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History effects in visual search for monsters: Search times, choice biases, and liking

Andrey Chetverikov · Árni Kristjánsson

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Abstract Repeating targets and distractors on consecutive visual search trials facilitates search performance, whereas switching targets and distractors harms search. In addition, search repetition leads to biases in free choice tasks, in that previously attended targets are more likely to be chosen than distractors. Another line of research has shown that attended items receive high liking ratings, whereas ignored distractors are rated negatively. Potential relations between the three effects are unclear, however. Here we simultaneously measured repetition benefits and switching costs for search times, choice biases, and liking ratings in color singleton visual search for “monster” shapes. We showed that if expectations from search repetition are violated, targets are liked to be less attended than otherwise. Choice biases were, on the other hand, affected by distractor repetition, but not by target/distractor switches. Target repetition speeded search times but had little influence on choice or liking. Our findings suggest that choice biases reflect distractor inhibition, and liking reflects the conflict associated with attending to previously inhibited stimuli, while speeded search follows both target and distractor repetition. Our results support the newly proposed *affective-feedback-of-hypothesis-testing* account of cognition, and additionally, shed new light on the priming of visual search.

Keywords Attention · Priming · Choice bias · Liking · Preferences · Visual search

What we have recently attended to has a powerful influence over what we attend to next. The more often in a row observers attend to a visual search target containing a particular feature among distractors, the faster they will be to attend to the same target on the next trial (Kristjánsson, Ingvarsdóttir, & Teitsdóttir, 2008; Maljkovic & Nakayama, 1994; see Lamy & Kristjánsson, 2013, for a review). In addition, discrimination accuracy for brief masked displays is higher for repeated searches (Ásgeirsson, Kristjánsson, & Bundesen, 2014; Lamy, Yashar, & Ruderman, 2010; Sigurdardóttir, Kristjánsson, & Driver, 2008). Furthermore, attention is so strongly drawn to previously attended targets that preceding search history can almost completely determine free choice between items (Brascamp, Blake, & Kristjánsson, 2011a).

Such findings have interesting parallels in research on preferences following search. Studies on *distractor devaluation* have demonstrated that previously ignored stimuli are rated lower than novel items (Fenske & Raymond, 2006; Fragopanagos et al., 2009; Goolsby et al., 2009; Kiss et al., 2007; Raymond, Fenske, & Tavassoli, 2003). For example, Goolsby et al. found that observers in a visual search task not only preferred items attended previously, but also preferred novel stimuli to distractors. If one search trial is enough to change preferences, search history may as well have affective consequences. According to the newly proposed *affective-feedback-in-hypothesis-testing* approach of visual cognition, our perceptual system generates hypotheses that are based on previous history of perceiving and attending (Chetverikov, 2014). According to the account, correct hypotheses are rewarded with positive affect, whereas incorrect ones are punished by negative affect. In addition to the (dis)confirmation of prediction, the strength of feedback

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depends on the degree of novelty of the predictions, so that novel predictions lead to stronger feedback (Chetverikov, 2014, p. 387). Otherwise, simple predictions with the highest probability of confirmation (e.g., staring at a blank wall) would result in a constant stream of positive feedback. According to this account, affect reinforces the accumulation of accurate knowledge about the world.

This proposal draws support from studies on mere exposure and familiarity (Berlyne, 1970; Bornstein, 1989; Chetverikov, 2014; Zajonc, 1980), perceptual categorization (Chetverikov & Filippova, 2014; Muth & Carbon, 2013), and visual search (Chetverikov, Jóhannesson, & Kristjánsson, 2014) that demonstrate that the accuracy of decisions may influence preferences. A general result is that correct answers are associated with more positive affective ratings of targets, whereas errors are associated with more negative ratings, echoing recent findings on the tight association between affect and error-related event-related potentials (Hajcak, McDonald, & Simons, 2004; Larson, Gray, Clayson, Jones, & Kirwan, 2013; Luu, Collins, & Tucker, 2000; Olvet & Hajcak, 2012; Wiswede, Münte, Goschke, & Rüsseler, 2009). Further support has come from studies demonstrating that stimulus and response conflicts can lead to aversive tendencies—a finding that can be related to inconsistent predictions in cases of cognitive conflict (Aarts, De Houwer, & Pourtois, 2012, 2013; Dreisbach & Fischer, 2012; Fritz & Dreisbach, 2013; Schoupe, De Houwer, Ridderinkhof, & Notebaert, 2012). The account furthermore shares some characteristics with theories of reward (Schultz, 2006). Especially relevant are recent studies demonstrating activity in reward-related regions (ventral striatum) when no extrinsic reward is provided (Daniel & Pollmann, 2012, 2014; Satterthwaite et al., 2012). The present approach, however, differs from theories of reward-based learning in that the former concerns predictions and their (dis)confirmation as a source of affective feedback, whereas the latter emphasize predictions regarding reward.

