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Effects of top-down guidance and singleton priming on visual search

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Recent literature suggests that observers can use advance knowledge of the target feature to guide their search but fail to do so whenever the target is reliably a singleton. Instead, they engage in singleton-detection mode—that is, they search for the most salient object. In the present study, we aimed to test the notion of a default salience-based search mode. Using several measures, we compared search for a known target when it is always a singleton (fixed-singleton search) relative to when it is incidentally a singleton (multiple-target search). We examined the relative contributions of strategic factors (knowledge that the target is a singleton) and intertrial repetition effects (*singleton priming*, or the advantage of responding to a singleton target if the target on the previous trial had also been a singleton). In two experiments, singleton priming eliminated all the differences in performance between fixed-singleton and multiple-target search, suggesting that search for a known singleton may be feature based rather than salience based.

Imagine having to pick a black ball among white ones. This is an easy task. Because the black ball is different from its neighbors, it tends to attract attention. Intuitively, it seems that the task would not be substantially more difficult if you did not know in advance that the ball is black and were told only to pick the one ball with the odd color. That is, the ball might be black on some trials, blue or green on others, but always uniquely colored among the nontarget white balls.

Contrary to this intuition, performance on singleton search shows a strikingly different pattern depending on whether the target's unique feature remains constant (henceforth, the *fixed-singleton condition*) or varies randomly from trial to trial (henceforth, the *mixed-singleton condition*)—that is, whether it is known or unknown. Mixed-singleton search is typically slower than fixed-singleton search by up to several hundred milliseconds (see, e.g., Bravo & Nakayama, 1992). It is considerably more vulnerable to interference by salient irrelevant objects: Whereas in the fixed-singleton condition the presence of an irrelevant singleton slows search by 10–30 msec (see, e.g., Theeuwes, 1991), this effect is on the order of 100 msec or more in the mixed-singleton condition (see, e.g., Theeuwes, 1992). Finally, whereas in mixed-singleton search reaction times (RTs) decrease as the number of nontargets (and display density) increases, thus exhibiting negative search slopes, RTs are virtually unaffected by display density in fixed-singleton search, exhibiting flat search slopes (see, e.g., Wolfe, Butcher, Lee, & Hyle, 2003). These findings suggest that the two types of singleton search may rely on different mechanisms: In fixed-singleton search, observers appear to use their knowledge of the target feature for attentional guidance, whereas in mixed-singleton search they appear to rely on a salience-based search mechanism (Bravo & Nakayama, 1992).

However, there is an alternative to the conclusion that attention is guided by knowledge of the target feature in the search for a known singleton. Specifically, it has been suggested that automatic intertrial repetition effects, or "priming of pop-out" (PoP), rather than an attentional set for a known feature, account for the differences observed between the mixed- and fixed-singleton types of search (Maljkovic & Nakayama, 1994): Performance in the mixed-singleton condition is enhanced if the target has the same feature on consecutive trials, and, after eight repetitions or so, RTs reach the level observed in the fixed-singleton condition. PoP has also been shown to reduce interference by an irrelevant singleton in the mixed-singleton condition down to the magnitude observed in the fixed-singleton condition (Pinto, Olivers, & Theeuwes, 2005). These findings suggest that the same salience-based search mechanism underlies singleton

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search whether or not the target feature is known, with no need to postulate the operation of a goal-directed feature-based mechanism that guides attention to the target in fixed-singleton search.

We recently challenged this conclusion by showing that PoP does not eliminate all the differences between the mixed- and fixed-singleton conditions (Lamy, Carmel, Egeth, & Leber, in press). We found that when, contrary to the situation that prevailed in Maljkovic and Nakayama's (1994) and Pinto et al.'s (2005) studies, top-down factors were strictly controlled, RTs in the mixed-singleton condition remained considerably slower than those in the fixed-singleton condition and PoP did not modulate distractor interference. In addition, in contrast to the flat search slopes observed in the fixed-singleton condition, the search slopes in the mixed-singleton condition remained negative even after several target feature repetitions. Finally, on target-absent trials of a detection task—in which repetition of the target feature could of course play no role—the patterns of performance observed in the mixed- and fixed-singleton conditions differed substantially. We concluded that the mixed- and fixed-singleton types of search are not subserved by the same mechanism after all. This conclusion was recently corroborated by Huang and Pashler (2005), who measured accuracy in singleton search for very brief masked displays. They showed fixed-singleton search to be more accurate than mixed-singleton search, and no PoP effect in the latter condition.

