the experiment, we performed an additional saccadic latency analysis on the first 25 trials. No significant difference was found between saccadic latency when the center item was a singleton compared with when it was not ($M_s = 353$ and 337 ms, $SD_s = 111$ and 104 , respectively), $t(7) = 0.30$, $p = .77$.

The results of Experiment 1 demonstrate that attentional disengagement from a color singleton within the current focus of attention (i.e., at fixation) was not slowed relative to a nonsingleton object. This suggests that in contrast to previous demonstrations that irrelevant color singletons may attract overt attention, they do not appear to necessarily hold attention (at least overtly). However, because congruent and incongruent trials occurred with equal frequency, Experiment 1 only succeeds in demonstrating that color singletons defined only by within-trial distinctiveness fail to hold attention. In Experiments 2 and 3, we examined whether irrelevant color singletons at fixation might delay the disengage-

ment of overt attention when they violate perceptual expectations (i.e., they are distinctive within and across trials).

Experiment 2

In both reading and scene processing, unexpected words or objects tend to enjoy longer fixation durations, suggesting that they require the observer to devote additional attentional resources to processing them. For example, words that are unexpected in the context of a sentence (but make perfect syntactic and semantic sense) and objects that are semantically inconsistent with a scene's gist tend to be looked at longer than more likely words and objects (Antes & Penland, 1981; Brockmole & Henderson, 2008; De Graef, Christiaens, & d'Ydewalle, 1990; Friedman, 1979; Frisson, Rayner, & Pickering, 2005; Henderson, Weeks, & Hollingworth, 1999; Loftus & Mackworth, 1978; McDonald & Shillcock, 2003; Rayner, Ashby, Pollatsek, & Reichle, 2004). To test whether color singletons might hold overt attention when they violate perceptual expectations, in Experiment 2 (and Experiment 3), we made incongruent displays rare events. As such, in this experiment, unique visual features were defined with respect to the immediate perceptual context within a trial but also with respect to perceptual expectations derived over the course of the experiment (we refer to the former as an object's *uniqueness* or *distinctiveness*, and we refer to the later as an object's *novelty*). The question of interest was whether the disengagement of overt attention from a color singleton is delayed when its presence violates top-down expectations based on an observer's memory for previous displays.

The same search task was used as in Experiment 1; however, the experiment was divided into five contiguous blocks each of 80 trials. Block 1 consisted entirely of congruent trials on which the center and peripheral circles turned red. These trials established perceptual expectations. Within Blocks 2–5, the familiar congruent trials were randomly intermixed with incongruent trials. Within each of these blocks, 72 trials (90%) were congruent and 8 (10%) were incongruent. On these incongruent trials, the peripheral circles continued to turn red at the start of search, but the center circle changed to a unique color (1 trial each of light blue, dark blue, dark green, light green, pink, yellow, purple, and orange). As a result, within Blocks 2–5, the central circle was novel in comparison to the color changes previously experienced by the observer, and, across the experiment, each of the colors on incongruent trials were seen only four times. As in Experiment 1, the value of the color change was task irrelevant as all color changes signaled the availability of the search array. If perceptual novelty across trials places additional processing demands on the observer, then saccade latency prior to search should be longer on the incongruent trials compared with the congruent trials.

Method

Participants. Eight students at the University of Edinburgh who did not participate in Experiment 1 participated in Experiment 2. All participants reported normal color vision and normal or corrected-to-normal visual acuity and were each paid £5 (approximately \$9.30) for their participation in one 40-min session.

Stimuli. Stimuli were almost identical to those in Experiment 1. However, in Experiment 2, the outer circles in the search display were always red. The center circle could be red, light blue, dark blue, light green, dark green, yellow, orange, pink, or purple.

Apparatus. Apparatus was the same as in Experiment 1.

Design and procedure. Design and procedures were very similar to those in Experiment 1. Participants were instructed to find the *C* in the search display as quickly as possible and respond by pushing one of two buttons on the game controller depending on the target's orientation. The outer circles in the search display were always red. On the large majority of trials, the circle at fixation was also red. Participants completed five blocks of 80 trials. During the first block of trials, the item at fixation was always red. In Blocks 2–5, on 10% of trials, the center item of the search display was a color singleton (i.e., it was light blue, dark blue, light green, dark green, yellow, orange, pink, or purple). A color singleton occurred unpredictably every 5, 10, or 15 trials, with the average number of intervening trials being 10. On each of these color singleton trials within each block, the color of the center circle was chosen randomly without replacement from the set of eight potential colors. All other aspects of the procedure were identical to the procedure followed in Experiment 1.