The affective-feedback account predicts that search history should influence preferences toward the target through influences on observers' predictions. Here we tested this hypothesis. We investigated interdependencies between search times, choice biases, and liking in visual search, by measuring the effects of target and distractor repetition and role reversal on affective evaluation ("liking") and comparing them with changes in search times and choice biases. Observers searched for the odd "monster" out among two sets of distractor monsters (see Figs. 1 and 2) in two experiments, locating it with a mouse click. The trial blocks consisted of sequences of four searches with similarly colored target and distractors, followed by a "critical" trial on which either the colors of target and distractors were unchanged, the target color changed, and/or one distractor color changed. On a subsequent "liking" trial, observers chose between three monsters containing the target color and two distractor colors. To separate biases from

preferences, we varied the instructions on "liking" trials: On half of the trials observers chose the most pleasant monster, whereas on the other trials they chose the least pleasant one. We hypothesized that when expectations created via priming are violated, targets would be liked less. Changes in preferences with confirmed expectancies were not expected, because, as we described above, the proposed approach suggests that previously confirmed predictions would not provide strong feedback. Additionally, if choice biases are different from preferences, we would expect to observe a tendency to choose the target independently of whether observers were instructed to choose the most pleasant or the least pleasant monster.

Two experiments were conducted that differed only in that in Experiment 1B target position was randomized not only during search, but also on liking trials, to neutralize any position effects. The results of the experiments were almost identical. To make sure that we did not miss any of the effects due to insufficient statistical power, we ran the analyses while including experiment as a variable. There were no differences in the results of the experiments. Consequently, for the sake of brevity, we present only the results from the analyses of the combined data in the main text. However, the figures show data from each of the experiments separately to demonstrate the consistency of the obtained findings, and separate analyses of each experiment are presented in the [Appendix](#).

Method

Participants

A group of 59 observers (33 females, 26 males; 18–35 years old, median 19 years) at Saint Petersburg State University voluntarily participated. All reported normal or corrected-to-normal acuity and no color vision deficiencies.

Stimuli and procedure

Observers searched for a color singleton "monster" among two sets of distractors of two different colors (see Fig. 1). There were always 11 distractors in total, and the number of distractors in each color set was chosen randomly, but with no less than four distractors in each set. "Monster" shapes are simple enough for the color singleton search, but unlike simpler shapes, provided the variability needed for observers to have preferences regarding them. Each stimulus was a $2.8^\circ \times 2.6^\circ$ monster (viewing distance = 60 cm, with the observers' position controlled with the position of the chair and mouse) chosen randomly from a set of 12 and positioned randomly in a $18.4^\circ \times 17.0^\circ$ space at display center. Observers clicked with a mouse on the "odd-color-out" target monster. The

