IRRELEVANT SINGLETONS DO NOT CAPTURE ATTENTION BUT AFFECT PERCEPTION

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Abstract

There is ongoing debate surrounding the questions of whether and how salient visual information can be ignored when it is irrelevant to the observer's attentional set. While some authors have shown that in search for a color-defined target, an irrelevant-color precue delays response when it appears at the same location as the target than at a different location, others have reported no effect for irrelevant-color precues. Our objective here was to determine the boundary conditions of this same-location cost. While a same-color precue captured attention to its location, there was a same-location cost when the target and precue colors did not match. However, the cost emerged only when the exposure duration of the precue display was long enough. These findings suggest that the cost is not a form of inhibitory process independent of attentional set and is unrelated to perceptual masking.

While there has been much debate surrounding the question of the relative contributions of stimulus-driven and goal-directed factors to the allocation of attentional priority (e.g., Theeuwes, 2010), there is growing consensus that attention can be guided at least in part by top-down information. In several studies, Folk and colleagues (e.g., Folk & Remington, 1998; Folk & Anderson, 2010) have shown that in search for a target defined by its color, a salient (singleton) precue of the same color captures attention to its location while a precue of a different color does not (but see Folk, Remington, & Johnston, 1992). Specifically, search performance is equally fast whether or not the target appears at the same location as the irrelevant precue. They reported similar findings whether the color-defined target was a singleton or a non-singleton. However, using a similar paradigm, Lamy and colleagues (Lamy & Egeth, 2003; Lamy, Leber, & Egeth, 2004) have reported that in search for a non-singleton target with a known color, a singleton precue of a different color not only does not capture attention to its location but in fact delays response to a target that appears at that same relative to a different location. They interpreted their findings as supporting the idea that when observers have to repeatedly ignore a known salient distracter, capture may be overcome by inhibiting the salient precue's location. Indirect corroboration of this claim was provided by a recent ERP study by (Eimer, Kiss, Press, & Sauter, 2009) who interpreted the ERP components associated with irrelevant-color precues as indicative of location-specific inhibition mechanisms that can delay subsequent target selection.

The objectives of the present study were (1) to test new predictions of the feature-based inhibition hypothesis, (2) to determine the boundary conditions of the same-location cost reported by Lamy and colleagues and (3) to clarify the discrepancies between the two set of findings (e.g., Folk & Remington, 1998 vs. Lamy & Egeth, 2003).

Experiment 1

The objective of this experiment was to replicate Lamy and colleagues findings' and to investigate whether the same-location cost reflects feature-based inhibition. In previous studies which reported such cost (Eimer et al., 2009; Lamy & Egeth, 2003; Lamy et al., 2004)

the non-target color precue had the same color throughout the experiments. If the cost reflects feature-based inhibition, such inhibition should disappear when the precue varies unpredictably from trial to trial. Subjects searched for a target defined by its color (e.g., red) among heterogeneously colored distractors and responded to the location of a T letter inside the target. A non-informative precue display appeared for 150 ms immediately before the target display. It contained a color singleton, which could unpredictably be either of the same color as the target (target-color precue) or of a different color (nontarget-color precue).

Method

Participants

Fifteen Tel Aviv University undergraduate students participated in the experiment. All subjects reported having normal or corrected-to-normal vision.

Apparatus and stimuli

The experiment was run on a HP DV5-1110ej laptop computer. Stimuli were presented on the computer built-in 15.6" LCD high-resolution (1280*800) wide screen (60Hz refresh rate). Distance from the screen was about 60cm.

A ready display, a cue display, a target display and a response display were presented in each trial. All displays were presented on black background. The ready display included a central grey 6x6mm plus sign surrounded by 4 grey circles (9 mm in radius and 3-pixels thick) positioned 28mm above, below to the left and to the right of the fixation sign. Each circle enclosed an 8x8mm T rotated to either the right or left. The cue display was identical to the ready display, except that the circles were 5-pixels thick. In the no-cue condition, all circles remained grey. In the target-color cue condition, one of the circles was drawn in the same color as the target T (e.g., red) while the others remained grey. In the non-target-cue condition, one of the circles had a unique color that was different from the target color. The non-target color was randomly drawn from 5 possible colors (green, yellow, cyan and magenta – as well blue for one group of subjects and red for the other group). The target display was identical to the ready display, except that the rotated Ts were colored red, green, yellow and blue. The location of each colored T was set randomly. The response display was similar to the ready display, except that the rotated Ts were absent.