Does search for a known singleton, then, rely exclusively on attentional guidance from knowledge of the target feature? The results of several studies suggest that it does not. Indeed, search performance has been shown to differ substantially depending on whether or not task demands induced a set for singleton targets (see, e.g., Bacon & Egeth, 1994; Lamy & Egeth, 2003, Experiments 5 and 6; Lamy & Tsal, 1999; Pashler, 1988; Yantis & Egeth, 1999). For instance, Bacon and Egeth showed that whereas the presence of an irrelevant color singleton interfered with search when the target was a known shape singleton on each trial (fixed-singleton search), such interference was not observed when the target happened to be a singleton on a minority of the trials—that is, when "singleton-ness" was not a defining feature of the target. In their Experiment 2, performance was similar on distractor-present and distractor-absent trials when up to three objects possessing the target shape could appear on each trial (multiple-target search), and therefore subjects could not use the strategy of searching for a salient object to find the target. Thus, with exactly the same displays (e.g., a target circle among diamond-shaped nontargets), interference by an irrelevant color singleton was contingent on whether task demands allowed subjects to search for a singleton target as in the fixed-singleton condition (singleton-detection mode) or forced them to search for a specific feature as in the multiple-target condition (feature-search mode). This finding suggests that different mechanisms underlie fixed-singleton and multiple-target search.

The tentative conclusion that emerges from the data reviewed thus far is that search for a known singleton appears to be neither exclusively salience based nor exclusively feature based. Observers appear to use the two sources of available knowledge simultaneously—that is, they search for a salient discontinuity *and* for a specific feature. Note that salience-based search is intrinsically slow, yet it appears to be used even when it is clearly detrimental to performance (i.e., when an irrelevant singleton that is more salient than the target is present on 50% of the trials; see, e.g., Bacon & Egeth, 1994, Experiment 1) and despite the fact that an alternative search strategy is available—namely, that of searching for the target feature. Thus, salience-based search appears indeed to be a default search mechanism in the sense that it is triggered whenever singleton-ness is a defining feature of the target.

An alternative and intriguing possibility arises from our recent discovery of a phenomenon we called *singleton priming* (Lamy, Bar-Anan, & Egeth, 2005). We observed that in the multiple-target condition, subjects responded reliably faster to a target that happened to be a singleton if the target in the previous trial had also been a singleton rather than a doublet or a triplet. We replicated this finding using different procedures designed to induce subjects to search for a specific feature rather than for a discrepant object. Thus, it appears that directing one's attention to a singleton, or perhaps to any salient object, facilitates the subsequent direction of attention to a singleton. It is important to note that this effect was specific to singleton targets: RTs on a two-target trial, for instance, were typically no shorter when the preceding trial had also included two targets in comparison with one or three.

We suggest that the differences between fixed-singleton and multiple-target search that have been attributed to the use of a default salience-based search mechanism (in the fixed-singleton condition) may in fact result from intertrial repetition effects—namely, from singleton-repetition priming. In other words, although it has been suggested that search for a known singleton relies on a salience-based search mechanism and benefits from implicit memory of the target's feature on previous trials (see, e.g., Maljkovic & Nakayama, 1994; Pinto et al., 2005), we challenge the very notion of a default salience-based search mechanism (see, e.g., Bacon & Egeth, 1994; Lamy et al., in press; Lamy & Tsal, 1999; Yantis & Egeth, 1999) and raise the possibility that search for a known singleton relies on a feature-based search mechanism and benefits from implicit memory of the target's salience on previous trials. The objective of the present study was to examine this hypothesis.

EXPERIMENT 1

Subjects' performance was compared in the fixed-singleton and multiple-target conditions. Display size and presence of an irrelevant color singleton were manipulated. We expected to replicate the following previous findings: (1) shorter RTs in the fixed-singleton condition than in the multiple-target condition; (2) interference by the irrelevant color singleton in the fixed-singleton condition but not in the multiple-target condition; (3) relatively flat search slopes in both conditions; and (4) a significant singleton-repetition priming effect. Mainly of interest, however, was the question of whether singleton priming would eliminate the differences in performance between the multiple-target and fixed-singleton conditions.