Results and Discussion

The same trial trim was applied as in Experiment 1. Trials were excluded from the analysis if (a) the first eye movement did not start within 1.35° of the fixation cross (3% of trials), (b) the first eye movement did not cross an invisible boundary halfway between the center and peripheral circles (8% of trials), or (c) the latency of the first eye movement was less than 100 ms (4% of trials). In addition, 18% of trials were aborted prematurely because of online detection of saccades or blinks during the premask display. In sum, a total of 25% of incongruent trials and 27% of congruent trials were discarded, $t(7) = 0.76$, $p = .47$. Target discrimination accuracy was near ceiling and did not differ between trial type (for incongruent trials, $M = 98\%$, $SD = .04$; for congruent trials, $M = 98\%$, $SD = .01$), $t(7) = 0.03$, $p = .98$.

Analyses focused on saccade latency in Blocks 2–5, which contained both singleton and nonsingleton trials. In contrast to Experiment 1, saccade latencies were reliably longer when the center item was a singleton ($M = 357$ ms, $SD = 189$) compared with when it was a nonsingleton ($M = 301$ ms, $SD = 128$), $t(7) = 2.4$, $p < .05$. The magnitude of this effect was, on average, 56 ms, representing a growth in saccade latency of 19%.

The results of Experiment 2 provide evidence that when expectations are violated, a unique but task-irrelevant item can hold attention. In conjunction with the results from Experiment 1, this suggests that a color singleton within the focus of attention can delay the disengagement of overt attention but that this is subject to top-down control settings. Experiment 3 refines this conclusion by considering whether a rare but relatively familiar task-irrelevant singleton also generates this slowing.

Experiment 3

In Experiment 2, color singletons were unexpected in terms of both their frequency and their identity (several different colors were used to create singletons). The purpose of Experiment 3 was to investigate whether a rare color singleton would continue to delay the disengagement of overt attention when its identity was more predictable. The methods and logic paralleled those of Ex-

periment 2; however, the color singleton, when present, was always blue.

Method

Participants. Eight students at the University of Edinburgh who did not participate in Experiments 1 or 2 participated in Experiment 3. All participants reported normal color vision and normal or corrected-to-normal visual acuity and were each paid £5 (approximately \$9.30) for their participation in one 40-minute session.

Stimuli. Stimuli were almost identical to those in Experiment 2. The outer circles were always red. However, the color of the center circle was limited to either red (for congruent trials) or blue (for incongruent trials).

Apparatus. Apparatus was the same as in Experiments 1 and 2.

Design and procedure. Save for the change in the color of the singleton on incongruent trials, the design and procedures were identical to those in Experiment 2.

Results and Discussion

Trials were trimmed as in previous experiments. Trials were excluded from the analysis if (a) the first eye movement did not start within 1.35° of the fixation cross (12% of trials), (b) the first eye movement did not cross an invisible boundary halfway between the center and peripheral circles (5% of trials), or (c) the latency of the first eye movement was less than 100 ms (2% of trials). In addition, 21% of trials were aborted prematurely because of online detection of saccades or blinks during the premask display. In sum, a total of 30% of incongruent trials and 34% of congruent trials were discarded, $t(7) = 2.0$, $p = .08$. Target discrimination accuracy was near ceiling and did not differ between trial type (for incongruent trials, $M = 95\%$, $SD = .04$; for congruent trials, $M = 98\%$, $SD = .01$), $t(7) = 1.8$, $p = .16$.

Analyses focused on saccade latency in Blocks 2–5, which contained both singleton and nonsingleton trials. As in Experiment 2, saccade latencies were reliably longer when the center item was a singleton ($M = 286$ ms, $SD = 43$) compared with when it was a nonsingleton ($M = 262$ ms, $SD = 32$), $t(7) = 3.10$, $p < .05$. The magnitude of this effect was, on average, 24 ms, representing a growth in saccade latency of 10%.

Familiarity with a rare object's identity did not eliminate the congruency effects observed in Experiment 2. Indeed, a subanalysis indicated that this slowing was equally strong in Blocks 4 and 5 ($M = 19$ ms) as in Blocks 2 and 3 ($M = 25$ ms), $t(7) < 1$. Although it is interesting to note that the temporal magnitude of the congruency effect in Experiment 3 was numerically smaller than that observed in Experiment 2, this difference was not statistically reliable as tested by the interaction term in a mixed-model analysis of variance (ANOVA) that directly compared saccade latencies across conditions and experiments, $F(1, 14) = 1.75$, $p = .21$. Even though we accept that this lack of interaction may be due to modest statistical power in the across-experiment comparison, it does suggest that any effects of familiarity were smaller than the effects of rarity on attentional disengagement.

The results of Experiments 1–3 suggest that a color singleton within the focus of attention can delay the overt disengagement of attention to peripheral objects but that this is subject to top-down

control settings. In Experiment 4, we tested whether this effect requires the presence of a singleton, as the mere presence of an unexpected novel color—regardless of its environmental context—might produce a surprise response that is manifest with a delay in the onset of search.