Procedure

The participants had to determine the orientation of the T with the known target color (red for half of the subject and blue for the remaining half). They were asked to respond by pressing designated keys on the computer keyboard as quickly as possible, while maintaining high accuracy. The target color was fixed for the whole session, and was counterbalanced between subjects. Subjects were explicitly requested to maintain fixation throughout each trial. Each trial began with the fixation display that was followed by the cue display after 1 sec. The cue display was presented for 150ms. It was immediately replaced by the target display, which appeared for 150ms. The cue (when present) and target locations were set randomly, and were therefore uncorrelated. The target display was followed by the response display, presented for 1350ms or until response. The experiment consisted of a 30-trial practice block followed by two 360-trial experimental blocks.

Results and discussion

An Analysis of Variance (ANOVA) was conducted on mean correct reaction times (RTs) with cue type (no cue, target-color cue and non-target-color cue) and cue location (same vs. different) as within-subject factors (see Figure 1). The interaction between cue type and cue location was highly significant ($F(2,28) = 28.74$, $p<0.001$). Planned comparisons revealed that RTs were faster on same- than on different-location trials when the cue shared the target color, (523ms vs. 608ms respectively, $F(1,14)=20.59$, $p<0.001$), and showed a same-location cost when the cue color was different from the target's (595ms vs. 555ms respectively, $F(1,14)=20.36$, $p<0.001$). This cost resulted exclusively from the significant difference between same-location trials and no-cue trials: RTs did not differ between no-cue and different-location trials, (549ms vs. 555ms respectively, $F(1,14)=1.42$, $p>0.25$).

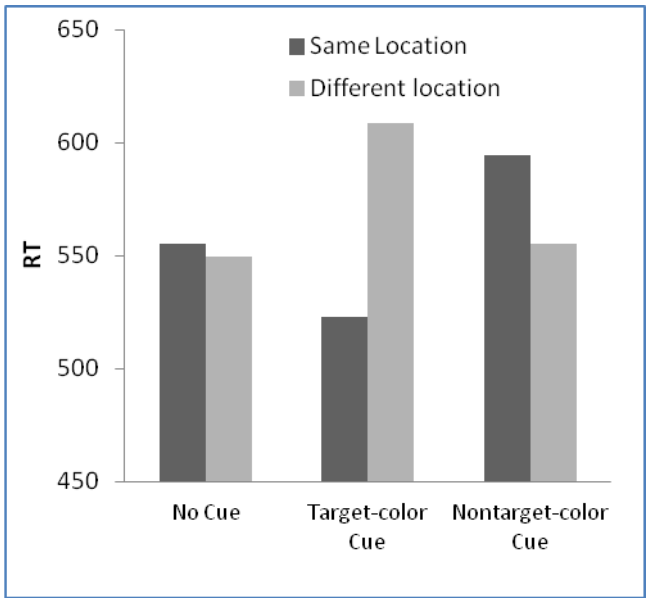

Figure 1: Interaction between condition and cue location in Experiment 1.

We found a same-location cost for cues not sharing the target color in a color-guided search task, and observed no performance advantage on different-location trials, suggesting that the same-location cost does not result from lower attentional priority being assigned to irrelevant-color salient objects. Thus, we replicated Lamy et al.'s (Lamy & Egeth, 2003; Lamy et al., 2004) main findings. However, the same-location cost was observed despite the fact that the cue color could unpredictably take on one of 5 possible colors, thus weakening an interpretation of our finding in terms of feature-based inhibition.