Method

Subjects. The subjects were 12 Tel Aviv University undergraduate students who participated in the experiment for course credit. All reported having normal or corrected-to-normal visual acuity and normal color vision.

Stimuli. The fixation display was a white 0.2º × 0.2º plus sign (+) in the center of a black background. Stimulus displays consisted of the fixation display with the addition of five or nine colored shapes (circles, diamonds, or seven-point stars) equally spaced around the fixation display. At a viewing distance of 50 cm, the centers of the shapes were 3.4º from fixation. The circles subtended 1.4º in diameter. The diamonds were 45º-rotated squares, 1.6º on a side. The points of the stars were located on the circumference of a circle subtending 1.6º in diameter. Each shape contained a white horizontal or vertical line (0.5º in length). The subjects were randomly assigned to one of the three possible target shapes (a circle, a diamond, or a star), which remained constant throughout the experiment. The nontarget shapes switched unpredictably from trial to trial between the two remaining shapes. There were two search conditions and two distractor conditions. In the fixed-singleton condition, the target was a unique shape (singleton). In the multiple-target condition, displays were identical to those in the fixed-singleton condition except that up to three targets (each containing a line of the same orientation) appeared on each trial. In the distractor-absent condition (50% of the trials), all shapes were of the same color. In the distractor-present condition (50% of the trials), one of the nontargets was of a different color. For half of the subjects, the color singleton distractor was red and the other shapes were green, and for the other half of the subjects the color assignments were reversed. The red and green colors were matched for luminance (21 and 20.5 cd/m^2, respectively) using a light meter (Minolta ColorCAL colorimeter).

Procedure. Each trial began with the fixation display. After 350 msec, the stimulus display appeared and remained visible for 2,000 msec or until response. The screen went blank for 500 msec before the next trial began. The subjects were instructed to determine the orientation of the line inside the target shape and to respond by pressing designated keys as quickly as possible while maintaining high accuracy. Error trials were followed by a 500-msec feedback beep. Eye movements were not monitored, but the subjects were explicitly requested to maintain fixation.

Design. There were three between-subjects variables: search condition order, target shape (circle, diamond, or star), and distractor color (red or green), all counterbalanced between subjects. There were four within-subjects variables: search condition (fixed singleton vs. multiple targets, blocked), distractor presence (present vs. absent, mixed), display size (five items vs. nine items, mixed; henceforth, Display Sizes 5 and 9, respectively), and number of repetitions, defined as number of consecutive trials with the same number of targets (0 vs. 1, mixed).[1] Each search condition began with one block of 30 practice trials, which was followed by 372 trials divided into three blocks of 124 trials each.

Results

This experiment and the next included three sets of analyses. First, we compared performance in the fixed-singleton and multiple-target conditions irrespective of singleton priming. To ensure examination of comparable trials, only single-target trials from the multiple-target condition were included. Second, we verified that singleton priming occurred in the present experiment. Finally, we investigated whether or not this effect eliminated the differences observed between the two search conditions. In both experiments, preliminary analyses showed no significant effect involving condition order, with the exception of a main effect due to practice. In order to increase power, this factor was not included in subsequent analyses.

In all the RT analyses, error trials (6.3% of the total) were excluded, and RTs for each subject were sorted into cells according to search condition, distractor presence, and display size. An RT exceeding the mean of a given cell by more than 3 *SD*s was trimmed (fewer than 1% of all observations). Preliminary analyses showed no effect of intertrial nontarget shape repetition in either the fixed-singleton or the multiple-target condition, and no interaction involving this factor.

First ANOVA. A first ANOVA was conducted with search condition, distractor presence, and display size as within-subjects factors. This analysis included only trials with comparable displays in the two conditions—that is, only one-target trials for the multiple-target condition. Mean RTs on correct trials and accuracy data are presented in Figure 1A.

