ARTICLE IN PRESS

Vision Research xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Vision Research

journal homepage: www.elsevier.com/locate/visres

Letter to the Editor

Target activation and distractor inhibition underlie priming of pop-out: A response to Dent (this issue)

ARTICLE INFO

Keywords:
Priming of pop out
Inter-trial priming
Target activation
Distractor inhibition
Visual attention
Visual search
Implicit memory

ABSTRACT

Visual search is faster when the target and distractors features repeat than when they switch on successive trials, a phenomenon known as priming of pop-out (PoP). In previous work, we suggested that two mechanisms, each indexed by a repetition benefit and a switch cost underlie PoP: target activation and distractor inhibition. Consistent with this account, we reported strong correlations between the benefit and cost indexing each mechanism and concluded that there are stable individual differences on target-activation and distractor-inhibition processes. In subsequent work, we noted flaws in our baseline for benefits and costs and suggested a different baseline. Yet, we did not explore the implications of these flaws for our previous conclusions - a gap that Dent (this issue) filled in a large-scale replication of our study. He found our reported correlations to entirely vanish when the corrected baselines are used, whereas repetition benefits were correlated and so were switching costs. He concluded that his findings invalidate the activation-inhibition account of PoP and proposed a hybrid account, according to which repetition effects reflect activation and inhibition, whereas switch costs index a conflict-resolution process. Here, we claim that failure to observe correlations between indices of the same components invalidates the claim that there are stable individual differences on these components but does not challenge the idea that target-activation and distractor inhibition underlie PoP. We reanalyzed the data from four published experiments. As Dent (this issue), we find no correlations between indices of the same component. However, we show that novel predictions of the activation-inhibition components account are supported, whereas the predictions of the conflict-resolution account are disconfirmed.

1. Introduction

In a seminal study, Maljkovic and Nakayama (1994) showed that what observers attend to at a given time affects how their attention is deployed in the few moments that follow. Observers searched for a target defined as the uniquely colored item among homogeneously colored distractors and made a discrimination response regarding its shape. The target and distractors' colors unpredictably either repeated or switched roles from trial to trial. Reaction times (RTs) were substantially faster when the target and distractor colors repeated than when they switched, an effect known as priming of pop out (PoP). This finding was replicated in numerous studies and for a variety of target properties, such as shape (e.g., Lamy, Carmel, Egeth, & Leber, 2006), orientation (Hillstrom, 2000), size (Wolfe, Butcher, Lee, & Hyle, 2003), location (e.g., Maljkovic & Nakayama, 1996) and facial expressions (e.g., Amunts, Yashar, & Lamy, 2014).

1.1. Initial evidence for the activation-inhibition components account of PoP

In a previous paper (Lamy, Antebi, Aviani, & Carmel, 2008) we suggested that two mechanisms underlie PoP: target activation and distractor inhibition. Using a variant of the PoP task in which the target and distractors colors could repeat, exchange roles, or be new, we suggested that the effects of each of these mechanisms could be quantified using two measures: a benefit and a cost. We showed that it is easier to select a target with the same color as the previous target than with a new color (target repetition benefit) and more difficult to reject distractors with the color of the previous target than with a new color (distractor switch cost). We took these two effects to reflect increased target activation, which results from selection of the target's color on the previous trial. Likewise, we showed that it is easier to reject distractors with the same color as the previous distractors than with a new color (distractor repetition benefit) and more difficult to select a target with the color of the previous distractor than with a new color (target switch cost). We took these two effects to reflect increased distractor inhibition, which results from rejection of the distractors' color on the previous trial.

Furthermore, we reported strong correlations between the benefit and cost indexing each mechanism within the same session and across sessions. By contrast, we found no correlation either between the two benefits or between the two costs, that is, between indices related to what we hold to be different mechanisms.

Our conclusion from these findings was two-fold: (1) Independent target-activation and distractor-inhibition mechanisms, each indexed by a repetition benefit and a switch cost, underlie PoP and (2) there are measurable and stable individual differences on each mechanism.

1.2. Dent's evidence against the activation-inhibition components account of PoP

In a later paper (Yashar & Lamy, 2010a), we noted flaws in the baseline used to calculate the benefits and costs in PoP, and suggested a

https://doi.org/10.1016/j.visres.2018.03.009
Received 20 December 2017; Received in revised form 24 February 2018; Accepted 2 March 2018

different baseline[1]. Yet, we did not explore the implications of these flaws for our earlier conclusions - a gap that Dent (this issue) filled in a large-scale replication of our experiment. He showed that while target repetition did not interact with distractor repetition, as reported by Lamy et al. (2008), target switch interacted with distractor switch, in contradiction with Lamy et al. (2008) findings. Moreover and most crucially, he found that the pattern of correlations reported by Lamy et al. (2008) were replicated when their flawed benefit and cost measures were used, yet entirely broke down when the corrected measures proposed by Yashar and Lamy (2010a) were used. Instead, significant correlations between the two repetition benefits and between the two switch costs were found, and none between the benefit and cost taken to index target activation nor between the benefit and cost taken to index distractor inhibition.

