Towards a Resolution of the Attentional-Capture Debate

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The relative contributions of stimulus-driven and goal-directed control of attention have been extensively studied by investigating which irrelevant stimuli capture attention. Although much of this research has focused on color-singleton distractors, the circumstances under which these capture attention remain controversial. In search for a target with a unique known color (known-singleton search), whether singletons in an irrelevant color can be successfully ignored is a hotly debated issue. In search for a target that is not a singleton (feature search), no capture by irrelevant-color singletons is typically observed, but a reverse cueing effect was occasionally reported in the spatial-cueing paradigm. In 3 experiments, we resolve these controversies, by showing that the net spatial effect observed in the spatial-cueing paradigm reflects the sum of 3 separate effects. (a) A same-location benefit, which is determined by the match between the cue and the target colors and indexes contingent attentional capture. (b) A same-location cost, which is also determined by the match between the cue and the target colors, but occurs after selection and indexes processes related to visual working memory; and (c) task-dependent capture by singletons that occurs only when the target is consistently a singleton. Crucially, we show that the same-location cost is strongly determined by cue exposure duration, which explains previous failures to isolate it. The implications of these findings for the attentional capture debate are discussed.

Keywords: attentional capture, feature search, singleton search, same-location cost

Over the last 25 years or so, there has been a heated debate over the relative contributions of the physical salience of stimuli and of the observer's goals in the allocation of attention (see Burnham, 2007; Lamy, Leber, & Egeth, 2012; Theeuwes, 2010 for reviews). Most researchers have addressed this issue by investigating under what conditions a nominally irrelevant object captures attention.

Theeuwes (e.g., 1991, 2010) showed that when observers are engaged in parallel search for a shape singleton (e.g., a unique diamond among circles), an irrelevant-color singleton that is more salient than the target singleton (e.g., a unique red element among green ones) interferes with search, even though observers know they have to ignore it. Theeuwes concluded that top-down guidance is not possible at the preattentive stage, because the most salient item in the display captures attention independently of the observers' goals.

Bacon and Egeth (1994) challenged this conclusion by showing that capture by an irrelevant-color singleton occurred only when the target was consistently also a singleton: when the target was only occasionally a singleton, search was unaffected by the presence of a color singleton distractor. To account for these findings, the authors suggested that observers adopt a "singleton-detection mode" as their default search strategy whenever the target can be found by searching for a singleton. Only when this strategy is inappropriate do observers adopt "feature-search mode" and search for the target-defining shape. Bacon and Egeth (1994) concluded that irrelevant-color singletons may or may not cause distraction during parallel search for a known singleton shape, depending on the search strategy employed.

Folk and colleagues (e.g., Folk & Remington, 1998; Folk, Remington, & Johnston, 1992) also provided strong support for the prominent role of attentional sets in visual search. For instance, Folk and Remington (1998) showed that in search for a red singleton target, a color singleton distractor cue presented prior to the target display captured attention to its location only when it shared the target color and did not affect performance when it was in a different color. The authors concluded that attentional capture by a salient color singleton is contingent on its match with the observer's attentional set.

The notion of a default singleton detection mode (Bacon & Egeth, 1994) is not easy to reconcile with the latter finding. It is unlikely that when participants search for a color singleton they are able to tune their attentional set to a specific target color and thus to ignore an irrelevant-color distractor (Folk & Remington, 1998), but when they search for a shape singleton, they adopt a singleton-detection mode that encompasses singletons across the color and shape dimensions (Bacon & Egeth, 1994). Obviously, there is a serious risk of circularity if the strategy attributed to participants is inferred from the pattern of results (see Lamy et al., 2012 for a detailed argumentation).

Several authors have noted that irrelevant-color singletons are typically found to capture attention in the context of the additional singleton paradigm (e.g., Bacon & Egeth, 1994; Lamy, Carmel, Egeth, & Leber, 2006; Lamy & Egeth, 2003; Theeuwes, 1991,

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1994), whereas they can be ignored in the context of the modified spatial-cueing paradigm pioneered by Folk and colleagues (e.g., Eimer & Kiss, 2010; Folk & Remington, 1998). There have been various suggestions as to what the critical differences between these paradigms might be. Some have argued that the former paradigm measures filtering costs, while the latter measures spatial capture (e.g., Becker, 2007; Folk & Remington, 1998; Folk, Remington, & Wu, 2009, but see Schreij, Theeuwes, & Olivers, 2010; Theeuwes & Chen, 2005). Others have claimed that the latter allows fast disengagement of attention from the distractor because the target usually appears 150 ms after the distractor, whereas in the former, the distractor and target appear simultaneously (e.g., Belopolsky, Schreij, & Theeuwes, 2010; Theeuwes, 2010; but see Chen & Mordkoff, 2007; Folk & Anderson, 2010; Folk & Remington, 2010; Lamy, 2005, 2010 for criticisms of this account). However, despite intensive research, there is currently no consensus on the simple question of whether an irrelevant-color singleton captures attention in search for a known singleton target (henceforth, "known-singleton search").

When the target is not a singleton (e.g., when observers search for a red target among heterogeneously colored nontargets, henceforth, "feature search"), most of the evidence suggests that an irrelevant-color singleton distractor does not capture attention (e.g., Bacon & Egeth, 1994; Folk & Remington, 1998; Jonides & Yantis, 1988; Lamy, Leber, & Egeth, 2004; Lamy & Tsal, 1999; Lamy, Tsal, & Egeth, 2003; Yantis & Egeth, 1999; but see Lamy & Zoaris, 2009; see also Theeuwes, 2004 for counter evidence and Leber & Egeth, 2006 for a criticism of this counterevidence). However, in studies using the spatial-cueing paradigm, a same-location cost has sometimes been reported: performance was found to be *impaired* when the target appeared at the location of an irrelevant-color singleton cue relative to when it appeared at a different location (Anderson & Folk, 2012; Becker, Folk, & Remington, 2013, Experiment 3; Belopolsky et al., 2010; Carmel & Lamy, 2014; Eimer, Kiss, Press, & Sauter, 2009; Folk & Remington, 2008; Lamy, Alon, Carmel, & Shalev, 2015; Lamy et al., 2004; Schönhammer & Kerzel, 2013). Yet, several studies failed to observe this same-location cost (e.g., Becker et al., 2013, Experiment 2; Folk & Anderson, 2010; Folk & Remington, 1998).

The accounts put forward to explain the same-location cost are also at considerable variance (see Carmel & Lamy, 2014, for a review). Some authors suggest that this effect is a marker of the successful prevention of attentional capture (e.g., Eimer et al., 2009; Lamy et al., 2004), while others claim that this cost is indicative of attentional capture followed by rapid disengagement (Belopolsky et al., 2010, but see Anderson & Folk, 2012 for a criticism of this interpretation). Finally, we suggested that this cost is in fact unrelated to attentional allocation (Carmel & Lamy, 2014; Lamy et al., 2015). Specifically, borrowing from the notion of object-file pioneered by Kahneman and colleagues (Kahneman, Treisman, & Gibbs, 1992), we proposed that the same-location cost reflects either the cost of updating an object's feature information in visual working memory when this feature changes across time (Carmel & Lamy, 2014) or the cost of maintaining conflicting feature information associated with the same object in visual working memory (Carmel & Lamy, 2015). These tentative accounts relied on three main findings. First, we provided several demonstrations (described later in the manuscript) that the same-location cost reflects a mechanism that is independent of and

follows attentional selection. Second, we showed that the cost is object based, as it is contingent on the cue and target being perceived as belonging to the same object (Carmel & Lamy, 2014, Experiment 3). Finally, we showed that the same-location does not reflect early sensory processes and is more likely to occur in visual working memory, as its magnitude remains virtually constant over a cue-to-target interval of up to 800 ms (Carmel & Lamy, 2015).