Reaction times. The main effect of search condition was not significant [$F(1,11) = 1.76$, $p > .2$], but in the distractor-absent condition, RTs were significantly shorter in the fixed-singleton than in the multiple-target condition [$F(1,11) = 5.79$, $p < .04$]. The main effect of display size was significant [$F(1,11) = 9.72$, $p < .001$] albeit very small (3.75 msec/item), and slopes did not differ between the two search conditions ($F < 1$). Display size interacted with distractor presence [$F(1,11) = 18.50$, $p < .002$]: Distractor interference became larger as display size increased, irrespective of search condition. Planned comparisons revealed shorter RTs on distractor-absent trials relative to distractor-present trials in the fixed-singleton condition [$F(1,11) = 4.88$, $p < .05$] and a nonsignificant numerical trend in the opposite direction in the multiple-target condition ($F < 1$). Further analyses revealed that whereas distractor effects were similar in the two search conditions for Display Size 9 ($F < 1$), they differed sharply for Display Size 5 [$F(1,15) = 7.16$, $p < .03$], with RTs in the multiple-target condition actually being shorter in the distractor-present than in the distractor-absent condition [$F(1,11) = 10.90$, $p < .008$].

Accuracy. No effect approached significance.

Second ANOVA. A second ANOVA with number of targets (1 vs. 2 vs. 3) and number of repetitions (0 vs. 1) as factors was conducted.

Reaction times. There was a significant interaction between number of targets and number of repetitions [$F(2,22) = 5.08$, $p < .002$]. Paired comparisons revealed that repetition of the number of targets significantly reduced RTs in the one-target condition [singleton priming effect; $F(1,11) = 13.00$, $p < .005$] but did not affect RTs in either the two- or the three-target condition (Fs < 1).

Accuracy. The interaction between number of targets and number of repetitions approached significance

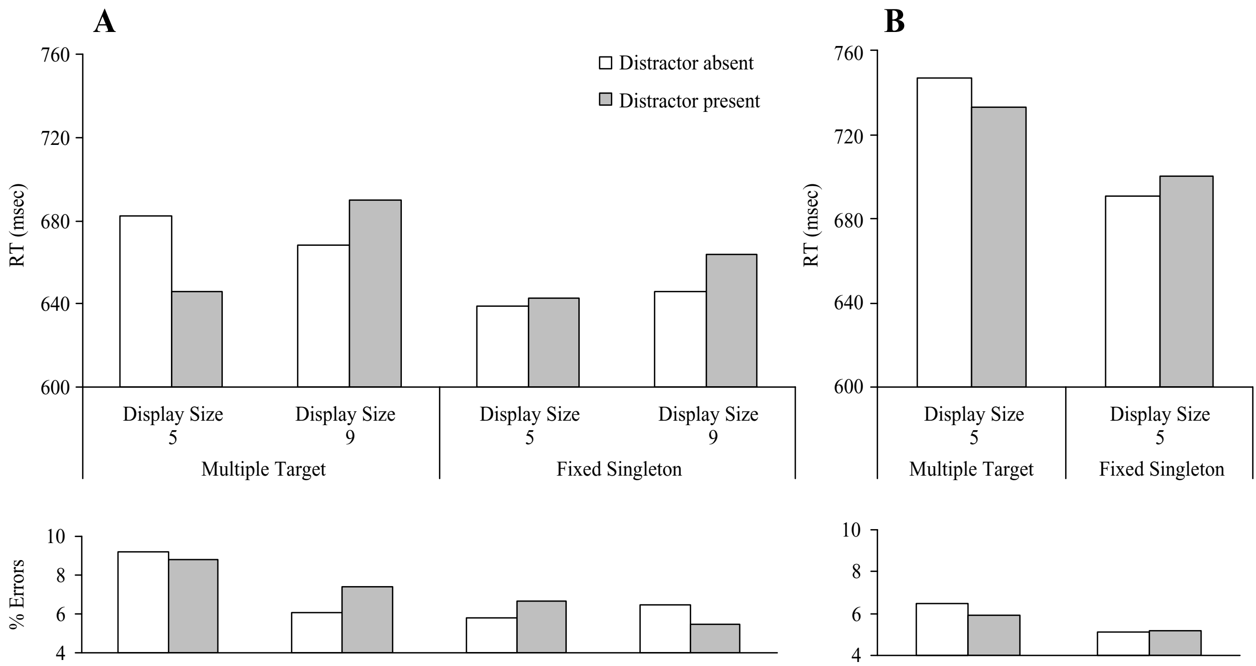

Figure 1. Target identification performance by conditions of search, display size, and distractor presence in Experiments 1 (panel A) and 2 (panel B). Upper panels: Mean reaction times (RTs, in milliseconds). Lower panels: Percentages of errors.