Experiment 4

An unexpected stimulus that appears in a visual display can elicit an increase in saccade latency in a visual search task, a phenomenon known as *saccadic inhibition* (Reingold & Stampe, 2000). One possible explanation for this effect is that unexpected changes to parameters of a visual stimulus following habituation produce a form of orienting response that decreases saccade frequency—in essence by increasing fixation duration—within a 60- to 180-ms window following the appearance of the unexpected stimulus (Graupner, Velichkovsky, Pannasch, & Marx, 2007). It is possible, therefore, that the prolonged saccade latencies observed in the incongruent condition of Experiments 2 and 3 are not specifically due to the appearance of an unexpected singleton within the focus of attention. Instead, any novel object may cause delays in the disengagement of overt attention.

To test whether delays in attentional disengagement can occur for novel objects that are not singletons, we conceptually replicated Experiment 2 with heterogeneously colored peripheral circles. In an alternating pattern, three of the peripheral circles were tan and three were white. By destroying the homogeneity of the displays, novel objects at fixation were no longer singletons (cf. Bacon & Egeth, 1994; Folk & Remington, 1998). If novelty alone is sufficient to cause a delay in overt attentional disengagement, then the results obtained in Experiments 2 and 3 should be replicated with these heterogeneous displays. However, if attentional disengagement is controlled by the joint effects of novelty and uniqueness, then no differences between the expected and unexpected objects in Experiment 4 should be observed.

Method

Participants. Eight students at the University of Edinburgh who did not participate in Experiments 1–3 participated in Experiment 4. All participants reported normal color vision and normal or corrected-to-normal visual acuity and were paid £5 (approximately \$9.30) for their participation in one 40-min session.

Stimuli. Stimuli were almost identical to those in Experiment 2. The center circle could be red, light blue, dark blue, light green, dark green, yellow, orange, pink, or purple. However, in Experiment 4, the outer circles in the search display were not homogeneously colored. Instead, in an alternating pattern, three of the peripheral circles were tan and three were white.

Apparatus. Apparatus was the same as in Experiments 1–3.

Design and procedure. Save for the change in the colors of the peripheral circles, the design and procedures were identical to those in Experiment 2.

Results and Discussion

Trials were trimmed as in previous experiments. Trials were excluded from the analysis if (a) the first eye movement did not start within 1.35° of the fixation cross (7% of trials), (b) the first

eye movement did not cross an invisible boundary halfway between the center and peripheral circles (10% of trials), or (c) the latency of the first eye movement was less than 100 ms (1% of trials). In addition, 8% of trials were aborted prematurely because of online detection of saccades or blinks during the premask display. In sum, a total of 22% of incongruent trials and 21% of congruent trials were discarded, $t(7) = 0.53$, $p = .61$. Target discrimination accuracy was near ceiling and did not differ between trial type (for incongruent trials, $M = 97%$, $SD = .03$; for congruent trials, $M = 97%$, $SD = .03$), $t(7) = 0.23$, $p = .82$.

Analyses focused on saccade latency in Blocks 2–5, which contained novel trials. In contrast to Experiments 2 and 3, where a reliable slowing of attentional disengagement was observed when rare colors at fixation constituted singletons, in Experiment 3, the difference between expected color ($M = 245$ ms, $SD = 62$) and novel color ($M = 241$ ms, $SD = 64$) trials was reduced to an unreliable -4 ms, $t(7) = 0.86$, $p = .42$. The reduction in the congruency effect was further supported by reliable interaction terms in mixed-model ANOVAs that directly compared saccade latencies across conditions and Experiments 2–4: For Experiment 2 versus Experiment 4, $F(1, 14) = 6.58$, $p < .05$; for Experiment 3 versus Experiment 4, $F(1, 14) = 9.60$, $p < .01$.

These data provide evidence that an unexpected change to the parameters of a visual stimulus following habituation does not necessarily result in the slowing of attentional disengagement. The mere presence of a novel item at fixation does not account for the slowing observed in Experiments 2 and 3. Instead, these data suggest that a task-irrelevant but visually novel object delays the disengagement of overt attention when it specifically appears as a singleton. This means that the mechanisms that determine how long attention dwells on an object are sensitive not only to the information at fixation but also to the visual context in which that information appears—novelty and uniqueness are necessary but not sufficient factors in determining whether task-irrelevant visual properties of a fixated object can delay shifts of overt attention to peripheral targets.