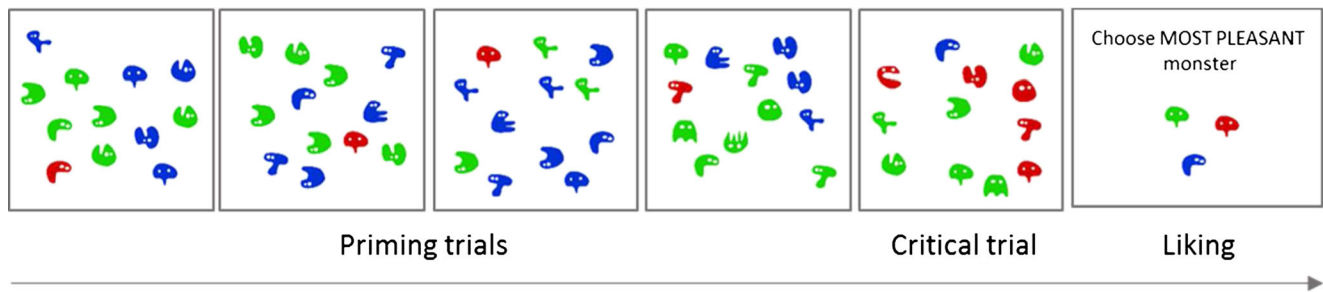


Fig. 1 Trial sequence. In the sequence presented here, the colors of the target and one of the distractor subsets are switched on the fifth, *critical* trial. On one half of the liking trials, observers chose the “most pleasant”

monster (as shown), and on the other half, they chose the “least pleasant” one. Note that shape was irrelevant to the task and was randomly determined for all items on each trial

experiment consisted of 60 sequences like the one shown in Fig. 1, which were performed in one 15- to 20-min session.

On the first four trials of each sequence, the target and distractor colors were constant (their shapes and positions were randomly chosen for all objects on each trial, so shape was always irrelevant to the task and could not influence the results). On the fifth trial, the target color and one distractor set color were determined according to one of six conditions (Fig. 2). The other distractor color was constant throughout each sequence. The colors were red (0/255/106, in 0–255 HSL color space), yellow (40/255/106), green (80/255/106), maroon (120/255/106), or blue (160/255/106). The intertrial interval was 500 ms. Displays were programmed using PsychoPy (Peirce, 2007) and presented on a 19-in. CRT LG Flatron F920P display.

Following the fifth (critical) trial, observers rated the targets and distractors from the last trial. The target and two randomly selected distractors of different colors were presented equidistant from each other at 4° eccentricity. On half of the trials, observers chose the stimulus that they found most pleasant, and the least pleasant one on the other trials. The order of trial sequences with “choose most pleasant” and “choose least pleasant” questions was randomized. The chosen object then disappeared, and observers chose between the two remaining

stimuli. Finally, they clicked on the remaining stimulus, starting the next sequence. Forced-choice tasks are common in liking studies (see, e.g., Bornstein, 1989) because they are less dependent on response strategies and the ability to quantify preferences than are Likert-type ratings. Two directions of ranking then allowed us to separate choice biases and liking (see below). Each color was the target color in all six conditions with each liking order (12 sequences for each color in total), so color preferences could not influence the results in any systematic way.

Results

Observers found the target on 99.5% of the trials (99.6% on critical trials). Error trials were not analyzed.

Search times

Search times were log-transformed to reduce outlier influences (Fazio, 1990), but all figures reflect the original scales. Search times decreased as search was repeated from Trials 1 to 4 in each sequence (see Fig. 3). A repeated measures analysis



Fig. 2 Examples of the stimuli and different experimental conditions. The figure shows the possible changes in target or distractor colors from the preceding trial to the critical trial, which was followed by the liking

trial (see Fig. 1). Note, importantly, that the shapes here are only shown as constant for clarity of presentation; the actual shapes were chosen randomly on each trial. T, target; D1 and D2, the two distractor sets