To summarize, although a large portion of the abundant experimental literature on attentional capture has focused on color singleton distractors, the circumstances under which capture by these singletons occurs remain unspecified. In known-singleton search, capture was typically observed when using the additional-singleton paradigm but not when using the spatial-cueing paradigm. In feature search, capture was typically not observed, but a same-location cost was occasionally reported when using the spatial-cueing paradigm. The objective of the present study was to resolve these long-standing inconsistencies in the literature.

Experiment 1

We first set out to characterize the conditions under which the same-location cost is observed during feature search using the spatial-cueing paradigm. Specifically, we investigated the role of cue duration. We relied on two sets of observations in our choice of this variable. First, we noted that most studies using 50-ms cue presentation durations (e.g., Eimer et al., 2009; Folk & Remington, 2008; Schönhammer & Kerzel, 2013) reported overall small and volatile effects, whereas we used 150-ms durations, and our effects were large and reliable (Carmel & Lamy, 2014; Lamy et al., 2015). Notably, Becker et al. (2013) used 100-ms cues and found same-location costs of intermediate magnitude.

Second, we recently showed that when cue duration is held constant, the same-location cost is entirely contingent on conscious perception of the cue (Lamy et al., 2015). We used continuous flash suppression and brief low-contrast presentation to render the cue liminal. We measured subjective perception of the cue on each trial and verified that cue localization was at chance when participants reported null visibility of this cue. Our results showed a robust same-location cost when the cue was consciously perceived and none when it was invisible. By contrast, same-color cues captured attention to the same extent whether or not they were perceived consciously.

Taken together, these findings suggest that cue exposure duration, which strongly determines conscious perception of the cue, may be a critical factor for the occurrence of the same-location cost. As previous studies differed not only in cue exposure but also in the specific stimuli used, we directly tested our hypothesis by comparing the same-location cost at the location of an irrelevant-color cue during color feature search with 50- versus 150-ms cue durations, with all other parameters being kept constant.

Probing conscious perception of the cue on each trial modifies task demands by rendering the cue relevant and may therefore affect the spatial effect associated with the cue. Here, our objective was not to reexamine the role of conscious perception, but to explain the discrepancies between the findings from previous studies investigating attentional capture, which invariably did not include a measure of cue awareness. Thus, we did not measure conscious perception of the cue in any of the present experiments.

In Experiment 1, each display contained four gray circles, each of which enclosed a gray *T* letter rotated to either the left or the right. Two critical events occurred during each trial: first, during the "cue" display, all circles thickened. On most trials, one of them became a color singleton for a brief time interval (e.g., the cue display contained one green circle among gray ones). Then, during the "target" display, each *T* took on a different color (red, yellow, green, and blue). Observers searched for the *T* defined by its specific color (e.g., red). The cue color either matched the target color (relevant-color cue condition) or did not (irrelevant-color cue condition). It was presented for either 50 ms or 150 ms. In line with numerous previous reports (e.g., Folk et al., 1992), we expected relevant-color cues to capture attention. Crucially, we predicted a same-location cost in the irrelevant-color cue condition, but only for the 150-ms and not for the 50-ms cue duration. By contrast, we did not expect cue duration to affect attentional capture by the relevant-color cue (Lamy et al., 2015).

Method

Participants. Eleven Tel Aviv University undergraduate students, all female (aged 19–34, $M = 24.2$, $SD = 3.95$), participated in the experiment for course credit. All participants reported having normal or corrected-to-normal visual acuity and normal color vision.

Apparatus. The experiment was performed on a desktop computer. Stimuli were presented on a cathode ray tube (CRT) monitor (1,024*768, 85 Hz refresh rate). Viewing distance was set at about 60 cm. The experiment room was dimly lit.

Stimuli. Each trial consisted of a ready display, a cue display, an interstimulus interval (ISI) display, a target display, and a response display (see Figure 1). All stimuli were presented on a black background. The ready and ISI displays consisted of a gray $0.6 \times 0.6°$ plus sign (+), surrounded by 4 gray 0.1°-thick outline circles, subtending 0.9° in radius and positioned 2.8° above, below, to the left, and to the right of the fixation sign. Centered inside each circle was a *T* letter ($0.8 \times 0.8°$) rotated by 90 degrees and pointing either to the right or to the left. The cue display was

similar to the ready display except that the circles were thicker (0.17°). In the cue-absent condition, all four circles remained gray. In the cue-present condition, one of the circles was drawn in one of six possible colors: red, blue, green, yellow, magenta, or cyan. The target display was similar to the ready display, except that the rotated *T*s were colored red, green, yellow, and blue. Colors were randomly assigned to locations. The response display was similar to the ready display except that the circles were empty.

The colors used were gray (CIE [Commission Internationale d'Eclairage] .281, .291, 25.1 cd/m²), red (CIE .585, .335, 25.3cd/m²), green (CIE .312, .537, 42.5cd/m²), yellow (CIE .432, .464, 70.2cd/m2), blue (CIE .180, .183, 21.6cd/m²), cyan (CIE .303, .210, 28.3cd/m²), and magenta (CIE .229, .330, 57.7cd/m²).

Procedure. The participants were instructed to determine the orientation of the target *T*, defined by its known color (either red or blue), and to respond by pressing designated keys on the computer keyboard as quickly as possible, while maintaining high accuracy. Each trial began with the fixation display that was replaced after 1,000 ms with a cue display. The cue display appeared for either 50 or 150 ms, and was followed by the ISI display presented for either 100 ms or 0 ms, respectively. Hence, stimulus onset asynchrony was constant across conditions (150 ms). In the same-color cue condition, the cue color was identical to the target color, while in the different-color cue condition, it was one of the five remaining possible cue colors. The target display was presented for 150 ms, and was followed by the response display for 1,350 ms or until response. There was no intertrial interval. Eye movements were not monitored, but subjects were explicitly requested to set their eyes on the fixation cross throughout each trial. Erroneous responses or failures to respond during the presentation of the response display were followed by a 150 ms 1,000 Hz beep.

Design. Following a 30-trial practice block, the experimental trials were divided into two blocks of 360 trials each, and separated by a self-paced break. The cue was absent on 20% of the trials. On cue-present trials, the cue was equally likely to share or not to share the target color (relevant vs. irrelevant-color cue conditions, respectively) trials were equally probable. Cue and target locations were set randomly, and were uncorrelated, such that the cue location validly indicated the target location on 25% of the trials and was invalid on the remaining 75% of the trials. Except for target color (which was counterbalanced across participants), all variables were manipulated within participant and randomly mixed across each block of trials.

Figure 1. Sequence of events in Experiment 1. The target was defined by its known color and the irrelevant-color cue could take one of five non-target colors. In this example, the target is the red *T* (light gray in the print version). The relevant-color cue (light gray circle in the print version) is also red, and the irrelevant-color cue (the black circle) is green. See the online article for the color version of this figure.

Results

The data from 1 participant were removed from analysis because her response accuracy was lower than the group's mean by more than 2 standard deviations (78.7% vs. $M = 94.2\%$, $SD = 6.2\%$). All reaction time (RT) analyses were conducted on correct trials (95.0% of all trials). In all experiments, outlier-RT trials (i.e., trials with RTs faster than 150 ms or exceeding the mean of their cell by more than 2.5 standard deviations—2.0% of all correct trials in this experiment) were removed from analysis.