[$F(2,22) = 3.39$, $p < .06$]. Paired comparisons showed that target number repetition tended to reduce error rates in the one-target condition [$F(1,11) = 3.85$, $p < .08$] but did not affect accuracy in either the two-target [$F(1,11) = 1.24$, $p > .2$] or the three-target ($F < 1$) condition.

Third ANOVA. Finally, we conducted a third ANOVA on one-target trials of the multiple-target condition with singleton-target repetition (0 vs. 1), distractor presence, and display size as factors. Mean RTs on correct trials and accuracy data are presented in Figure 2.

Reaction times. Singleton priming interacted with distractor presence [$F(1,11) = 6.82$, $p < .03$]. This effect was qualified by a triple interaction with display size [$F(1,11) = 5.48$, $p < .04$]. In order to clarify this interaction, we examined each display size condition separately. With Display Size 5, RTs were significantly *shorter* when the distractor was present than when it was absent [$F(1,11) = 12.95$, $p < .005$], and this difference disappeared after one singleton-target repetition ($F < 1$). With Display Size 9, singleton priming did not modulate the effect of distractor presence (which, as was reported in the first analysis, was not different from that observed in the fixed-singleton condition; $F < 1$). Singleton priming did not interact with display size ($F < 1$).

Further analyses showed that after one singleton-target repetition, the differences between fixed-singleton and multiple-target searches disappeared. Mean RTs on distractor-absent trials became similar in the two conditions ($F < 1$), and so did the effect of distractor presence with Display Size 5 ($F < 1$).

Accuracy. No effect approached significance.

Discussion

On the one hand, the fixed-singleton and multiple-target conditions generated comparable search slopes, and in neither condition was performance affected by intertrial repetition of the nontarget feature.[2] Moreover, distractor interference was similar in the two conditions with Display Size 9. On the other hand, responses in the multiple-target condition were slower, and with Display Size 5 the presence of the distractor facilitated performance rather than impairing it. However, these differences between the two search conditions disappeared after one singleton-target repetition.

The present results suggest that singleton priming eliminates the differences between fixed-singleton and multiple-target search. However, this conclusion may be premature on two accounts. First, these results were obtained against the backdrop of unexpected findings concerning the influence of the irrelevant color singleton on multiple-target search. The finding of significant distractor interference in feature-guided search with relatively dense displays (here, Display Size 9), though not ubiquitous (see, e.g., Bacon & Egeth, 1994), has sometimes been reported (see, e.g., Lamy et al., in press; Theeuwes, 2004). However, the finding that subjects are slower to respond on distractor-absent than on distractor-present trials with low-density displays (here, Display Size 5) has not been reported in earlier studies in which similar displays and tasks were used: Distractor-absent trials sometimes took longer than distractor-present trials (see, e.g., Bacon & Egeth, 1994, Experiment 2; Lamy et al., in press, Experiment 1; Lamy & Tsal, 1999; Theeuwes, 2004, Experiment 2), but this trend did not reach significance. Second, the finding of