General Discussion

Visually unique items presented away from fixation and outside the scope of focused attention have the ability to disrupt goal-driven behavior by causing involuntary shifts of spatial attention toward themselves. Until now, attention and oculomotor capture research has examined how task-irrelevant features attract attention while the question of whether these same visually distinctive features hinder an observer's ability to disengage attention from an item at fixation and within the scope of attention has been left unstudied. This is an important oversight because full consideration of attention allocation should not be limited to where attention goes but also extend to how long it stays in any particular place. It is therefore unknown whether the kinds of task-irrelevant features that attract attention also tend to hold attention.

In Experiments 1–3, observers engaged in a visual search task through homogeneously colored displays or a display in which one item was a task-irrelevant color singleton. Critically, this singleton was revealed at fovea during a fixation. Saccade latency was taken as a measure of the time required to disen-

gage overt attention from this object. Longer saccade latencies when a singleton was present compared with when it was absent was taken as evidence that visual distinctiveness at fixation, despite its task irrelevance, obligatorily demands attentional processing. In Experiment 1, congruent and incongruent displays occurred equally often, and attentional disengagement from a singleton was not slowed relative to a nonsingleton object. This suggests that color singletons, when defined only by within-trial distinctiveness and presented within the focus of attention, do not reflexively hold overt attention. In Experiment 2, incongruent displays were rare events and, as such, singletons were not only unique visual features with respect to the immediate perceptual context within a trial but were also novel features with respect to perceptual expectations derived over the course of the experiment. In contrast to Experiment 1, when these expectations were violated, distinctive, novel, but task-irrelevant items did delay attentional disengagement. Experiment 3 extended this finding by showing that increased familiarity with a rare singleton does not reliably decrease the congruency effect. These results suggest that the disengagement of overt attention can be delayed by a singleton at fixation but that this is subject to top-down control settings. Finally, Experiment 4 demonstrated that task-irrelevant but visually novel objects only delay the disengagement of overt attention when they appear as singletons, ruling out the hypothesis that general violation of expectation causes delays in attentional disengagement and suggesting that the mechanisms underlying attentional disengagement are affected by not only the information at fixation but also the visual context in which that information appears. Collectively, then, these four experiments indicate that two conditions must be jointly met before a task-irrelevant visual property of a fixated object will demand processing and hamper the engagement of attention toward other objects. First, the fixated object must be unexpected in the context of previous experience (i.e., it must be novel). Second, the object must be unique within the context of the larger display (i.e., it must be singleton).

The results of this study, therefore, extend the understanding of attention control in important ways. First, the experiments suggest that visually unique but task-irrelevant objects can both draw attention toward themselves and delay the disengagement of attention from themselves. However, from the evidence presented here, it appears that a unique object's ability to direct spatial shifts is more robust than its ability to delay them. Whether these processes arise from the same mechanisms and how they might compete against each other remain interesting questions. Second, the time spent attending to an object is determined, at least in part, by task-irrelevant properties of stimuli. Although fixations on words and objects are known to vary, attempts to account for this variance have focused on task-relevant and semantic constraints. For example, experiments discussed earlier have shown that fixation durations are related to a word or object's visibility and the degree to which it is unexpected in a given context. However, in each of these demonstrations, the processing of these words and objects was required for successful task completion (e.g., understanding the sentence or scene). In the present experiments, color singletons were task irrelevant and observers could have successfully completed the task even if they were unable to perceive the object presented at fixation. This result is the first that we are

aware of to suggest that task-irrelevant aspects of visible stimuli also contribute to fixation duration.¹

The general restriction of research focus on the locations that are attended in a display is not limited to work on attention capture. Although researchers conducting work on reading have been concerned for at least 20 years with the amount of time spent fixating words, researchers doing work on scene perception are only now starting to consider the factors that influence fixation duration and how this relates to attention (Henderson, 2003, 2007). The implicit assumption has been that fixation placement provides a good indication of where attention is allocated over the course of scene viewing. However, fixation duration may provide a better and more sensitive index of the allocation of attention in a scene (Henderson, 2003). For example, fixation durations are highly related to moment-to-moment visual and cognitive processing load (Henderson & Ferreira, 2004; Henderson & Hollingworth, 1998; Henderson & Pierce, 2008; Rayner, 1998). The present results provide a good example of this. By measuring saccade latency (a portion of a fixation's entire duration), we were able to observe an effect of visually novel objects on the allocation of attention within a visual display that has been overlooked because of the overwhelming focus on shifts of spatial attention in visually guided tasks. These experiments, therefore, open the door to a new line of research investigating the kinds of features that determine the time a stimulus enjoys the spotlight of attention and the conditions under which these features exert this influence.

¹ One contrast with the present findings can be made with the gap effect (e.g., Saslow, 1967), where saccade latency to a suddenly appearing peripheral target is shorter if the object at fixation disappears prior to target onset. Hence, the removal of an irrelevant item at fixation can, in some cases, facilitate attentional disengagement. Whether the same mechanism can account for the present findings as well as the gap effect is an interesting question for future research.

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