Mean RTs and accuracy are presented in Figure 2. A repeated-measures analysis of variance (ANOVA) was conducted on cue-present trials, with cue location (same vs. different), cue color
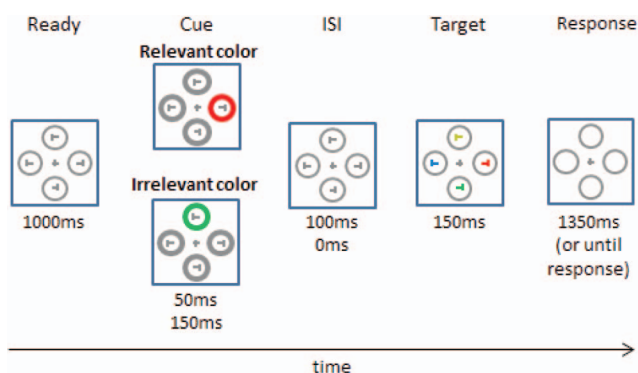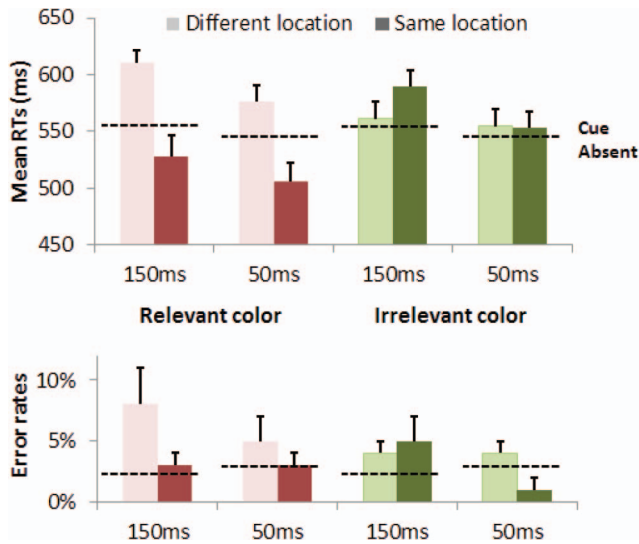
Figure 2. Mean RTs and error rates in Experiment 1 for same and different cue-target location trials, by conditions of cue color (relevant vs. irrelevant) and cue duration (50 vs. 150 ms). The dark bars refer to same-location trials and the light bars to different-location trials. The four left-hand bars refer to the relevant-color conditions and the four right-hand bars to the irrelevant-color conditions. The hatched lines represent performance on cue-absent trials. See the online article for the color version of this figure.

(relevant- vs. irrelevant-color), and cue duration (50 ms vs. 150 ms) as within-subjects factors. Specific hypotheses regarding the interaction between cue duration and location were tested as planned comparisons.

RTs. Overall, RTs were faster on 50-ms than on 150-ms cue trials, $F(1, 9) = 36.3$, $p < .0002$, $\eta_p^2 = 0.80$, and on same-location than on different-location trials, $F(1, 9) = 26.7$, $p < .0001$, $\eta_p^2 = 0.74$. The main effect of cue color was not significant, $F(1, 9) = 1.9$, $p < .21$, $\eta_p^2 = 0.17$, but strongly interacted with cue location, $F(1, 9) = 66.4$, $p < .001$, $\eta_p^2 = 0.88$, replicating previous studies (e.g., Carmel & Lamy, 2014); responses were faster on same-location than on different-location trials when the cue was in the same color as the target, 76 ms, $F(1, 9) = 58.3$, $p < .001$, $\eta_p^2 = 0.86$, indicating attentional capture, but this effect was reversed when the cue had a different color, -14 ms, $F(1, 9) = 5.28$, $p = .047$, $\eta_p^2 = 0.37$, indicating a same-location cost. This interaction was significantly modulated by cue duration, $F(1, 9) = 6.40$, $p < .03$, $\eta_p^2 = 0.42$; on irrelevant-color cue trials, the same-location cost was significant for 150-ms cues, -28 ms, $F(1, 9) = 7.90$, $p < .05$, $\eta_p^2 = 0.47$, but not for 50-ms cues, -1 ms, $F(1, 9) = 0.1$, $p = .73$, $\eta_p^2 = 0.01$, with a significant difference between these effects, $F(1, 9) = 10.2$, $p = .01$, $\eta_p^2 = 0.53$. On relevant-color cue trials, the same-location benefit was significant for both cue durations, 82 ms, $F(1, 9) = 91.9$, $p < .0001$, $\eta_p^2 = 0.91$, and 70 ms, $F(1, 9) = 34.0$, $p < .0005$, $\eta_p^2 = 0.79$, for 150-ms and 50-ms cues, respectively, with no significant difference between these effects, $F(1, 9) = 1.5$, $p > .25$, $\eta_p^2 = 0.14$. All other interactions involving cue duration were nonsignificant, all p values > 0.15.

Accuracy. The accuracy data mirrored the RT data. Accuracy was higher on 50-ms than on 150-ms cue trials (95.4% vs. 97.6%, respectively, $F(1, 9) = 7.2$, $p < .03$, $\eta_p^2 = 0.44$). The three-way interaction between cue color and cue duration was significant, $F(1, 9) = 6.8$, $p = .03$, $\eta_p^2 = 0.43$. However, follow-up analyses revealed that none of the location effects was significant (see Figure 2).

Discussion

The results of Experiment 1 support our hypothesis that cue exposure can explain the discrepancy between studies that reported a same-location cost during feature search and studies that did not. The effect was significant with 150-ms cues and disappeared when cue exposure was reduced to 50 ms. By contrast, attentional capture by the relevant-color cues was equally strong for both cue durations. This dissociation provides additional support for the notion that the same-location cost is independent of attentional capture (Carmel & Lamy, 2014).

We now turn to address the inconsistencies prevailing in the literature on attentional capture by irrelevant-color singletons during known-singleton search. Our core hypothesis is that in line with findings emanating from the additional singleton paradigm, an irrelevant-color singleton captures attention in search for a known singleton target (e.g., Bacon & Egeth, 1994; Lamy, Carmel et al., 2006; Theeuwes, 1991), but in the spatial-cueing paradigm, this effect is masked by an effect in the opposite direction, the "same-location cost," hence the finding of no capture using this paradigm (e.g., Becker et al., 2013, Experiment 2; Eimer & Kiss, 2010, Experiment 2; Folk & Remington, 1998).

This hypothesis relies on several recent findings from our lab. Carmel and Lamy (2014) showed that in search for an unpredictable color singleton, the spatial-cueing effect was smaller when the cue and target colors differed than when they were the same. As all cues had the same attentional status, this difference was taken to reflect a same-location cost that is independent of attentional selection, and we concluded that the same-location benefit and cost are additive. In a later study (Lamy et al., 2015), we showed that the same-location benefit was unaffected by conscious perception of the cue, while the same-location cost was entirely wiped out when the cue was not consciously perceived—a pattern of results that also indicates that the two effects are independent. Finally, we showed that the same-location cost occurred only when the cue and target were perceived to belong to the same object (Carmel & Lamy, 2014, Experiment 3). We concluded that the same-location cost reflects an object-based effect that occurs after attentional selection.

These ideas have two central implications in the present context. One is that the processes underlying the same-location cost should occur only in the spatial-cueing paradigm, in which the cue and target are perceived as successive events occurring in the same object and not in the additional singleton paradigm in which the critical distractor and target appear simultaneously as different objects. The second implication is that the same-location cost should occur irrespective of the type of search the subjects are engaged in: in unknown singleton search (as demonstrated by Carmel & Lamy, 2014), in feature search (Carmel

& Lamy, 2014; Lamy et al., 2015 and Experiment 1 of the present study), but also in known singleton search, as we set out to demonstrate in Experiments 2 and 3.

The objective of Experiment 2 was to test the hypothesis that evidence for attentional capture by an irrelevant-color singleton during search for a known color singleton can be unmasked when the same-location cost is eliminated.

In Experiment 3, we adopted a complementary approach and tested the prediction that when cue exposure duration is long enough, the same-location cost observed in search for a known color singleton (e.g., in Experiment 1 of the present study) is substantially smaller than during feature search, with the difference between the two effects reflecting attentional capture in the former but not in the latter search type (Bacon & Egeth, 1994; Lamy, Bar-Anan, Egeth, & Carmel, 2006; Lamy, Carmel et al., 2006).

Experiment 2

This experiment was similar to Experiment 1 except that (a) participants searched for a color target that appeared among homogenously rather than heterogeneously colored nontargets, so that the task was a known-singleton search instead of a feature search; and (b) cue exposure was either 50 ms or 17 ms instead of either 50 ms or 150 ms.