Dent (this issue) concluded that these results are “at odds with the suggestion of Lamy et al. (2008) that PoP is driven by two primary factors one related to distractor inhibition and one related to target activation, with each reflected in one switch and one repetition effect”.

1.3. *Objective of the present paper*

The correlation data provided by Dent (this issue) are fully convincing and provide a crucial rectification of erroneous inferences drawn by Lamy et al., 2008. However, we disagree with his conclusion that his findings refute the activation-inhibition account of PoP. The primary objective of this paper is to put forward the arguments that lead us to such disagreement.

Dent’s (this issue) conclusion relies on four claims. (1) The absence of a correlation between target repetition benefit and distractor switch cost, and between distractor repetition benefit and target switch cost, is incompatible with the claim that these index the same target-activation and distractor-inhibition mechanism, respectively. (2) The presence of an interaction between target and distractor switch costs is incompatible with the idea that the effects of target and distractor switching are independent measures of target activation and distractor inhibition. (3) Previous findings (Lamy et al., 2013), showing that both distractor inhibition indices are present in orientation singleton search and both target activation indices are absent, do not necessarily support the components account. (4) The correlations between repetition benefits and between switch costs, as well as the finding that the latter two interact with each other, suggest that repetition benefits index the same mechanism, which is different from the mechanism underlying switch costs.

We address each of these claims below and then present new evidence in favor of the components account. Before we do, however, it is important to clarify what the notions of target activation and distractor inhibition stand for in our account.

1.4. *Clarification of the notions of target activation and distractor inhibition according to the components account*

In our original paper, we suggested two possible interpretations of our findings (Lamy et al., 2008, p.39). Specifically, we proposed that increased target activation and distractor inhibition following target selection and distractor rejection on the previous trial may reflect either (a) the modulation of the preattentive representation of these features or (b) processes that occur at selection (i.e., attentional shifts or attentional engagement) after the target is detected. More recent findings from our lab allowed us to test these accounts against each other and clearly supported the latter.

We first demonstrated that PoP does not reflect only perceptual effects but also later, response-related effects (Lamy, Yashar, & Ruderman, 2010). We showed that the perceptual component of PoP (which we hold to consist of a target-activation and distractor-inhibition subcomponents), was apparent early in a search trial and was not affected by response factors. By contrast, the response-based component of PoP emerged later during search as an interaction between target-distractor repetition/switch and response repetition, which we showed to be driven by motor response repetition rather than by response repetition (Yashar & Lamy, 2011; Yashar, Makovski, & Lamy, 2013).

More critically for the present purposes, we further characterized the perceptual component of PoP in a series of studies showing that PoP does not affect the early, preattentive stage of perceptual processing that determines attentional salience, but a later stage, during which attention is engaged to the target and response-relevant features are extracted. Specifically, we showed that (a) selecting a given feature on a previous trial does not increase attentional capture by this feature on the current trial (Biderman, Biderman, Zivony, & Lamy, 2017; see also Yashar, White, Fang, & Carrasco, 2016; see Lamy & Kristjansson for a review); repeating the target and distractor features from one trial to the next (b) does not reduce search slopes (Amunts et al., 2014), (c) improves performance during temporal search in the absence of spatial uncertainty (Yashar & Lamy, 2010b) and (d) improves search accuracy under limited stimulus exposure conditions only when the task requires focal attention (i.e., in fine discrimination task but not in a coarse localization task).

Thus, target activation and distractor inhibition arise from the previous selection episode and come into play after stimulus-driven and goal-directed factors have determined attentional salience and a candidate target is detected: the larger the activation level of the current target feature relative to the activation level of the current distractor feature in a given search display, the faster attentional engagement to the target[2].

2. Responses to Dent (this issue) claims

2.1. *Claim 1: absence of a correlation between indices of the same component*

The absence of a correlation between indices of the same component convincingly demonstrates that there are no stable individual differences on target activation and distractor inhibition measures. It suggests that a given individual’s visual search performance may rely on each of these processes to different extents from trial to trial.

However, it is important to underscore that target activation and distractor inhibition may nonetheless prove to be distinct, dissociable processes even if there are not stable individual differences on the benefits and costs that we take to index them. Finding manipulations that selectively affect the indices reflecting one mechanism, while leaving the indices reflecting the other mechanism intact would constitute solid evidence for a dissociation.

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[1] The original analyses pertaining to conditions of target-color variation (repeated, new, switched) were conducted across distractor-color conditions, and the analyses pertaining to conditions of distractor-color variation (repeated, new, switched) were conducted across target-color conditions. Yashar and Lamy (2010a) noted that this procedure resulted in biased sampling of the orthogonal dimension: for instance, in the repeated- vs. new-target-color comparison used to measure the target-activation benefit, the repeated-target condition included only repeated- and new-distractor trials, whereas the new-target condition included also switched-distractor trials. Thus, activation effects were contaminated by inhibition effects, and vice versa. In order to address this problem, we suggested a different procedure for measuring repetition benefits and switch costs. Specifically, the baseline for repetition effects no longer included switched-feature trials and the baseline for switching effects no longer included repeated-feature trials. This procedure was used by the subsequent papers pertaining to target and distractor inter-trial variations published by our group (Lamy, Zivony, & Yashar, 2011; Lamy, Yashar, and Ruderman, 2013; Yashar & Lamy, 2010).