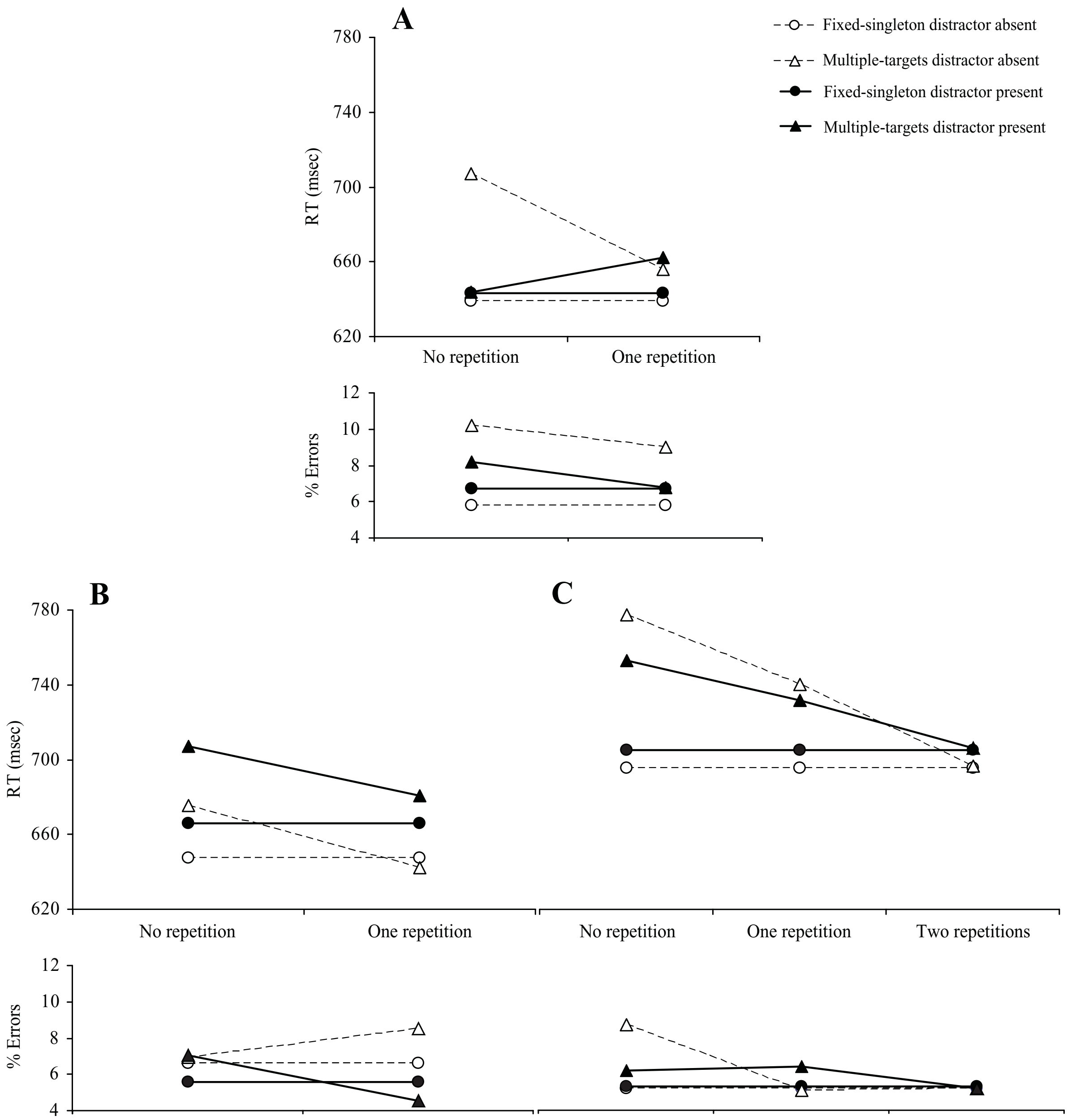

Figure 2. Target identification performance as a function of distractor presence and number of one-target repetitions (singleton priming) in the multiple-target versus fixed-singleton conditions. Panels A and B show data from Experiment 1 for Display Sizes 5 and 9, respectively. Panel C shows data from Experiment 2. Upper panels: Mean reaction times (RTs, in milliseconds). Lower panels: Percentages of errors.

null differences between the fixed-singleton and multiple-target conditions after one singleton-target repetition might result from a lack of power.

Accordingly, the objectives of Experiment 2 were to examine whether or not the unexpected distractor facilitation effect observed with Display Size 5 in the multiple-target condition of Experiment 1 could be replicated, and to investigate the effects of singleton priming on the differences between fixed-singleton and multiple-target search with more repetitions.

EXPERIMENT 2

Method

Subjects. The subjects were 16 Tel Aviv University undergraduate students who participated in the experiment for course credit. All 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 the same as in Experiment 1, except for the following changes. Only five-item displays were used. Since the total number of trials remained the same as in the preceding experiment, there were about twice as many trials for each level of singleton-target repetition in the multiple-target condition. In order to approximate as closely as possible the procedure used in earlier research (e.g., Bacon & Egeth, 1994; Bravo & Nakayama, 1992; Theeuwes, 2004), the nontarget shape remained constant throughout the experiment instead of varying from trial to trial.