In Experiment 1, we showed that a 50-ms cue exposure is short enough to eliminate same-location costs. However, Folk and Remington (1998) reported no capture by cues in the irrelevant color that appeared for only 50 ms during search for a known-color singleton. According to our hypothesis, such failure should have resulted from a same-location cost offsetting the same-location benefit. These findings seem to contradict each other, although stimulus parameters may of course modulate the exposure duration necessary for a same-location cost and are likely to differ across studies.

However, it may be important to also keep in mind that the null same-location cost we reported in Experiment 1 with 50-ms exposure was obtained using a feature search task. Previous research has shown that objects presented for a constant duration are more likely to access conscious awareness if they capture attention than if they do not (e.g., Lamy et al., 2015; see also Most, Scholl, Clifford, & Simons, 2005). If so, a 50-ms cue exposure may be short enough to prevent conscious perception of the cue during feature search (because the cue does not capture attention), whereas a 50-ms cue exposure may be long enough for the cue to access consciousness during known-singleton search (because the cue captures attention). Accordingly, a same-location cost may be expected with 50-ms cues in the known singleton search but not in feature search.

This rationale yields the counterintuitive prediction that the same-location benefit indicative of attentional capture should be larger with 17-ms cues than with 50-ms cues, because a same-location cost should offset attentional capture in the 50-ms but not in the 17-ms condition. In order to control for an alternative account according to which short cues might be more potent in capturing attention in general, we included a same-color cue condition. In that case, our prediction was that the same-location benefit would be either unaffected by cue duration or larger with the 50-ms than with the 17-ms cue.

Method

Participants. Fourteen Tel Aviv University undergraduate students (aged 18–39, $M = 25.9$, $SD = 5.7$, 9 female) participated in the experiment for course credit. All participants reported having normal or corrected-to-normal visual acuity and normal color vision.

Apparatus. The experiment was performed on a PC desktop computer. Stimuli were presented on an LCD monitor (23-in. Samsung SyncMaster) with a $1,920 \times 1,080$ pixel resolution and 120-Hz refresh rate, in a dimly lit room. Viewing distance was set at about 60 cm.

Stimuli, procedure, and design. The stimuli, procedure, and design were similar to those of Experiment 1, except for the following changes. The target was defined by its known color as in Experiment 1, but it was a singleton, that is, all nontarget *T*s shared the same color. This nontarget color was set to the mean in CIE color space of the three nontarget colors used in Experiment 1 in order to keep the contrast between target and nontarget colors similar across search conditions (and experiments). Cue duration was either 17 ms or 50 ms.

Results

Outlier-RT trials (1.7% of all correct trials) were removed from analysis. All RT analyses were conducted on correct trials (92.5% of all trials). Mean RTs and accuracy are presented in Figure 3. A repeated-measures ANOVA was conducted on cue-present trials,
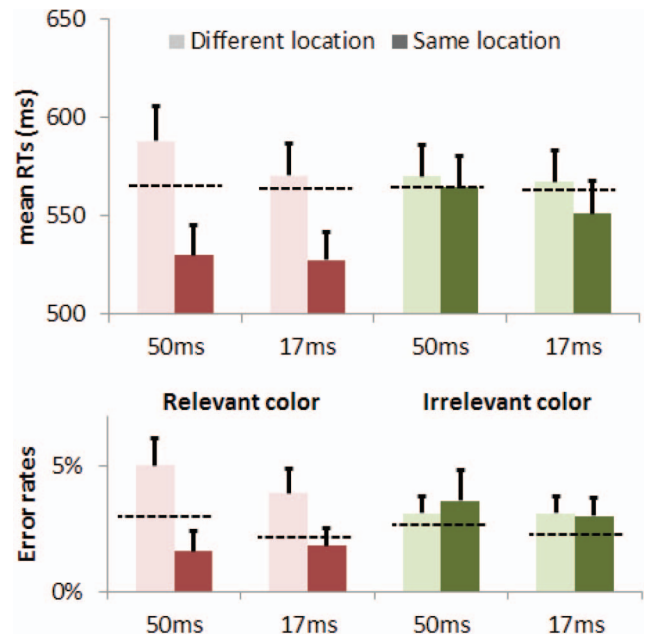

Figure 3. Mean RTs and error rates in Experiment 2 for same and different cue-target location trials, by conditions of cue color (relevant vs. irrelevant) and cue duration (17 vs. 50 ms). The dark bars refer to same-location trials, and the light bars to different-location trials. The four left-hand bars refer to the relevant-color conditions and the four right-hand bars to the irrelevant-color conditions. The hatched lines represent performance on cue-absent trials. See the online article for the color version of this figure.

with cue duration (17 ms vs. 50 ms), cue location (same vs. different), and cue color (relevant vs. irrelevant) as within-subjects factors.

RTs. All main effects were significant, $F(1, 13) = 13.3, p < .005, \eta_p^2 = 0.51$; $F(1, 13) = 15.6, p < .002, \eta_p^2 = 0.55$; and $F(1, 13) = 67.3, p < .0001, \eta_p^2 = 0.84$, for cue color, cue duration, and cue location, respectively. The interaction between cue color and cue location was significant, $F(1, 13) = 64.2, p < .0001, \eta_p^2 = 0.83$, and was modulated by cue duration, $F(1, 13) = 5.1, p = .042, \eta_p^2 = 0.28$. This three-way interaction was clarified using planned comparisons. With relevant-color cues, there was a significant location benefit for both the 17-ms cue, 43 ms, $F(1, 13) = 74.1, p < .0001, \eta_p^2 = 0.85$, and the 50-ms cue, 58 ms, $F(1, 13) = 75.7, p < .0001, \eta_p^2 = 0.85$. With irrelevant-color cues, although the interaction between cue location and cue duration failed to reach significance, $F(1, 13) = 3.1, p = .10$, the spatial benefit was significant only for the 17-ms cue, 16 ms, $F(1, 13) = 11.1, p < .01, \eta_p^2 = 0.46$, but not for the 50-ms cue, 5 ms, $F(1, 13) = 1.0, p = .33, \eta_p^2 = 0.07$.

Accuracy. There was no speed–accuracy trade-off. Only the interaction between cue color and location was significant, $F(1, 13) = 8.6, p < .02, \eta_p^2 = 0.39$; a significant location benefit was associated with relevant-color cues, 2.7%, $F(1, 13) = 8.0, p = .014, \eta_p^2 = 0.38$, but not with irrelevant-color cues, $-0.2\%, F < 1, \eta_p^2 = 0.007$. The main effect of cue location approached significance, $F(1, 13) = 3.40, p = .088, \eta_p^2 = 0.21$, and all other main effects and interactions were nonsignificant, p values > 0.24.

Discussion

Our predictions were fully confirmed. Evidence for attentional capture by an irrelevant-color singleton in search for a known color singleton did not emerge with 50-ms cues, therefore replicating Folk and Remington's (1998) null finding. In contrast, it was clearly observed with 17-ms cues. No such reduction of the same-location benefit with increased cue duration was observed with relevant-color cues: if anything, evidence for capture was numerically larger for the long exposure duration. Thus, our findings strongly support the idea that: (a) irrelevant singletons capture attention in known singleton search[1]; but (b) this effect is masked by same-location costs that occur in the context of the spatial-cueing paradigm with above-threshold cues.

It is important to highlight that this conclusion does not entail that such capture should be as large as when the cue shares the target color. The strong version of the singleton-detection mode account (Bacon & Egeth, 1994; Bravo & Nakayama, 1992) makes such a prediction because it claims that whenever the target is consistently a singleton, observers do not exploit explicit knowledge of the target feature despite such knowledge being available. However, we have strongly criticized the idea that observers adopt such a default feature-blind singleton-detection strategy. Instead, we have suggested that in search for a known singleton, both singletons and objects possessing the target-defining feature benefit from increased attention (Lamy, Bar-Anan, & Egeth, 2008; Lamy, Bar-Anan et al., 2006; Lamy, Carmel et al., 2006). Note that in line with this idea, the relevant-color cues did seem to produce stronger capture than the irrelevant-color cues in Experiment 2, as performance on different-location trials were overall slower in the relevant- than in the irrelevant-color cue condition.[2]

The main objective of Experiment 3 was to provide complementary evidence for our claim that irrelevant singletons capture attention in known singleton search, but this effect is masked by same-location costs. An additional objective was to provide further evidence in support of the claim that color information modulates attentional capture during search for a known singleton, in line with the contingent-capture hypothesis and in contradiction with Theeuwes's salience-based account or the notion of a default singleton-detection mode (Bacon & Egeth, 1994).