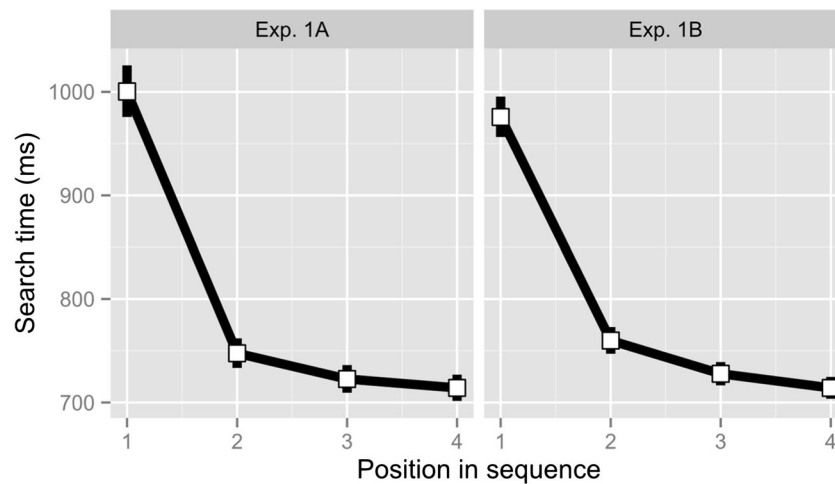


Fig. 3 Search times as a function of repetition of the target and distractor colors. Error bars show 95% confidence intervals

of variance (ANOVA; used subsequently unless noted)¹ with Observer as a random factor showed that the largest search time decrease followed the first trial, $F(1, 58) = 382.69$, $p < .001$, $\eta_G^2 = .868$, but further repetition of target and distractor colors led to additional decreases, $F(1, 58) = 45.78$, $p < .001$, $\eta_G^2 = .441$, consistent with other results in the literature on attentional priming (see, e.g., Brascamp, Pels, & Kristjánsson, 2011b; Martini, 2010; see Kristjánsson & Campana, 2010, for a review).

A 2 (target repetition: old vs. novel) \times 2 (distractor repetition: old vs. novel) ANOVA tested the effects of repetition on the fifth critical trial. We found significant effects of target color, $F(1, 58) = 118.27$, $p < .001$, $\eta_G^2 = .133$, and distractor color repetition, $F(1, 58) = 31.50$, $p < .001$, $\eta_G^2 = .036$, but no interaction, $F(1, 58) = 2.16$, $p = .147$, $\eta_G^2 = .003$. Search times increased both when a novel color replaced the target color and when the distractor color changed, but when both changed, the reaction time (RT) increase was largest (Fig. 4A). No additional effect of role reversal emerged, either from distractor color to target color, relative to a novel target color, $F(1, 58) = 1.20$, $p = .278$, $\eta_G^2 = .003$, or from target and distractor color role reversals, $F(1, 58) = 0.25$, $p = .616$, $\eta_G^2 = .001$.

Liking

Selection ranks were transformed to a scale from negative (1) to positive (3). That is, regardless of the instruction (“choose MOST pleasant” or “choose LEAST pleasant”), higher liking ratings meant more positive evaluations. To separate the effects of search repetition on target liking from other possible liking effects (such as exposure effects), liking ratings were

computed as differences between the ranks of target color and old distractor color (when both of the distractors were old, their mean rank was used). Positive values indicated that the target was liked more than the old distractor, and negative ones that the target was liked less. So, for example, if a target was chosen first following a “choose MOST pleasant” instruction and an old distractor was chosen last, the target liking rating would be +2. In the reversed situation, it would be −2.

We found a significant effect of distractor-to-target role reversal upon liking, $F(1, 58) = 7.96$, $p = .007$, $\eta_G^2 = .046$ (novel target vs. distractor-to-target), but no effect of additional target-to-distractor role reversal, $F(1, 58) = 1.23$, $p = .272$, $\eta_G^2 = .007$ (distractor-to-target vs. switch). Separate t tests showed that following distractor-to-target reversal, a target was liked significantly less than were old distractors, both when the second distractor had a novel color, $t(58) = -4.55$, $p < .001$, $d = 0.59$, and when it had previously been a target, $t(58) = -3.26$, $p = .002$, $d = 0.42$. In sum, the target color was liked less if it had previously been a distractor. There were no effects of target repetition, $F(1, 58) = 2.43$, $p = .124$, $\eta_G^2 = .008$, or distractor repetition, $F(1, 58) = 1.69$, $p = .198$, $\eta_G^2 = .007$, nor an interaction, $F(1, 58) = 1.23$, $p = .272$, $\eta_G^2 = .007$ (see Fig. 4B). When target rankings were compared with zero for each factor combination, no significant effects were observed (all $ps > .1$), indicating that targets were liked no more than old distractors.