There were two between-subjects variables: target shape (circle vs. diamond) and distractor color (red vs. green). There were three within-subjects randomly mixed variables: distractor presence (present vs. absent), number of targets (1 vs. 2 vs. 3), and number of repetitions (0 vs. 1 vs. 2). There were 10 blocks of 75 experimental trials each.

Results and Discussion

In all the RT analyses, error trials (5.0% of the total) were excluded. The same cutoff procedure was used as in Experiment 1.

First ANOVA. The first ANOVA with search condition and distractor presence as factors included only one-target trials for the multiple-target condition. Mean RTs on correct trials and accuracy data are presented in Figure 1B.

Reaction times. The main effect of search condition was significant [$F(1,15) = 9.57$, $p < .008$], and in the distractor-absent condition RTs were shorter in the fixed-singleton than in the multiple-target condition [$F(1,15) = 12.96$, $p < .003$]. Planned comparisons revealed that the presence of the distractor interfered with search in the fixed-singleton condition [$F(1,15) = 5.22$, $p < .04$] but tended to facilitate search in the multiple-target condition [$F(1,15) = 3.53$, $p < .08$].

Accuracy. Only the effect of search condition approached significance [$F(1,15) = 3.14$, $p < .1$], with a trend toward more errors in multiple-target than in fixed-singleton search.

Second ANOVA. A second ANOVA, with number of targets (1 vs. 2 vs. 3) and number of repetitions (0 vs. 1 vs. 2) as factors, was conducted.

Reaction times. There was a significant interaction between the two factors [$F(4,60) = 3.01$, $p < .03$]. Further analyses revealed that repetition of the number of targets significantly reduced RTs in the one-target condition [singleton priming; $F(2,30) = 8.23$, $p < .002$] but did not affect RTs in the two- and three-target conditions [$F < 1$ and $F(2,30) = 1.16$, $p > .3$, respectively].

Accuracy. None of the relevant effects approached significance.

Third ANOVA. Finally, we conducted a third ANOVA on one-target trials of the multiple-target condition with singleton-target repetition (0 vs. 1 vs. 2) and distractor presence as factors. Mean RTs on correct trials and accuracy data are presented in Figure 2C.

Reaction times. Planned comparisons showed that whereas the presence of the distractor facilitated search on no-repetition trials [$F(1,15) = 7.09$, $p < .02$], this effect disappeared on one- and two-repetition trials (Fs < 1). Further analyses showed that after one singleton-target repetition, RTs on distractor-absent trials were still shorter in the fixed-singleton than in the multiple-target condition [$F(1,15) = 5.29$, $p < .04$], but the effect of distractor presence was similar in the two conditions [$F(1,15) = 1.13$, $p > .3$]. After two repetitions, RTs in the two conditions became similar [$F(1,15) = 2.38$, $p > .1$], and so did the distractor effects ($F < 1$).

Accuracy. No effect approached significance.

All the findings obtained for Display Size 5 in Experiment 1 were closely replicated. We can thus conclude that singleton priming eliminates all the differences observed between the fixed-singleton and multiple-target conditions, and that the presence of an irrelevant singleton indeed facilitates search in the multiple-target condition with Display Size 5.

GENERAL DISCUSSION

The objective of the present study was to investigate the existence of a default salience-based search mechanism. The idea that such a mechanism exists has achieved a relatively wide consensus (see, e.g., Ruz & Lupiáñez, 2002) based on two separate lines of findings: (1) PoP was found to eliminate the differences, observed in singleton search, in mean RTs (Maljkovic & Nakayama, 1994) and distractor interference (Pinto et al., 2005) when the unique target feature is known relative to when it is unknown, which suggests that search for a known singleton is solely salience based; and (2) distractor interference in singleton search was found to depend on whether singletonness is a defining feature of the target (see, e.g., Bacon & Egeth, 1994). In a previous study (Lamy et al., in press), we challenged the conclusions of the former line of findings. We showed that search for a known singleton does not rely exclusively on a salience-based mechanism. In the present study, we challenged the conclusions of the latter line of findings by comparing fixed-singleton and multiple-target search. We showed that although search for a known singleton is faster and more vulnerable to distractor interference when singleton-ness is a defining feature of the target than when it is not, these differences are eliminated by singleton priming. Moreover, we observed no difference in slope or in the effect of nontarget repetition (Experiment 1) between the two conditions, and no difference in performance on target-absent trials of a detection task (Lamy et al., in press). We thus conclude that when task demands allow subjects to rely on either salience or feature knowledge, subjects rely only on the latter. This constitutes an argument against the very notion of a default salience-based mode.[3]