[2] Lleras and colleagues (e.g., Tseng, Glaser, Caddigan, & Lleras, 2014; Wan & Leeras, 2010) offered a similar account of the distractor previewing effect (DPE), which refers to slower identification of a color singleton when the distractor color vs. the target color was viewed in the preceding target-absent trial. They characterized the stage at which DPE operates as an “attentional-decision” stage.

As we will argue in Section 2.3, Lamy et al. (2013) reported such dissociation by showing that both the distractor repetition benefit and the target switch cost (which both reflect distractor inhibition) are observed during orientation search, whereas neither the target repetition benefit nor the distractor switch cost (which both reflect target activation) are observed. In addition, in the section of the present paper entitled "Novel evidence in favor of the activation-inhibition account of PoP" (Section 3), we provide support for a dissociation between target activation and distractor inhibition by presenting new analyses of two color and two orientation search experiments reported in Lamy et al. (2008) and Lamy et al. (2013)[3].

2.2. *Claim 2: interaction between target switch and distractor switch*

Dent (this issue) found target switch and distractor switch to interact and concluded that "the presence of the interaction by itself supports the idea that the effects of target and distractor switching are not independent measures of target activation and distractor inhibition". Although we have no straightforward account for this finding, we speculate that it might occur only in studies in which PoP interacts with response repetition. We base this conjecture of the findings reported by Lamy et al. (2011). They noted that the interaction between PoP and response repetition, which is the marker of the response-based component, has been inconsistent across studies. They attempted to delineate the conditions under which it is observed and found selection difficulty to be a modulating factor.

Directly relevant to the present purposes, reanalysis of Lamy et al. (2011) data shows that while target switch and distractor switch did not interact when search was easy and PoP did not interact with response repetition, the two switch effects interacted when search was difficult and PoP interacted with response repetition. The fact that in Dent's large-scale study, where the two switch costs interacted, PoP also interacted with response repetition (personal communication) provides additional evidence in favor of our hypothesis.

Although these observations are clearly post-hoc and call for further research, they suggest that under some circumstances, namely when PoP interacts with response repetition, repetition and switch effects may not be pure measures of target activation and distractor inhibition. According to this rationale, the interaction between target switch and distractor switch reported by Dent (this issue) does not necessarily entail that the underlying mechanisms (distractor inhibition and target activation, respectively) are not independent. What matters is that certain circumstances can be found (e.g., when search is easy), under which no interaction is observed.

2.3. *Claim 3: distractor inhibition in orientation search*

Lamy et al. (2013) noted that while PoP on the color dimension is a robust finding (e.g., Maljkovic & Nakayama, 1994) PoP on the orientation dimension is elusive (see e.g., Hillstrom (2000) for positive evidence and Found and Müller (1996) and Lustig, Simons, Lleras, and Beck (2012) for negative evidence). They further noted that studies that failed to report PoP in orientation singleton search probed only target-activation measures. They suggested that unlike in color search, PoP in orientation search might rely solely on distractor-inhibition processes. They noted that this suggestion is consistent with the notion that selection of an orientation singleton is essentially mediated by iso-feature suppression of the background elements (e.g., Knierim & van Essen, 1992; Li, 2000; Sagi, 1990). In line with their hypothesis, they showed that target repetition and distractor switch were absent for orientation search, whereas distractor repetition and target switch were present.

Dent (this issue) argued that this finding does not necessarily support the activation-inhibition components idea. He suggested that "the distractors may be well represented without the specific target feature being represented. As a result switch costs and repetition benefits related to distractor features are observed without those related to target features". However, the inhibition cost *is* related to the target feature, since it is measured as slower responses when the *target* feature matches the previous distractors' feature. If the target feature was not represented during orientation search (and only the response-feature at the location of the non-distractor location, say, its color, was represented to allow correct responding), there would be no reason to expect that a match between the current target feature and the previous distractor feature should affect performance.

According to the activation-inhibition components account, following target selection in orientation search, the distractor feature is associated with a negative (inhibitory) value, whereas the target feature is associated with a neutral value because search is presumably guided to the target by iso-feature suppression of the distractors. Thus, for instance, when attention is shifted to the target and this target's feature on the selection dimension matches the feature of the distractors on the previous trial, attentional engagement is slowed because the distractors' feature was inhibited, but no slowing is observed when the distractors take on the feature of the previous target because the target's feature was not activated. Likewise, when the distractor feature is repeated, attentional engagement is speeded because the distractor's feature was inhibited, but repetition of the target does not affect performance because the target's feature was not activated.