Experiment 2

The objective of this experiment was to elucidate what differences between the procedures used by Lamy and Egeth (2003) – as well as in Exp 1 of the present study - and by Folk and Remington (1998) - may account for the discrepant findings. One candidate difference is that whereas in Folk and colleagues the precue was presented for 50 ms and followed by the target after an ISI of 100 ms, in Lamy and Egeth's study (Exps 5 and 6), the precue was presented for 150 ms with no ISI. In the present experiment, both precue durations were tested. If precue duration is indeed the source of the discrepant findings, we should replicate the same-location cost with the 150-ms duration and the null effect of the non-target-color precue location with the 50-ms duration.

Method

Participants

Eight Tel Aviv University undergraduate students participated in the experiment. All subjects reported having normal or corrected-to-normal vision.

Apparatus stimuli and procedure

The apparatus, stimuli and procedure were similar to those used in Experiment 1, except for the cue display, which was presented for either 150ms (identical to Experiment 1), or 50ms. An inter-stimuli interval (ISI) of 0ms or 100ms, respectively, was added, such that the stimulus-onset asynchrony (SOA) between the cue and target displays was of 150ms in both conditions. During the ISI, the ready display was presented.

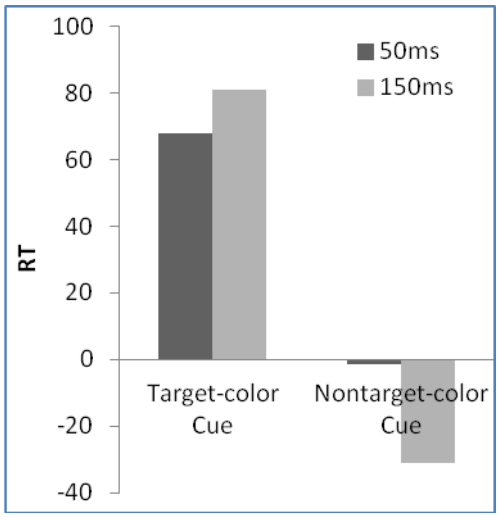

Figure 2: *Cue exposure affects cue location - condition interaction*

Results and discussion

An ANOVA was conducted on mean correct RTs with cue type, cue location and cue exposure (150ms or 50ms) as within-subject factors (see Figure 2). The 3-way interaction between cue type, cue exposure duration and cue location was significant ($F(2,12)=4.32$, $p<0.04$). We further investigated this interaction using planned comparisons. In the target-color cue condition, RTs were faster on same- relative to different-location trials for both cue exposure durations (547ms vs. 628ms, $F(1,6)=20.64$, $p<0.01$ for the 150ms cue and 528ms vs. 596ms, $F(1,6)=73.36$, $p<0.001$ for the 50ms cue). By contrast, in the non-target-color cue condition, the same-location cost depended on cue exposure: it approached significance for the 150ms cue (612ms vs. 560ms, $F(1,6)=4.7$, $p<0.075$), but was utterly non-significant for the 50ms cue (575ms vs. 574ms, $F < 1$).

These findings confirm that cue exposure duration is an important factor for occurrence of the same-location cost. As the same-location advantage observed with target-color cues did not depend on pre-cue exposure duration, our findings also suggest that attentional capture by a target-color cue and local interference by a non-target color cue can be dissociated and follow different time courses.

Experiment 3

One may argue that the critical difference between the two precue durations in the previous experiment might be ISI duration rather than precue duration per se. Specifically, it may be the case that presenting an object of one color (the precue) interferes with perception of an object of a different color (the target in the nontarget-color cue condition) but does not interfere with perception of an object of the same color (the target in the target-color cue condition). If the same location cost indeed reflects a form of low-level interference or of object-substitution masking (Enns & Di Lollo, 1997), it should wane gradually the longer the ISI, and fade completely after about 100ms (Enns & Di Lollo, 1997). To test this prediction, in the present experiment precue exposure duration was set at 150 ms but the ISI between the precue and target was varied.

Method

Participants

Ten Tel Aviv University undergraduate students participated in the experiment. All subjects reported having normal or corrected-to-normal vision.

Apparatus stimuli and procedure

The apparatus, stimuli and procedure were similar to those used in Experiment 1, except that the inter-stimuli interval between the cue display and the target display was unpredictably of 0ms, 100ms or 200ms. During ISI, the ready display was presented.