Choice biases

If attending to a target makes it subsequently more salient than other items, it should on average be chosen independently of liking. As a result, targets should be chosen before distractors, both when observers are asked to choose the “most pleasant” item and when they are asked to choose the “least pleasant” one. In other words, we assumed that bias effects would

¹ Analyses using linear mixed-effects regression yielded the same results. For the sake of simplicity and to provide an estimation of effect sizes, we describe the ANOVA results here.

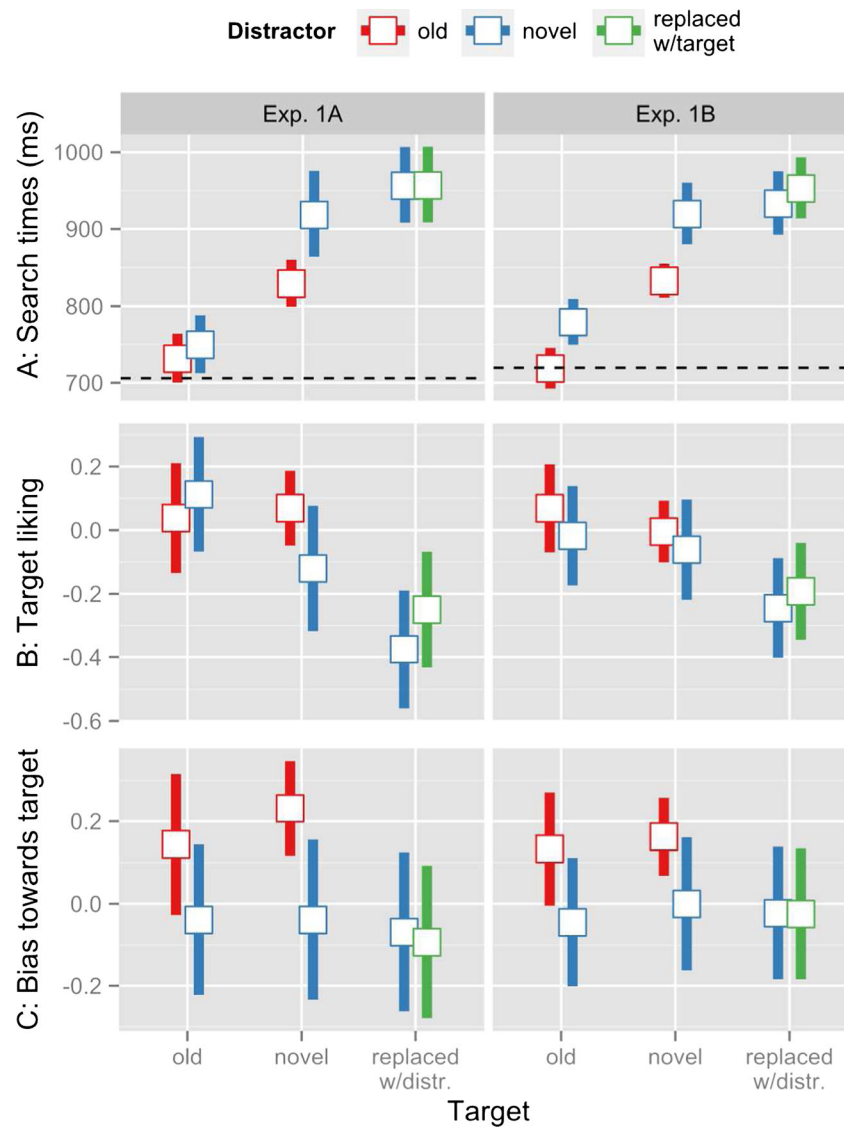


Fig. 4 Search times, liking, and choice bias as functions of target and distractor color repetition or color role reversal on *critical trials* for Experiments 1A (left column) and 1B (right column). (A) The dashed lines in search times show the mean reaction time on the previous trial.

(B) Positive liking ratings indicate that targets were liked more than the old distractors. (C) A positive bias indicates that targets were selected earlier than the old distractors, independently of the suggested selection order. Error bars show 95% confidence intervals

influence the probability of choosing the target item independently of the instruction given.