This account thus accommodates the notions that (1) orientation search is guided by iso-feature suppression of the distractors, (2) PoP in orientation search relies only on distractor inhibition processes, and (3) a match between the current *target* feature and the previous distractors feature nevertheless affects performance in orientation search.

2.4. *Claim 4: repetition benefits and switch costs reflect different mechanisms*

Dent's (this issue) account of PoP is similar to ours in that it situates the mechanism underlying switch costs at an attentional decision stage. However, his account also differs from ours in two important respects. First, Dent suggests that repetition effects index processes that modulate the perceptual salience of the previous target and distractor features, whereas switch effects index a later attentional decision stage. In contrast, we propose that target activation and distractor inhibition affect the same "engage" or "decision-to-engage" stage of processing and are each indexed by both a repetition benefit and a switch cost. Second, Dent stipulates that this attentional decision stage is mainly influenced by conflict between feature status on the previous vs. on the current trials– whereas according to the components account, engagement speed is influenced by activation/inhibition levels resulting from the previous trial.

On the one hand, Dent (this issue) provided convincing evidence showing that the two repetition effects are correlated and may therefore measure the same mechanism. However, this correlation is uninformative as to what search processes this mechanism affects. Dent (this issue) provided no evidence supporting the idea that repetition effects reflect the modulation of preattentive processes. On the other hand, the evidence for a correlation between the two switch indices is less convincing, as it may entirely result from the fact that the two effects interacted in Dent's study. In addition, the idea that the superadditive correlation reflects the extra cost incurred when two sources of conflict (target switch and distractor switch) burden the common decision making stage is clearly speculative in the absence of measures more specifically related to conflict resolution.

In the next section, we provide new evidence (resulting from new analyses on the data of published studies) designed to test predictions of the two accounts with regard to the mechanisms underlying switching costs.

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[3] We did not include the reanalysis of Lamy et al. (2008; Exp.2) because the data were lost.

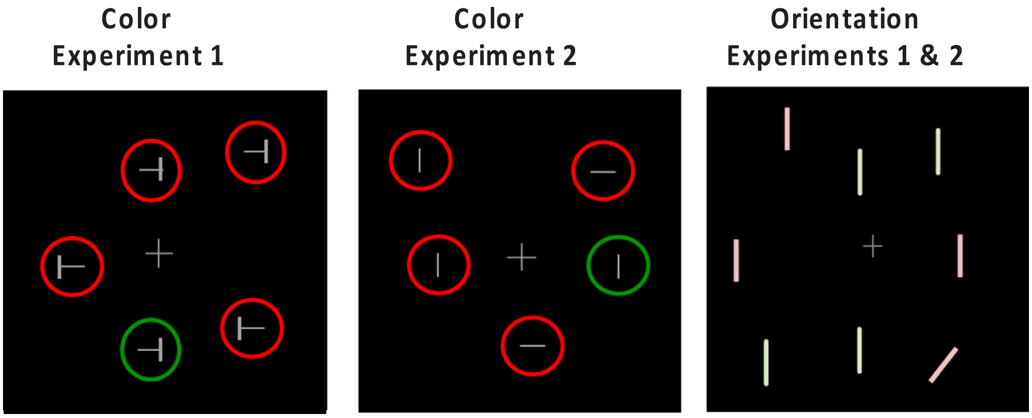

Fig. 1. Sample displays. If the color displays depict trial n, then on repeated-target trials the target on trial n-1 was green, on new-target trials it was blue or yellow and on switched-target trials the distractor on trial n-1 was green. Likewise, on repeated-distractor trials, the distractor on trial n-1 red, on new-distractor trials it was blue or yellow and on switched-distractor trials the target on trial n-1 was red. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

3. Novel evidence in favor of the activation-inhibition components account of PoP

3.1. Rationale of the new analyses

The activation-inhibition components account stipulates that responses on switched-distractor trials are slowed because selection of the target feature on the previous trial increases *target-feature activation* and makes it more difficult to reject the distractors on the current trial when they take on the previous target's feature. This account therefore predicts that the distractor-switch cost should be larger when it follows a trial in which the target repeated vs. did not repeat[4], but only in color search and not in orientation search. Indeed, we have claimed that PoP reflects both target activation and distractor inhibition in color search, but only distractor inhibition in orientation search (Lamy et al., 2013).

By contrast, Dent (this issue) suggests that the slowing on switched-distractor trials reflects the time required to resolve the conflict surrounding the distractor feature's status. Borrowing from Botvinick, Braver, Barch, Carter, and Cohen's (2001) suggestion that behavioral costs that result from conflict trials are reduced following a conflict trial (conflict adaptation, e.g. Gratton, Coles, & Donchin, 1992), Dent (this issue) suggested that switch costs should be reduced following a switch trial. Thus, his account predicts that the distractor-switch cost should be smaller when it follows a trial in which the distractors took on the feature of the target on the previous trial relative to a neutral feature, irrespective of the search dimension.