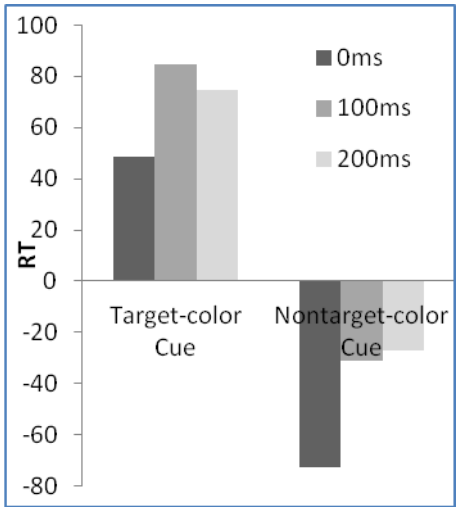

Figure 3: *ISI effect on cue location - condition interaction*

Results and discussion

An ANOVA was conducted on the mean correct RTs with cue type, cue location and ISI (0ms, 100ms or 200ms) as within-subject factors (see Figure 3). The interaction between cue type and cue location was significant ($F(2,18)=30.49$, $p<0.001$) and followed the same pattern as in Experiment 1. The interaction between ISI cue type and cue location was not significant ($F< 1$). In the non-target-color cue condition, the same-location cost did not significantly differ between ISIs ($F(1,9)=2.94$, $p>0.1$ and $F<1$ for 0-vs-100ms and 100-vs-200ms, respectively). In particular, it was still significant at the longest (200-ms) ISI (27ms, $F(1,9)=5.21$, $p<0.05$). These findings clearly suggest that the same-location cost does not reflect low-level perceptual interference or object-substitution masking.

General Discussion

The findings from this study show that in search for a non-singleton target defined by its known color, a precue of a different color interferes with participants' responses to the target when this precue spatially (but not temporally) overlaps the target location. This same-location cost does not reflect feature-based inhibition because it occurred even when the color of the precue varied unpredictably from trial to trial. In addition, it does not reflect low-level perceptual interference because it does not wane with time after the precue has disappeared, as to be expected from a low-level process such as object substitution masking (Enns & Di Lollo, 1997). Finally, the same-location cost was observed only when cue exposure was relatively long (150ms). As most spatial cueing studies of attentional capture have followed Folk and colleagues' (e.g., Folk et al., 1992) procedure and used a 50ms precue exposure duration, the latter finding explains why the same-location cost has seldom been reported. Using a single non-target color as singleton precue throughout their experiment, Lamy et al. (2004) reported same-location cost after a 50ms exposure to the cue. A single uninformative cue may be actively inhibited, while inhibition of the current study's multiple cue colors inhibition is improbable. If indeed both studies describe different processes, the apparently contradicting findings do not reflect on one another. We should not ignore the possibility that precue energy rather than precue duration per se is the critical factor. Further research is needed to elucidate the mechanisms underlying this effect. Exploring the extent to which it may be dependent on the combination of luminance level and exposure duration (i.e., on the precue energy level) may therefore be a fruitful avenue for future studies.

References

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*(5), 1316-1328. doi:10.1037/a0015872

Enns, J. T., & Di Lollo, V. (1997). Object Substitution: A New Form of Masking in Unattended Visual Locations. *Psychological Science*, *8*(2), 135 -139. doi:10.1111/j.1467-9280.1997.tb00696.x

Folk, C. L., & Remington, R. W. (1998). Selectivity in distraction by irrelevant featural singletons: Evidence for two forms of attentional capture. *Journal of Experimental Psychology: Human Perception and Performance*, *24*(3), 847-858. doi:10.1037/0096-1523.24.3.847

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*(4), 1030-1044. doi:10.1037/0096-1523.18.4.1030

Lamy, D., & Egeth, H. E. (2003). Attentional capture in singleton-detection and feature-search modes. *Journal of Experimental Psychology: Human Perception and Performance*, *29*(5), 1003-1020. doi:10.1037/0096-1523.29.5.1003

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*(6), 1019-1031. doi:10.1037/0096-1523.30.6.1019