Experiment 3

In this experiment, participants searched for a color-defined target. For one group of participants, the target was a singleton (known-singleton condition) whereas for another group, it was a nonsingleton (feature-search condition).[3] The cue, again either in the relevant or in an irrelevant color, appeared for 150 ms. This exposure duration should be long enough for a same-location cost to be observed both in the feature-search condition (as shown in Experiment 1) and in the known-singleton search condition (as shown in Experiment 2). However, as the irrelevant-color singleton cue should capture attention in known-singleton search (Experiment 2) but not in feature search (Experiment 1), we expected a smaller net same-location cost in the former condition than in the latter condition.

We hypothesized that the net spatial effect observed in the spatial-cueing paradigm reflects the sum of three separate effects. (a) A same-location benefit, which is determined by the match between the cue and the target colors and indexes contingent attentional capture; this effect is largely independent of cue exposure duration. (b) A same-location cost, which is also determined by the match between the cue and the target colors but indexes processes that follow attentional selection and seem to occur in visual working memory; this effect is strongly modulated by cue exposure duration; and (c) task-dependent capture by irrelevant-color singletons that occurs only when the target is consistently a singleton.

Accordingly, we expected an interaction between cue color and cue location, indicating that the match between the cue and target color affects attentional allocation. We also expected an interaction between search type and cue location, indicating that singletons are

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[1] Note that our design differed from Folk and Remington's (1998) in the fact that the irrelevant-color cue in our experiment could take on 5 different colors unpredictably, whereas in these authors' study, the cue's color was constant. As advance knowledge of a singleton distractor's color makes it easier to ignore (e.g., Vatterott & Vecera, 2012; Zehetleitner, Goschy, & Müller, 2012), attentional capture by the cue may have been smaller if we had used a fixed-color cue. However, this difference between the two studies does not undermine our main conclusion, namely, that the same-location cost can mask attentional capture.

[2] In order to compare capture by the two types of cues, one cannot rely on the overall location effect or on performance on same-location trials, because these cannot disentangle attentional capture from the same-location cost (Anderson & Folk, 2012; Carmel & Lamy, 2014). Instead, performance on different-location trials can serve as a proxy of capture strength. In Experiment 2, different-location trials were slower with relevant-color than with irrelevant-color cues. This difference reached significance with 50-ms cues, $F(1,13) = 6.06, p < 0.03$, but not with 17-ms cues, $F(1,13) = 1.13, p > 0.3$.

[3] The feature-search condition were previously published as Experiment 2 of Carmel and Lamy (2014).

more potent in capturing attention in known-singleton than in feature search. Finally, we did not expect a three-way interaction, because our hypothesis was that (a) target-feature information affects attentional allocation to the same extent in feature search and in known singleton search, and (b) the same-location cost is of the same magnitude in the two search conditions.

Method

Participants. Overall, 21 Tel Aviv University undergraduate students participated in the study for course credit (12 in the feature-search condition and 9 in the known-singleton search condition). All participants were female (aged 21–39, $M = 25.0$, $SD = 5.9$). All participants reported having normal or corrected-to-normal visual acuity and normal color vision.

Apparatus, stimuli, procedure, and design. The apparatus, stimuli, procedure, and design were similar to those of Experiment 1 except for the following changes. The feature-search condition was the same as the 150-ms cue-duration condition of Experiment 1. The known-singleton search condition was the same as in Experiment 2. Cue duration was set to 150 ms throughout the experiment, and the ISI display was absent. Search type (feature vs. known singleton) was a between-subjects variable.

Results

The data from 1 participant were removed from the analysis of each search type because their response accuracy was lower than the group's mean by more than 2 standard deviations (78.0% vs. $M = 92.5\%$, $SD = 6.1\%$ and 78.1% vs. $M = 93.6\%$, $SD = 3.4\%$ for the known singleton and feature search conditions, respectively). Outlier-RT trials were removed from analysis (2.1% and 1.3% of all correct trials in the known-singleton and feature-search conditions, respectively). All RT analyses were conducted on correct trials (90.5% and 92.4% of all trials in the known-singleton and feature-search conditions, respectively).

Mean RTs and accuracy are presented in Figure 4. A repeated-measures ANOVA was conducted on cue-present trials, with search type (feature vs. known singleton) as a between-subjects factor, and cue location (same vs. different) and cue color (relevant vs. irrelevant) as within-subjects factors.

RTs. The main effect of location was significant, $F(1, 19) = 15.5$, $p < .001$, $\eta_p^2 = 0.45$. It interacted with cue color, $F(1, 19) = 81.4$, $p < .0001$, $\eta_p^2 = 0.81$, and tended to interact with search type, $F(1, 19) = 3.36$, $p = .08$, $\eta_p^2 = 0.15$. Crucially, these interactions were not significantly modulated by a three-way interaction, $F(1, 19) = 0.1$, $p = .75$, $\eta_p^2 = 0.005$. These results indicate that the location effect was significantly larger in the relevant- than in irrelevant-color cue condition, but to the same extent in known-singleton and in the feature-search conditions (see Figure 4). Likewise, the location effect tended to be larger in known-singleton search than in feature search, and to the same extent for relevant- and for irrelevant-color cue conditions. The location effects in each search type and cue color conditions were assessed using planned comparisons. In the known-singleton search condition, the location effect was significant with relevant-color cues, 112 ms, $F(1, 8) = 53.5$, $p < .0001$, $\eta_p^2 = 0.87$, but not with irrelevant-color cues, 7 ms, $F < 1$, $\eta_p^2 = 0.03$, with a significant difference between the two effects, $F(1, 8) = 88.5$, $p < .0001$,
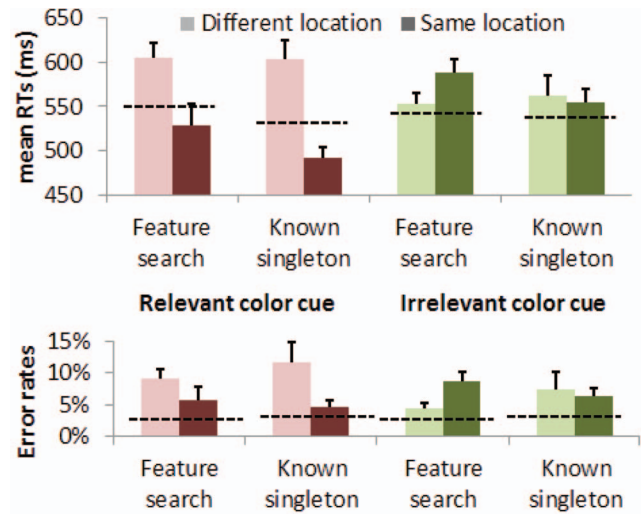

Figure 4. Mean RTs and error rates in Experiment 3 for same and different cue-target location trials as a function cue color (relevant vs. irrelevant) and search type (feature vs. known singleton). The dark bars refer to same-location trials, and the light bars to different-location trials. The four left-hand bars refer to the relevant-color conditions and the four right-hand bars to the irrelevant-color conditions. The hatched lines represent performance on cue-absent trials. See the online article for the color version of this figure.