A similar rationale applies for switched-target trials. The activation-inhibition components account predicts that the switched-target cost should be larger when it follows a trial in which the distractor repeated vs. did not repeat, in both color and orientation search. Dent's conflict-resolution account predicts that the switched-target cost should be smaller when it follows a trial in which the observer had to resolve a conflict with regard to the target feature, that is, when the target took on the feature of the distractors on the previous trial relative to a neutral feature, irrespective of the search dimension.

We tested these predictions by conducting new analyses of the data from experiments reported in Lamy et al. (2008) and Lamy et al. (2013). We pooled the data from two similar color-search experiments (Lamy et al., 2008, Exp.1 and Lamy et al., 2013, Exp.2, color session, henceforth, Color Experiments 1 and 2) and the data from two similar orientation-search experiments (Lamy et al., 2013, Exp.1 and Exp.2, orientation session, henceforth, Orientation Experiments 1 and 2).

3.2. Methods

All experiments involved a singleton search but differed in the target-defining dimension. In Orientation Experiments 1 (N = 24) and 2 (N = 23), participants searched for an orientation singleton and responded to its color. In Color Experiments 1 (N = 20) and 2 (N = 23) participants searched for a color singleton and reported the orientation of either a rotated T or a line segment enclosed in each display item, respectively (see Fig. 1).

In all experiments, there were four possible features on the target-defining dimension and on each trial, two different features were randomly drawn and assigned to the target and distractors. Thus, on two successive trials, the target could repeat, take on a new feature or take on the feature of the distractors on the previous trial. Likewise, the distractors could repeat, take on a new feature or take on the feature of the target on the previous trial. A detailed description of the methods can be found in Lamy et al. (2008, Exp.1) and Lamy et al. (2013; Exps.1 & 2).

3.3. Statistical analyses and predictions

In our previously published analyses (Lamy et al., 2008; 2013), we reported significant target activation benefits and costs (i.e., target repetition and distractor switch effects, respectively) for color but not for orientation search and significant distractor inhibition benefits and costs (i.e., distractor repetition and target switch effects, respectively) for both color and orientation search. Finally, we reported that the interaction between target and distractor repetition benefits and between target and distractor switch costs was not significant for either of the search dimensions. Here we conducted new analyses. In all these analyses, the new-target and new-distractor baselines were calculated according to the method suggested by Yashar and Lamy (2010a) and used by Dent (this issue), as explained in footnote 1. Thus, separate baselines were used for analyses involving feature repetition and for analyses involving feature switch, both for trial n and for trial n-1.

3.3.1. Correlation analyses

We conducted four correlation analyses between (a) target repetition and distractor switch (activation indices), (b) distractor repetition and target switch (inhibition indices), (c) target repetition and distractor repetition (repetition indices) and (d) target switch and distractor switch (switch indices). We present the correlations only for the data from the color experiments to facilitate the comparison with Dent's data (which included only color search). The analyses including the orientation experiments are presented in the (Appendix Table A).

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[4] Note that the activation-inhibition components account also predicts that repetition of the target feature or distractor feature on the previous trial should speed responses to repeated targets or distractors, respectively, on the current trial. However, Maljkovic and Nakayama (1994; see also e.g., Hillstrom, 2000; Lamy et al., 2006) showed that the PoP effect saturates with multiple repetitions. In other words, the repetition benefit is larger when it follows a no-repetition trial than when it follows a repetition trial. Thus, because of this saturation effect, we only tested the predictions of the activation-inhibition components account on switched-feature trials.

3.3.2. Factors modulating distractor-switch effects

To test the prediction that increasing target activation slows RTs on switched-distractor trials, we conducted an ANOVA with target repetition on trial n-1 (repeated vs. new target relative to trial n-2) and distractor switch on trial n (switched vs. new distractor relative to trial n-1) as factors. Because we hold target activation to contribute to PoP in color but not in orientation search, we expected a significant interaction (i.e., a larger distractor switch cost on trial n following a target repetition on trial n-1) in color but not in orientation search.

To test Dent's prediction that resolving a conflict regarding the distractor feature on the previous trial reduces the distractor-switch cost on the current trial, we conducted an ANOVA with distractor switch on trial n-1 (switched vs. new distractor relative to trial n-2) and distractor switch on trial n (switched vs. new distractor relative to trial n-1) as factors. According to the conflict-resolution account, a significant interaction (i.e., a reduced distractor-switch cost on trial n following a distractor switch on trial n-1) should be observed irrespective of the search dimension.

3.3.3. Factors modulating target-switch effects

To test our prediction that increasing distractor inhibition slows RTs on switched-target trials, we conducted an ANOVA with distractor repetition on trial n-1 (repeated vs. new distractor relative to trial n-2) and target switch on trial n (switched vs. new target relative to trial n-1) as factors. Because we hold distractor inhibition to contribute to PoP in both color and orientation search, we expected a significant interaction (i.e., a larger target switch cost on trial n following a distractor repetition on trial n-1) in both color and orientation search.