The analysis described above was repeated, now using differences between the choice orders (1–3) of the target and the old distractor. To reiterate, we ignored the direction of choosing (“most pleasant” vs. “least pleasant”), whereas in the liking analysis above we had transformed the choice order to a scale from negative to positive. That is, positive “bias toward target” meant that the target was selected before the old distractor independently of the question, and negative values, after it (Fig. 4C).

The distractor color repetition effect upon choice was significant, $F(1, 58) = 17.34, p < .001, \eta_G^2 = .056$, but the target color repetition effect was not, $F(1, 58) = 0.57, p = .454, \eta_G^2 =$

.002, nor the interaction, $F(1, 58) = 0.08, p = .781, \eta_G^2 < .001$. When distractors stayed constant, targets were chosen earlier than with sequences in which distractor colors were replaced with novel colors. The target was chosen before the old distractor, both when target and distractor color repeated from the previous trials, $M = 0.14 [0.04, 0.24], t(58) = 2.69, p = .009, d = 0.35$, and when the target color was novel but distractor colors were unchanged, $M = 0.19 [0.11, 0.27], t(58) = 4.68, p < .001, d = 0.61$. Finally, we found no significant effects of role reversals of the target and distractor colors on choice biases: $F(1, 58) = 0.09, p = .768, \eta_G^2 = .001$, for distractor-to-target versus novel target, and $F(1, 58) = 1.23, p = .272, \eta_G^2 = .007$, for distractor-to-target versus switch (Fig. 4C).

Correlational analyses

The findings described above demonstrated that changes in search times are accompanied by changes in choice biases in some conditions, and changes in liking in others. But whether the same mechanisms explained the different effects was still unclear. We therefore ran correlational analyses to measure how well changes in search times are followed by changes in liking and choice biases. We began with a simple correlation analysis of costs and gains in search times with liking and choice biases. For each sequence of trials, we first computed a repetition benefit for search times during the first four trials, and then a difference between the fifth critical trial and the fourth trial. The repetition benefit was computed by approximating a slope of search time decrease with linear regression. We reasoned that stronger inhibition of distractor and facilitation of targets during the first trials would lead to more pronounced effects of changes on the last trial. As we expected, repetition benefits were negatively correlated with switch costs: the larger the repetition benefits, the larger the switch costs (Table 1). Unexpectedly, benefits on the last trial in the “all-old” condition were also negatively correlated with the benefits during the first four trials (most probably, due to floor effects and regression to the mean).

As we described earlier in the [Results](#) section, observers' choices were biased in favor of targets when distractors were the same as on previous trials (“all old” and “novel target” conditions), and they liked targets less when the target had previously been a distractor (“distractor-to-target” and “switch” conditions). Thus, we expected to find correlations of liking and choice biases with RTs in these conditions. However, only liking was correlated with search times in the expected manner (Table 1).

We then used polynomial linear mixed-effects regression (LMER) to assess the possibility of nonlinear relationships, using search times to predict choice bias and liking in the aforementioned conditions. The log-search times were centered so as to avoid the collinearity of predictors.

A cubic regression on liking in the “distractor-to-target” and “switch” conditions indicated a significant linear term, B

$= -0.37$, $SE = 0.16$, $t = -2.33$, $p = .022$, a significant quadratic term, $B = 0.28$, $SE = 0.13$, $t = -2.33$, $p = .046$, and a weak tendency-level cubic term, $B = 0.26$, $SE = 0.15$, $t = -1.72$, $p = .100$. There were no significant effects of RTs on liking in any other conditions, indicating that the observed nonlinear correlation was not due to the relation between RTs and liking per se. The overall pattern in Fig. 5 shows decreasing liking with increasing RTs for relatively fast search. With longer search times, this became reversed. We used LMER for the analysis, so along with the overall effect of search time, random effects for each observer were estimated. Figure 5 demonstrates that the observed curvilinear pattern is unlikely to have been due to the influences of a specific group of observers. In fact, all but a very few followed the general pattern.

Parallel analyses of choice biases as function of search times in the “all-old” and “novel-target” conditions did not indicate any significant effects, all $ps > .15$. Neither did any significant effects emerge when other conditions were analyzed.