$\eta_p^2 = 0.92$. In the feature-search condition, a same-location advantage was observed in the relevant-color cue condition, 86 ms, $F(1, 11) = 11.85$, $p < 0.01$, $\eta_p^2 = 0.52$, whereas a same-location cost was observed in the irrelevant-color cue condition, -35 ms, $F(1, 11) = 11.30$, $p < .01$, $\eta_p^2 = 0.51$, again with a significant difference between the two effects, $F(1, 11) = 34.94$, $p < 0.001$, $\eta_p^2 = 0.76$. In order to better assess the probability of a null three-way interaction, we used Bayesian inference using the unit information prior (Masson, 2011). The Bayesian inference provided strong evidence supporting the null hypothesis, $\Delta BIC = 2.25$, Bayes Factor (BF) = 12, $p(H_0|D) = 0.92$. No other effect approached significance, all p values > 0.22.

Accuracy. The accuracy data mirrored the RT data and speed–accuracy trade-off was therefore not a concern. Only the interaction between cue color and location was significant, $F(1, 19) = 11.1$, $p < .01$, $\eta_p^2 = 0.37$. Follow-up analyses revealed that while there was a significant same-location benefit in the relevant-color cue condition, $F(1, 19) = 6.40$, $p = .02$, $\eta_p^2 = 0.57$, a nonsignificant effect in the opposite direction was observed on irrelevant-cue trials, $F < 1$. No other effect approached significance, all p values > 0.13.

Discussion

The results of Experiment 3 yielded three main findings. First, they show that the cost observed when the target appears at the same location as an irrelevant-color singleton is smaller (and in fact disappears) in the known-singleton relative to the feature search condition. This finding reinforces our conclusion from Experiment 2 that an irrelevant-color singleton indeed captures attention during known-singleton search, but this effect is masked

by an effect that is unrelated to attentional capture: the same-location cost.

Second, the present findings show that contingent capture (the difference in spatial capture by a relevant- vs. an irrelevant-color cue) in search for a color-defined target is of the same magnitude whether this target is always a singleton (known singleton search) or never a singleton (feature search). This finding argues against the ideas that (a) observers adopt a default singleton-detection mode that is blind to advance knowledge about the target feature whenever the target is reliably a singleton (Bacon & Egeth, 1994) or (b) attentional capture is strictly salience based (e.g., Theeuwes, 2010). Instead, it demonstrates that feature information contributes to attentional guidance in known singleton search (Lamy, Bar-Anan et al., 2006; Lamy, Carmel et al., 2006).

Finally, the findings also show that a singleton distractor produces stronger capture of attention in search for a color-defined target when this target is also reliably a singleton than when it is not. This finding can be accommodated by a milder version of Bacon and Egeth's (1994) notion of a singleton-detection mode, by which an attentional set for singletons contributes rather than entirely determines attentional priority during known-singleton search.

General Discussion

Summary of the Findings and Implications for the Attentional-Capture Debate

In this study, we resolved two enduring controversies in the study of attentional capture by irrelevant-color singletons. One concerns whether an irrelevant-color singleton summons attention to its location in search for a known-color singleton. The other concerns whether there is a performance cost when the target appears at the same location as an irrelevant-color cue in feature search, and if there is, whether this cost reflects mechanisms related to attentional allocation. Here, we show that the inconsistencies that characterize the current literature with regard to these questions arise at least in part from the existence of an effect that occurs in the spatial cuing paradigm (but not in the additional-singleton paradigm) and that we called the same-location cost. This cost has been overlooked in previous singleton-search studies and misinterpreted in previous feature-search studies.

We provide clear answers to both these questions. First, we show that an important prerequisite for the occurrence of the same-location cost is that cue exposure be long enough (Experiment 1 and 2). We therefore identify a major factor accounting for the difference in feature-search studies between reports of a reliable same-location cost (e.g., Becker et al., 2013; Carmel & Lamy, 2014; Lamy et al., 2015) and reports that the effect is either weak or absent (e.g., Eimer et al., 2009; Folk & Remington, 1998). Taken together, our findings strongly suggest that irrelevant-color singletons do not capture attention in feature search, in line with the contingent-capture account (Folk et al., 1992; see also Bacon & Egeth, 1994). In addition, by demonstrating dissociations between the same-location cost and attentional capture (see also Carmel & Lamy, 2014, Experiment 2; Lamy et al., 2015), they invalidate accounts that link the same-location cost to attentional selection by interpreting it as a marker of either successful prevention of

attentional capture (e.g., Eimer et al., 2009; Lamy et al., 2004), or of rapid disengagement following attentional capture (e.g., Belopolsky et al., 2010).

Second, we demonstrate that in search for a known singleton, an irrelevant-color singleton captures attention (Experiments 2 and 3), in line with the findings emanating from the additional-singleton paradigm (see Theeuwes, 2010 for a review). By showing that such capture is masked by the same-location cost in the spatial-cueing paradigm (e.g., Folk & Remington, 1998), we bridge the gap between the two lines of investigation.[4] Note, however, that our finding of capture by an irrelevant-color singleton during known singleton search should not be interpreted as supporting the salience-based account promoted by Theeuwes (2010). Indeed, this account predicts that a salient singleton should capture attention (a) irrespective of the type of search one is engaged in and (b) to the same extent whether or not it matches the target-defining feature. Our findings clearly disconfirm both predictions: we show that (a) an irrelevant-color singleton captures attention only in known-singleton search but not in feature search, and (b) capture is stronger by relevant-color than by irrelevant-color singletons. While the former finding supports the notion that capture by singletons is contingent on the target being reliably a singleton, in line with Bacon and Egeth's (1994) account, the latter finding invalidates the strong version of this account, according to which observers adopt a feature-blind singleton-detection mode. In fact, in previous studies, we showed that observers do not seem to adopt an attentional set for singletons at all, and that intertrial priming accounts for the presumed adoption of singleton-detection mode (Lamy et al., 2008; Lamy, Bar-Anan et al., 2006; see Lamy & Kristjánsson, 2013 for a review).

Is the Same-Location Cost Independent of Attentional Selection?

The notion that the same-location cost is independent of attentional selection is central to our argument. While the mechanism that we have invoked to account for this cost remains speculative (Carmel & Lamy, 2014; Carmel & Lamy, 2015; Lamy et al., 2015), several behavioral dissociations between attentional capture and the same-location cost strongly support our claim that these effects are indeed independent. Conscious perception of the cue (Lamy et al., 2015) and cue exposure (Experiments 1 and 2 of the present study) were shown to modulate the same-location cost but not to affect attentional capture. Conversely, advance knowledge of the target feature was shown to affect attentional capture, but not to modulate the same-location cost (Carmel & Lamy, 2014, Experiment 2).

Our claim can also be put to a very clear test in electrophysiological studies of attentional capture. Event-related potentials (ERPs) provide a continuous measure of brain activity and as such, they allow one to track the time course of the different processes that unfold from the onset of the cue display. In particular, the N2pc component (an enhanced negativity observed in the N2 range over posterior scalp electrodes contralateral to the side of an attended stimulus) is thought to be a temporal marker for the allocation of attention in visual space, and has, therefore, been

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[4] But see Footnote #1.

extensively used to investigate whether irrelevant objects capture attention (e.g., Eimer et al., 2009; Hickey, McDonald, & Theeuwes, 2006). If, as we claim, an irrelevant-color singleton captures attention in known-singleton search but the same-location cost, which occurs after selection, masks this effect, then one should expect a dissociation between behavioral and ERP markers of attentional capture. Specifically, a significant N2pc should be elicited by irrelevant-color cues, yet behavioral data should show no attentional capture by this cue (i.e., no benefit when the target occurs at the cue's location).

Two recent studies confirm this prediction. Eimer and Kiss (2010, Experiment 2) required observers to search for a singleton defined by a specific color and to refrain from responding if a singleton of a different color appeared in the target display. A singleton-cue preceding the target display was associated with a large spatial-cueing RT effect indicative of attentional capture when it shared the target color but with no spatial effect when it was in either the no-go color or a different nontarget color. Crucially, however, a significant N2pc was associated with no-go and nontarget color cues, indicating that these cues elicited a spatial shift of attention to their location. A strikingly similar pattern of results was reported by Ansorge, Kiss, Worschech, and Eimer (2011, uninformative cue condition). These findings are highly consistent with our conclusion that salient irrelevant-color objects capture attention in known-singleton search and that such capture is masked by a same-location cost that arises from processes that follow attentional selection. It is also noteworthy that in line with our claim that color-specific information guides attentional allocation during search for a known-color singleton, the N2pc components were strongly attenuated and delayed for the irrelevant-color relative to the relevant-color cues.