To test Dent's prediction that resolving a conflict regarding the target feature on the previous trial reduces the target-switch cost on the current trial, we conducted an ANOVA with target switch on trial n-1 (switched vs. neutral target relative to trial n-2) and target switch on trial n (switched vs. neutral target relative to trial n-1) as factors. According to the conflict account, a significant interaction (i.e., a reduced target-switch cost on trial n following a target switch on trial n-1) should be observed irrespective of the search dimension.

3.4. Results

Analyses of the accuracy data revealed no speed-accuracy trade-off. For conciseness purposes, only RT analyses are reported (but both mean RTs and mean error rates for all conditions are presented in the (Appendix Tables B and C).

3.4.1. Correlations

As reported by Dent (this issue), when Yashar and Lamy's (2010a) method was used to calculate target and distractor repetition and switch, neither the correlation between the target activation indices (target repetition and distractor switch) nor the correlation between the distractor inhibition indices (distractor repetition and target switch) were significant. The correlation between color repetition indices (target and distractor repetition) approached significance. The correlation between color switch indices (target and distractor switch) was far from significance. The correlation coefficients and p values are presented in Table 1 (see Appendix, Table A, for correlation analyses including the orientation experiments).

Table 1
Correlations between target-related effects and distractor-related effects for the color experiments (N = 43).

Target condition	Distractor condition	
	Distractor repetition	Distractor switch
Target repetition	.26 (.087)	.08 (.597)
Target switch	.09 (.553)	− .04 (.779)

Note: p-values are presented in parentheses.

3.4.2. Modulation of distractor-switch effects

3.4.2.1. Test of the activation-inhibition components account. The main effect of target repetition on trial n-1 was not significant for color, F(1, 42) = 2.37, p = .13 and was significant for orientation, F(1, 46) = 6.30, p = .016. The main effect of distractor switch on trial n, which we hold to reflect target activation, was significant for color, F(1, 42) = 50.63, p < .0001 and not for orientation, F < 1 The interaction between the two factors was significant for color, F(1, 42) = 6.10, p = .01, indicating that the distractor switch effect was larger when the target color repeated on trial n-1. It was not significant for orientation, F < 1. Thus, as predicted by the activation-inhibition components account, repeating the target feature on the previous trial increased the distractor switch cost for color and not for orientation (see Fig. 2A).

3.4.2.2. Test of Dent's conflict-resolution account. The main effect of distractor switch on trial n-1 approached significance for color, F(1, 42) = 3.86, p = .056 and was not significant for orientation, F < 1. The main effect of distractor switch on trial n was significant for color, F (1, 42) = 12.26, p = .001 and not for orientation, F < 1. The interaction between the two factors was not significant for either color, F(1, 42) = 1.22, p = .28 or orientation, F < 1. Thus, contrary to the predictions of the conflict-resolution account, a distractor switch on the previous trial did not reduce the distractor switch cost for either color or orientation (see Fig. 2B).

3.4.3. Modulation of target-switch effects

3.4.3.1. Test of the activation-inhibition components account. The main effect of distractor repetition on trial n-1 was not significant for either color, F < 1 or orientation, F(1, 46) = 1.59, p = .21. The main effect of target switch on trial n, which we hold to reflect distractor inhibition, was significant for color, F(1, 42) = 8.19, p = .007 and for orientation, F(1, 46) = 21.29, p < .0001. The interaction between the two factors was not significant for color, F(1, 42) = 1.42, p = .24 but was significant for orientation, F(1, 46) = 6.71, p = .013. These results indicate that the target switch cost increased following a distractor repetition for orientation as predicted by the activation-inhibition component account, but not for color, contrary to its prediction (see Fig. 3A).

3.4.3.2. Test of Dent's conflict-resolution account. The main effect of target switch on trial n-1 was not significant for either color, F < 1 or orientation F(1, 46) = 1.29, p = .26. The main effect of target switch on trial n was significant for color, F(1, 42) = 5.65, p = .02 and approached significance for orientation, F(1, 46) = 3.92, p = .054. The interaction between the two factors was not significant for either color, F < 1 or orientation, F(1, 46) = 1.77, p = .19. Thus, contrary to the predictions of the conflict-resolution account, switching the target feature on the previous trial did not reduce the target switch cost for either color or orientation (see Fig. 3B).

4. Discussion

The analyses presented here fully replicated Dent's (this issue) findings of no significant correlation between either target repetition and distractor switch or between distractor repetition and target switch. Thus, our findings further establish that, contrary to our initial claim (Lamy et al., 2008), there are no reliable individual differences on target activation and distractor inhibition mechanisms.