In sum, the correlational analyses suggest that changes in search time were not correlated with choice biases in the expected way, but were correlated with changes in liking. The correlation with liking was nonlinear, which could be explained by the negative effect of conflict on fast answers being overwhelmed by a positive effect of exposure with longer search times. However, it is important that a correlation with liking was observed only when the target was replaced with a previously distracting color. Although increased search times and changes in liking seem to have one source—a cognitive conflict aroused by role reversal—changes in liking were not a simple byproduct of longer search times. Otherwise, similar correlations would have been observed in other conditions as well, which was not the case.

Discussion

Search times gradually decreased with search-type repetition. On the fifth, critical trial, search took longer when the target or

Table 1 Correlations between repetition benefits during the first four trials and costs/benefits on the last trial

Condition	Search Times (ms)			Choice Bias			Liking	
	Benefit on Trials 1–4	Costs/Benefits on Last Trial	r	Mean	r With RTs on Last Trial		Mean	r With RTs on Last Trial
All old	113	8	-.24	0.14	.03		0.06	-.01
Novel target	109	-135	-.09	0.20	-.01		0.03	-.02
Novel distractor	107	-71	-.22	-0.03	.01		0.05	.03
All novel	109	-282	-.11	-0.03	-.02		-0.09	-.07*
Distractor to target	107	-298	-.26	-0.04	.05		-0.30	-.08*
Switch	103	-257	-.29	-0.05	-.01		-0.21	.04

For search times, positive values indicate decreasing reaction times (RTs; benefits), and negative values indicate increasing RTs (costs). RT correlations show a correlation between benefits in the first four trials and costs/benefits on the last trial (all $ps < .001$ except for the all-novel condition, in which $p = .011$). * $p < .05$

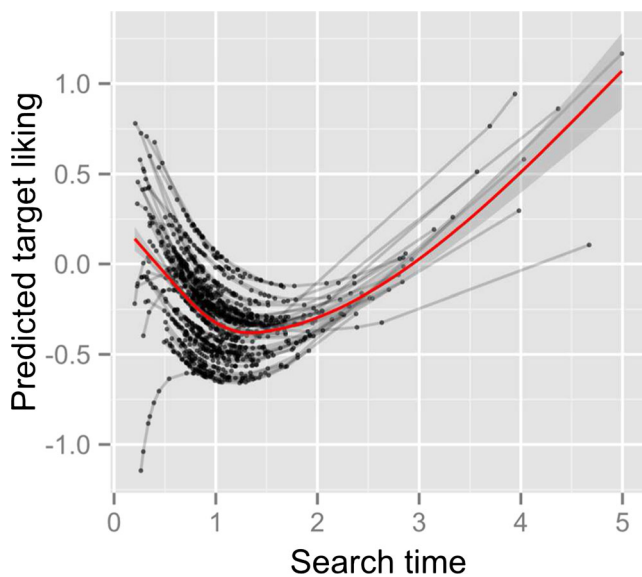


Fig. 5 Target liking as function of search time (in seconds) in “distractor-to-target” and “switch” conditions, based on the results of polynomial LMER (see the text). Dots show individual trials; black lines, each observer’s curve; and the colored line, averaged predictions

distractor colors were replaced with novel colors, when a distractor color replaced the target color, or when the target and distractor colors switched, consistent with previous findings (Kristjánsson & Driver, 2005, 2008; Lamy, Antebi, Aviani, & Carmel, 2008). But the critical new finding was that such changes in search times were accompanied by changes in both choice biases and liking ratings. More importantly, these changes were found in different conditions, suggesting different underlying mechanisms.

Choice bias differences were observed for novel than for old distractor colors. When distractor colors repeated, targets were selected earlier. Whether the target color was constant or was replaced with a new color did not matter. These choice-bias differences corresponded to increases in search times observed when novel colors replaced distractor colors. This suggests that choice biases and the corresponding differences in search times reflect distractor inhibition, not facilitation of target processing.

Liking preferences were, however, unaffected by whether the target or distractor was replaced with a novel color. Targets were liked less only when they had previous distractor colors. That is, only in the distractor-to-target and switch conditions were targets liked less than old distractors. This could reflect a conflict between a tendency to ignore a particular distractor color during the first four trials and the need to attend to it on the critical trial. In sum, some repetition effects on search times were accompanied by choice-bias changes, and others were accompanied by preference changes.