Methodological Implications

The spatial-cueing paradigm has been one of the most influential and widely used paradigms in the study of attentional capture since Folk et al.'s (1992) seminal study. This paradigm presents several important advantages. It yields highly replicable findings. It allows one to investigate contingent capture (e.g., capture by a red singleton in search for a red target), which is a more challenging endeavor using Theeuwes's additional-singleton paradigm. Finally, because the distractor precedes the target, this paradigm is amenable to the study of the time course of attentional capture.

Several authors have claimed that the interpretation of the findings obtained using this paradigm can be complicated by the unintended influence of a variety of factors. However, follow-up research has typically lent limited support to these claims. Theeuwes, Atchley, and Kramer (2000) suggested that the 150 ms that typically elapse between the cue and target allow fast disengagement from the cue after this cue captured attention. However, later findings invalidated this claim (e.g., Chen & Mordkoff, 2007; Lamy, 2005; see also Folk & Remington, 2010; Lamy, 2010). Belopolsky et al. (2010) suggested that selection of the target on a given trial primes the cue in the subsequent trial when they share the same color but not when they do not, such that intertrial priming rather than attentional set accounts for contingent-capture effects. However, a review of intertrial priming and attentional capture (Lamy & Kristjánsson, 2013) shows that evidence supporting this claim is scarce and unreliable. Finally, Lamy (2005)

suggested that the use of a fixed temporal interval between the cue and target generates strong temporal expectations that can overcome attentional capture by irrelevant objects. However, contradictory evidence was presented by Milliken, Lupiáñez, Roberts, and Stevanovski (2003) and by Seibold and Rolke (2014).

Here, we show that a robust same-location cost arises in most versions of the spatial-cueing paradigm (but see Folk & Anderson, 2010[5]), arguably as a result of the cue and target events being perceived as changes occurring in the same object (Carmel & Lamy, 2014). Crucially, we show that this cost mimics contingent-capture effects by masking attentional capture by irrelevant-color cues but not by relevant-color cues. The methodological implication of this finding is that in order to control for this possible confound, the spatial-cueing paradigm should be used under conditions that prevent the same-location cost, without altering attentional capture. We identified three conditions that fulfil this goal: short-cue exposures (Experiments 1 and 2), subliminal cues (Lamy et al., 2015), and cues that are not perceived as belonging to the same object as the target (Carmel & Lamy, 2014).

Conclusions

In this study, we reconcile between two lines of research that have so far yielded conflicting outcomes, one led by Folk (e.g., Folk & Remington, 1998) and the other by Theeuwes (e.g., 2010). We do that by demonstrating the existence of a same-location cost that is independent of attentional selection but has nevertheless obscured the debate on attentional capture. Despite the resulting methodological reservations this insight raises with regard to the spatial-cueing paradigm, our results strongly support the prominent role of attentional settings in visual search (e.g., Folk et al., 1992) and lend little support to the claim that stimulus salience per se determines whether irrelevant singletons capture attention—at least with the moderately salient distractors typically used in the attentional capture literature.

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[5] Folk and Anderson (2010, Experiment 1) reported data in which the expected same-location cost did not seem to occur. Participants searched for a color singleton (unpredictably either red or green). Cues appeared for 50 ms and were randomly red, green, or blue. All cues captured attention to the same extent. Although same-location trials seemed to be slightly faster when the cue and target colors matched than when they mismatched, this difference, which was not tested for significance, was much smaller than the same-location cost typically observed in our lab.

References

Anderson, B. A., & Folk, C. L. (2012). Dissociating location-specific inhibition and attention shifts: Evidence against the disengagement account of contingent capture. *Attention, Perception, & Psychophysics, 74,* 1183–1198. http://dx.doi.org/10.3758/s13414-012-0325-9

Ansorge, U., Kiss, M., Worschech, F., & Eimer, M. (2011). The initial stage of visual selection is controlled by top-down task set: New ERP evidence. *Attention, Perception, & Psychophysics, 73,* 113–122. http://dx.doi.org/10.3758/s13414-010-0008-3

Bacon, W. F., & Egeth, H. E. (1994). Overriding stimulus-driven attentional capture. *Perception & Psychophysics, 55,* 485–496. http://dx.doi.org/10.3758/BF03205306

Becker, S. I. (2007). Irrelevant singletons in pop-out search: Attentional capture or filtering costs? *Journal of Experimental Psychology: Human*

Perception and Performance, 33, 764–787. http://dx.doi.org/10.1037/0096-1523.33.4.764

Becker, S. I., Folk, C. L., & Remington, R. W. (2013). Attentional capture does not depend on feature similarity, but on target-nontarget relations. *Psychological Science, 24,* 634–647. http://dx.doi.org/10.1177/0956797612458528

Belopolsky, A. V., Schreij, D., & Theeuwes, J. (2010). What is top-down about contingent capture? *Attention, Perception, & Psychophysics, 72,* 326–341. http://dx.doi.org/10.3758/APP.72.2.326

Bravo, M. J., & Nakayama, K. (1992). The role of attention in different visual-search tasks. *Perception & Psychophysics, 51,* 465–472. http://dx.doi.org/10.3758/BF03211642

Burnham, B. R. (2007). Displaywide visual features associated with a search display's appearance can mediate attentional capture. *Psychonomic Bulletin & Review, 14,* 392–422. http://dx.doi.org/10.3758/BF03194082

Carmel, T., & Lamy, D. (2014). The same-location cost is unrelated to attentional settings: An object-updating account. *Journal of Experimental Psychology: Human Perception and Performance, 40,* 1465–1478. http://dx.doi.org/10.1037/a0036383

Carmel, T., & Lamy, D. (2015). *Object-file updating and attentional capture.* Talk presented at the conference of the Israeli Society for Cognitive Psychology (ISCOP), Akko.

Chen, P., & Mordkoff, J. T. (2007). Contingent capture at a very short SOA: Evidence against rapid disengagement. *Visual Cognition, 15,* 637–646. http://dx.doi.org/10.1080/13506280701317968

Eimer, M., & Kiss, M. (2010). Top-down search strategies determine attentional capture in visual search: Behavioral and electrophysiological evidence. *Attention, Perception, & Psychophysics, 72,* 951–962. http://dx.doi.org/10.3758/APP.72.4.951

Eimer, M., Kiss, M., Press, C., & Sauter, D. (2009). The roles of feature-specific task set and bottom-up salience in attentional capture: An ERP study. *Journal of Experimental Psychology: Human Perception and Performance, 35,* 1316–1328. http://dx.doi.org/10.1037/a0015872

Folk, C. L., & Anderson, B. A. (2010). Target-uncertainty effects in attentional capture: Color-singleton set or multiple attentional control settings? *Psychonomic Bulletin & Review, 17,* 421–426. http://dx.doi.org/10.3758/PBR.17.3.421

Folk, C. L., & Remington, R. (1998). Selectivity in distraction by irrelevant featural singletons: Evidence for two forms of attentional capture. *Journal of Experimental Psychology: Human Perception and Performance, 24,* 847–858. http://dx.doi.org/10.1037/0096-1523.24.3.847

Folk, C. L., & Remington, R. W. (2008). Bottom-up priming of top-down attentional control settings. *Visual Cognition, 16,* 215–231. http://dx.doi.org/10.1080/13506280701458804

Folk, C. L., & Remington, R. W. (2010). A critical evaluation of the disengagement hypothesis. *Acta Psychologica, 135,* 103–105. http://dx.doi.org/10.1016/j.actpsy.2010.04.012

Folk, C. L., Remington, R. W., & Johnston, J. C. (1992). Involuntary covert orienting is contingent on attentional control settings. *Journal of Experimental Psychology: Human Perception and Performance, 18,* 1030–1044. http://dx.doi.org/10.1037/0096-1523.18.4.1030