Our findings replicated the correlation between the two repetition effects reported by Dent (this issue). Here, the magnitude of this correlation (0.26) was numerically larger than that reported Dent (0.22), yet it failed to reach significance, probably because it included much fewer participants (43 vs. 312). Thus, this finding seems robust. However, neither the present study nor Dent (this issue) provided any clues

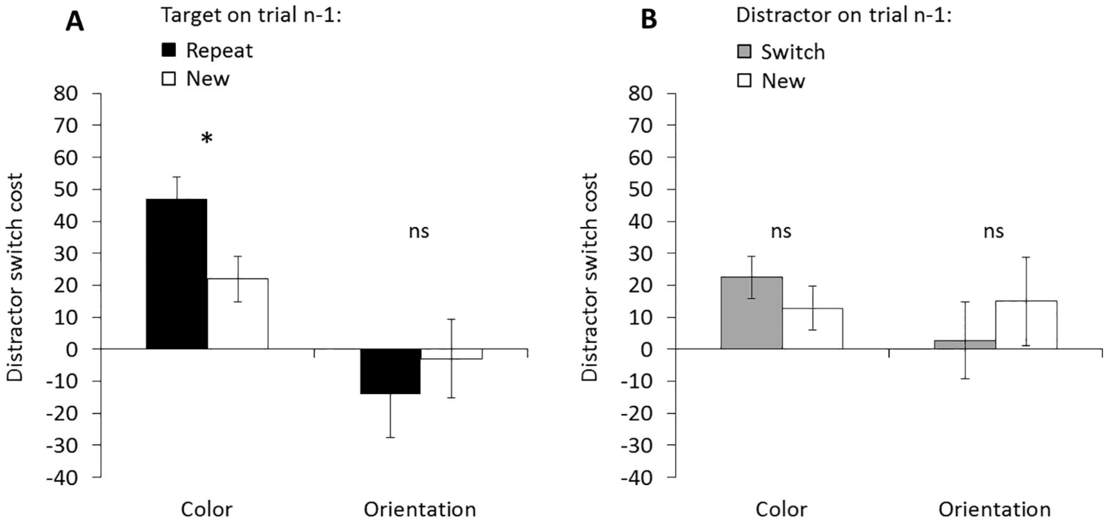

Fig. 2. Distractor switch costs (indexing target activation) in color and in orientation search, as a function of target repetition (repeat vs. new) on trial n-1 relative to trial n-2 (Panel A) and as a function of distractor switch (switch vs. new) on trial n-1 relative trial n-2 (Panel B). The bars denote ± 1 standard errors.

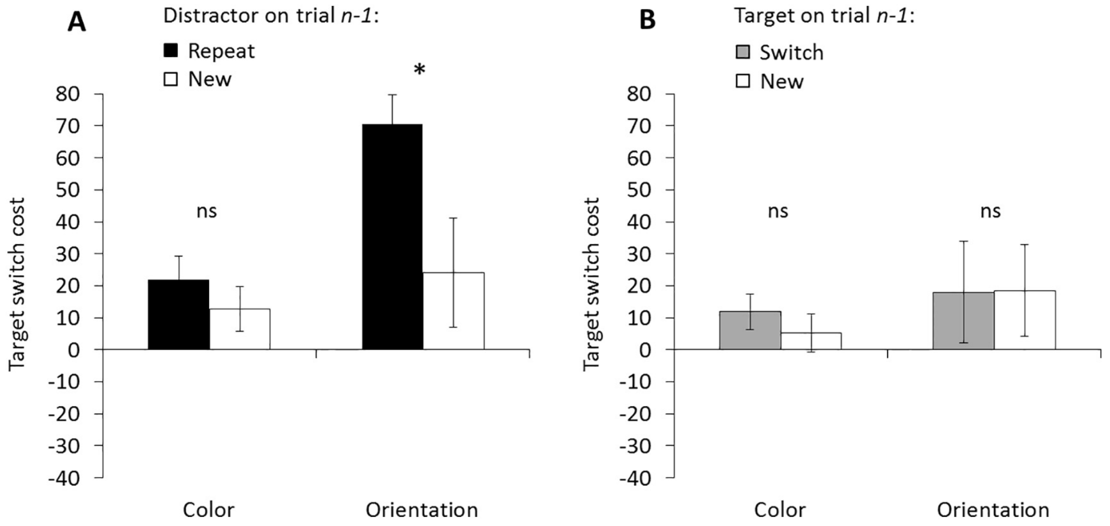

Fig. 3. Target switch costs (indexing distractor inhibition) in color and in orientation search, as a function of distractor repetition (repeat vs. new) on trial n-1 relative to trial n-2 (Panel A) and as a function of target switch (switch vs. new) on trial n-1 relative trial n-2 (Panel B). The bars denote ± 1 standard errors.

as to what mechanism it may reflect and more research is therefore required to elucidate this issue.

In contrast, the correlation between the two switch effects was entirely absent. Since unlike Dent (this issue) we found no interaction between target switch and distractor switch in either color or orientation search, the results suggest that the correlation between the two switch effects in Dent's study reflected the interaction between them.

The main thrust of the present response is that the activation-inhibition components account of PoP is supported despite the absence of correlation between indices reflecting the same mechanisms (target activation and distractor inhibition). Here, we reanalyzed the data from two color-search and two orientation-search experiments initially reported by Lamy et al. (2008) and Lamy et al. (2013). We showed that in line with the components account, (a) increasing target activation by repeating the target feature enhanced the cost of rejecting distractors sharing the target feature (distractor switch) on the following trial in color search, for which target activation contributes to PoP; (b) this did not happen in orientation search, for which only distractor inhibition plays a role; (c) increasing distractor inhibition by repeating the distractor feature enhanced the cost of selecting targets sharing the distractor feature (target switch) on the following trial in orientation search. However, contrary to our expectation, this did not happen in color search, despite a numerical trend in the expected direction (see Figure 3A). Thus, three out of the four predictions following from the activation-inhibition account were statistically supported.