This conclusion is consistent with the contingent capture account proposed by Folk and colleagues (e.g., Folk, Remington, & Johnston, 1992), according to which the most salient object in a display captures attention only if it matches the observer's current attentional settings. For instance, Folk and Remington (1998) found that an irrelevant green singleton captured attention when subjects searched for a green target but not when they searched for a red target. Such findings are in line with our proposal that search for a known singleton is feature based.

Two clarifications are in order. First, the conclusion that subjects do not automatically adopt an attentional set for singletons does not imply that salience-based search is never possible. Several studies have shown that subjects can perform efficient search (i.e., search in which performance does not deteriorate when the number of nontargets increases) to detect a singleton target when its unique feature—or even the dimension on which it is unique (see, e.g., Bravo & Nakayama, 1992; Müller, Heller, & Ziegler, 1995; Treisman & Gormican, 1988; Wolfe et al., 2003)—is unpredictable. However, such salience-based search is typically slow, at least with low-density displays (see, e.g., Bravo & Nakayama, 1992), which is consistent with our conclusion that it is not a preferred search mode.

Second, this conclusion does not imply that stimulus-driven salience plays no role in the search for a known singleton; rather, it implies only that a *set* of salient objects is not mandatory in singleton search. In fact, the data presented in Experiment 1 showed strong effects of stimulus-driven salience. Distractor interference substantially increased with display density in both search conditions—that is, irrespective of the relevance of salience to the task. Moreover, the fact that repetition of the number of targets on consecutive trials speeded search only for the one-target condition (singleton priming) also suggests a role for stimulus-driven salience.

A surprising finding of the present study concerns the influence of an irrelevant singleton in the low-density trials of the multiple-target condition. The presence of the distractor facilitated search rather than impairing search. Such facilitation cannot result from the subjects' having one object fewer to scan, because search rate was virtually flat. We can think of no reasonable account for this finding at this point. However, it was statistically reliable in Experiment 1, was replicated with 16 new subjects in Experiment 2, and was observed in all conditions except for the one-target trials preceded by a one-target trial. Thus, this finding does not appear to be spurious, and further research into the processes involved would be useful.

Conclusions

The present findings have two major implications. First, they argue against the notion of a default salience-based search mode or singleton-detection mode that is automatically triggered whenever the target is reliably a singleton. Second, in line with Maljkovic and Nakayama's (1994) idea, they suggest that effects traditionally attributed to a set or strategy may sometimes result from automatic, implicit repetition effects. Indeed, we showed that in certain conditions (e.g., low-density displays) the effects of singleton priming can mimic the effects attributed to advance knowledge that the target is a singleton.

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NOTES

1. There was an insufficient number of trials to examine the effects of more than one repetition.

2. Repetition of the nontarget feature has been shown to speed search performance in the mixed-singleton condition (see, e.g., Lamy et al., 2004; Maljkovic & Nakayama, 1994, Experiment 8). The fact that nontarget-feature repetition affected neither fixed-singleton nor multiple-target search further enhances the similarity between the two conditions.

3. After a number of consecutive singleton-target trials, performance in fixed-singleton search was similar to that in multiple-target search on all the measures used in the present experiment and in Lamy et al.'s (2004) study (i.e., RTs, distractor interference, search slopes, effect of nontarget repetition, and performance on target-absent trials). Note, however, that such a finding does not necessarily imply that the same mechanism underlies the two types of search, because the list of measures we used cannot be exhaustive. It remains possible, therefore, that the two search types might differ on another measure yet to be identified.

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