Folk, C. L., Remington, R. W., & Wu, S.-C. (2009). Additivity of abrupt onset effects supports nonspatial distraction, not the capture of spatial attention. *Attention, Perception, & Psychophysics, 71,* 308–313. http://dx.doi.org/10.3758/APP.71.2.308

Hickey, C., McDonald, J. J., & Theeuwes, J. (2006). Electrophysiological evidence of the capture of visual attention. *Journal of Cognitive Neuroscience, 18,* 604–613. http://dx.doi.org/10.1162/jocn.2006.18.4.604

Jonides, J., & Yantis, S. (1988). Uniqueness of abrupt visual onset in capturing attention. *Perception & Psychophysics, 43,* 346–354. http://dx.doi.org/10.3758/BF03208805

Kahneman, D., Treisman, A., & Gibbs, B. J. (1992). The reviewing of object files: Object-specific integration of information. *Cognitive Psychology, 24,* 175–219. http://dx.doi.org/10.1016/0010-0285(92)90007-O

Lamy, D. (2005). Temporal expectations modulate attentional capture. *Psychonomic Bulletin & Review, 12,* 1112–1119. http://dx.doi.org/10.3758/BF03206452

Lamy, D. (2010). Reevaluating the disengagement hypothesis. *Acta Psychologica, 135,* 127–129. http://dx.doi.org/10.1016/j.actpsy.2010.05.009

Lamy, D., Alon, L., Carmel, T., & Shalev, N. (2015). The role of conscious perception in attentional capture and object-file updating. *Psychological Science, 26,* 48–57. http://dx.doi.org/10.1177/0956797614556777

Lamy, D., Bar-Anan, Y., & Egeth, H. E. (2008). The role of within-dimension singleton priming in visual search. *Journal of Experimental Psychology: Human Perception and Performance, 34,* 268–285. http://dx.doi.org/10.1037/0096-1523.34.2.268

Lamy, D., Bar-Anan, Y., Egeth, H. E., & Carmel, T. (2006). Effects of top-down guidance and singleton priming on visual search. *Psychonomic Bulletin & Review, 13,* 287–293. http://dx.doi.org/10.3758/BF03193845

Lamy, D., Carmel, T., Egeth, H. E., & Leber, A. B. (2006). Effects of search mode and intertrial priming on singleton search. *Perception & Psychophysics, 68,* 919–932. http://dx.doi.org/10.3758/BF03193355

Lamy, D., & Egeth, H. E. (2003). Attentional capture in singleton-detection and feature-search modes. *Journal of Experimental Psychology: Human Perception and Performance, 29,* 1003–1020. http://dx.doi.org/10.1037/0096-1523.29.5.1003

Lamy, D. F., & Kristjánsson, A. (2013). Is goal-directed attentional guidance just intertrial priming? A review. *Journal of Vision, 13,* 14. http://dx.doi.org/10.1167/13.3.14

Lamy, D., Leber, A., & Egeth, H. E. (2004). Effects of task relevance and stimulus-driven salience in feature-search mode. *Journal of Experimental Psychology: Human Perception and Performance, 30,* 1019–1031. http://dx.doi.org/10.1037/0096-1523.30.6.1019

Lamy, D., Leber, A. B., & Egeth, H. E. (2012). Selective attention: Experimental psychology. In I. B. Weiner (Ed.), *Handbook of psychology* (2nd ed., Vol. 4, pp. 265–294). New York, NY: Wiley. http://dx.doi.org/10.1002/9781118133880.hop204010

Lamy, D., & Tsal, Y. (1999). A salient distractor does not disrupt conjunction search. *Psychonomic Bulletin & Review, 6,* 93–98. http://dx.doi.org/10.3758/BF03210814

Lamy, D., Tsal, Y., & Egeth, H. E. (2003). Does a salient distractor capture attention early in processing? *Psychonomic Bulletin & Review, 10,* 621–629. http://dx.doi.org/10.3758/BF03196524

Lamy, D., & Zoaris, L. (2009). Task-irrelevant stimulus salience affects visual search. *Vision Research, 49,* 1472. –1480http://dx.doi.org/10.1016/j.visres.2009.03.007

Leber, A. B., & Egeth, H. E. (2006). It's under control: Top-down search strategies can override attentional capture. *Psychonomic Bulletin & Review, 13,* 132–138. http://dx.doi.org/10.3758/BF03193824

Masson, M. E. J. (2011). A tutorial on a practical Bayesian alternative to null-hypothesis significance testing. *Behavior Research Methods, 43,* 679–690. http://dx.doi.org/10.3758/s13428-010-0049-5

Milliken, B., Lupiáñez, J., Roberts, M., & Stevanovski, B. (2003). Orienting in space and time: Joint contributions to exogenous spatial cuing effects. *Psychonomic Bulletin & Review, 10,* 877–883. http://dx.doi.org/10.3758/BF03196547

Most, S. B., Scholl, B. J., Clifford, E. R., & Simons, D. J. (2005). What you see is what you set: Sustained inattentional blindness and the capture of awareness. *Psychological Review, 112,* 217–242. http://dx.doi.org/10.1037/0033-295X.112.1.217

Schönhammer, J. G., & Kerzel, D. (2013). Some effects of non-predictive cues on accuracy are mediated by feature-based attention. *Journal of Vision, 13,* 76. Abstract retrieved from http://dx.doi.org/10.1167/13.9.76

Schreij, D., Theeuwes, J., & Olivers, C. N. L. (2010). Abrupt onsets capture attention independent of top-down control settings II: Additivity

is no evidence for filtering. *Attention, Perception, & Psychophysics, 72,* 672–682. http://dx.doi.org/10.3758/APP.72.3.672

Seibold, V. C., & Rolke, B. (2014). Does temporal preparation speed up visual processing? Evidence from the N2pc. *Psychophysiology, 51,* 529–538. http://dx.doi.org/10.1111/psyp.12196

Theeuwes, J. (1991). Cross-dimensional perceptual selectivity. *Perception & Psychophysics, 50,* 184–193. http://dx.doi.org/10.3758/BF03212219

Theeuwes, J. (1994). Stimulus-driven capture and attentional set: Selective search for color and visual abrupt onsets. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 799–806. http://dx.doi.org/10.1037/0096-1523.20.4.799

Theeuwes, J. (2004). Top-down search strategies cannot override attentional capture. *Psychonomic Bulletin & Review, 11,* 65–70. http://dx.doi.org/10.3758/BF03206462

Theeuwes, J. (2010). Top-down and bottom-up control of visual selection. *Acta Psychologica, 135,* 77–99. http://dx.doi.org/10.1016/j.actpsy.2010.02.006

Theeuwes, J., Atchley, P., & Kramer, A. F. (2000). On the time course of top-down and bottom-up control of visual attention. In S. Monsell & J. Driver (Eds.), *Control of cognitive processes.* Cambridge, MA: MIT Press.

Theeuwes, J., & Chen, C. Y. D. (2005). Attentional capture and inhibition (of return): The effect on perceptual sensitivity. *Perception & Psychophysics, 67,* 1305–1312. http://dx.doi.org/10.3758/BF03193636

Vatterott, D. B., & Vecera, S. P. (2012). Experience-dependent attentional tuning of distractor rejection. *Psychonomic Bulletin & Review, 19,* 871–878. http://dx.doi.org/10.3758/s13423-012-0280-4

Yantis, S., & Egeth, H. E. (1999). On the distinction between visual salience and stimulus-driven attentional capture. *Journal of Experimental Psychology: Human Perception and Performance, 25,* 661–676. http://dx.doi.org/10.1037/0096-1523.25.3.661

Zehetleitner, M., Goschy, H., & Müller, H. J. (2012). Top-down control of attention: It's gradual, practice-dependent, and hierarchically organized. *Journal of Experimental Psychology: Human Perception and Performance, 38,* 941–957. http://dx.doi.org/10.1037/a0027629