In contrast, the results showed no evidence supporting the conflict-resolution account. The cost of resolving a conflict with regard to the status of the target or distractors features on the current trial was not reduced following resolution of a similar conflict on the previous trial. Thus, none of the four predictions following from the conflict-resolution account was supported.

5. Conclusion

In the present paper, we provided new support for the idea that independent target-activation and distractor-inhibition mechanisms, each indexed by a repetition benefit and a switch cost, underlie PoP. In contrast, we found no evidence for the claim that switch costs reflect the extra time required to resolve the conflict between a feature's status on the previous trial and its status on the current trial. Thus, taken together with previous findings from our lab (Amunts et al., 2014; Biderman et al., 2017; Yashar & Lamy, 2010a,b), the notion that feature repetition and feature switch both modulate the speed at which attention is engaged in a potential target provides the most parsimonious account of the extent data. Finally, we replicated Dent (this issue) finding showing that there are no stable individual differences on these mechanisms and are grateful to him for rectifying the erroneous conclusions reported by Lamy et al. (2008).

Appendix

Table A

Correlations between indices of target activation (target repetition and distractor switch), distractor inhibition (distractor repetition and target switch), repetition (target repetition and distractor repetition) and switch (target switch and distractor switch) across experiments (N = 67). As Color Exp. 2 and Orientation Exp. 2 were conducted on the same participants, separate correlations are presented for inclusion of the color or orientation search. p-values are presented in parentheses.

Two color and one orientation searches	Distractor repetition	Distractor switch
Target repetition	.17 (.176)	.00 (.993)
Target switch	.05 (.662)	−.08 (.514)
One color and two orientation searches	Distractor repetition	Distractor switch
Switched distractor	.22 (.078)	−.13 (.313)
New distractor	.16 (.198)	−.12 (.319)

Table B

Factors modulating distractor switch costs. Mean reaction times (in milliseconds) and accuracy rates (in percentages) for switched- vs. new-distractor trials on trial n relative to trial n-1, as a function of target repetition on trial n-1 relative to trial n-2 (repeated vs. new target) and as a function of distractor switch on trial n-1 relative to trial n-2 (switched vs. new distractor) for color search and for orientation search.

	Color search		Orientation search	
	Distractor switch from trial n-1 to n		Distractor switch from trial n-1 to n	
Target repetition from trial n-2 to n-1	New	Switched	New	Switched
Repeated target	710 (13) 96% (0.7%)	757 (14) 96% (0.7%)	986 (18) 91% (0.9%)	972 (17) 90% (1%)
New target	718 (13) 96% (0.5%)	740 (15) 96% (0.6%)	955 (19) 89% (0.9%)	952 (15) 91% (0.7%)
Distractor switch from trial n-2 to n-1	New	Switched	New	Switched
Switched distractor	711 (13) 96% (0.6%)	733 (14) 96% (0.7%)	953 (17) 91% (0.8%)	956 (16) 90% (1%)
New distractor	707 (13) 96% (0.6%)	720 (13) 96% (0.7%)	942 (19) 87% (0.9%)	957 (18) 92% (1.1%)

Table C

Factors modulating target switch costs. Mean reaction times (in milliseconds) and accuracy rates (in percentages) for switched- vs. new-target trials on trial n relative to trial n-1, as a function of distractor repetition on trial n-1 relative to trial n-2 (repeated vs. new distractor) and as a function of target switch on trial n-1 relative to trial n-2 (switched vs. new target) for color search and for orientation search.

Distractor repetition from trial n-2 to n-1	Color search		Orientation search	
	Target switch from trial n-1 to n		Target switch from trial n-1 to n	
	New	Switch	New	Switch
Repeated distractor	722 (14) 96% (0.6%)	744 (14) 96% (0.8%)	937 (17) 91% (1%)	1007 (19) 88% (1%)

(*continued on next page*)

Table C (*continued*)

Distractor repetition from trial n-2 to n-1	Color search		Orientation search	
	Target switch from trial n-1 to n		Target switch from trial n-1 to n	
	New	Switch	New	Switch
New distractor	722 (13) 96% (0.7%)	734 (15) 96% (0.6%)	950 (17) 91% (0.8%)	974 (17) 90% (1.2%)
Target switch from trial n-2 to n-1	New	Switch	New	Switch
Switched target	713 (12) 96% (0.7%)	725 (14) 96% (0.7%)	946 (18) 90% (0.9%)	962 (17) 90% (0.9%)
New target	713 (13) 97% (0.6%)	718 (13) 95% (0.7%)	949 (20) 90% (0.9%)	968 (18) 89% (1.2%)

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