Our results are in accordance with the idea that the repetition benefits and role-reversal costs in visual search observed in many previous studies (e.g., Ásgeirsson & Kristjánsson,

2011; Goolsby & Suzuki, 2001; Kristjánsson, Saevarsson, & Driver, 2013; Meeter & Olivers, 2006) may reflect at least two independent mechanisms that are not easily separable with search time analyses only. First, observers selected targets before distractors when the latter were in previously presented colors, independently of the question asked. This did not depend on target color, suggesting changes in distractor processing through inhibition corresponding to lower RTs with distractor color repetition. This suggests that the choice biases toward previously found targets observed by Brascamp et al. (2011a) reflect distractor inhibition. Note that we did not observe the expected correlation between search times and choice biases, so further studies will be needed to investigate the link between these effects.

Second, observers liked targets less following distractor-to-target role reversals than otherwise. This cannot be explained by the same mechanism, because choice biases were not influenced in the same way. But this effect could be explained by the “affective-feedback-in-hypothesis-testing” approach to cognition (Chetverikov, 2014), which suggests that feedback about the accuracy of hypotheses (or predictions) tested by cognitive systems is subjectively experienced as positive or negative affect. Negative affect following broken expectancies corresponds to longer search times in this condition—a conclusion further supported by the correlation between the two. Additionally, the results can inform the proposed approach, since they indicate that unfulfilled predictions (e.g., the replacement of a target or distractors with novel colors) do not evoke affective feedback. Instead, the predictions should be “falsified” by novel information. So, for example, if a blue target (or a blue distractor) appears instead of the expected red one, this does not on its own compromise the prediction, because it may be a temporary change in the environment. But if red distractors appear when a red target is expected (or vice versa), the prediction becomes not only useless, but also harmful for further processing. This idea is supported by a number of studies demonstrating that stimulus and response conflict elicit negative affect (Aarts et al., 2012; Dreisbach & Fischer, 2012; Martiny-Huenger, Gollwitzer, & Oettingen, 2014).

Finally, search times increased following replacement of a target with a novel color not corresponding to changes in choice bias or liking. Choice-bias and liking measures are perhaps not sensitive enough to catch this effect. But search time analyses showed larger effects from target than from distractor repetition. Thus, if the same mechanism caused both effects, it is unclear why choice-bias differences would occur in one case but not the other. Speculatively, it is possible that in this case a novelty effect compensates for the priming effects.

Unlike previous studies (Kristjánsson & Driver, 2008; Lamy et al., 2008), we found no increase in search times following distractor-to-target role reversals, as compared with novel target and distractor colors. This was most likely a

ceiling effect, since numerically the expected difference in search times was present in both experiments.

Previous studies on preferences for distractors in attention-related tasks (e.g., Fenske & Raymond, 2006; Fenske et al., 2005) have revealed more negative ratings for distractors than for targets. This has typically been explained with inhibitory mechanisms. Here, however, when distractors were repeated during the whole sequence, and inhibition was therefore most likely, targets were not preferred to distractors. The major difference between previous studies and the present one was that we measured preferences following the fifth trial of a search sequence, whereas in the other studies each trial was immediately followed by liking ratings. Distractor devaluation in previous studies might not have been due to inhibition, but rather to distractor-induced conflict. During distractor repetition, conflict is successfully resolved through inhibition. Recent findings that only conflicting distractors are devalued support this claim (Martiny-Huenger et al., 2014).

We controlled for mere exposure effects (Bornstein, 1989; Zajonc, 1980) by comparing target and old distractors colors, which were presented for equal times during the search trials. One can argue that since there were multiple distractors on each search trial and only one target, the old distractors color occupied more space in the display than did the target color, causing more exposure. Consequently, the lack of significant differences between targets and old distractors in the “all-old” condition can be explained by a mutually compensating effect of more exposure for old distractors and more attention to the target. However, this line of reasoning fails to explain why novel targets were also liked no more and no less than old distractors. It also fails to explain why increased exposure to a distractor color leads to decreased liking of that color when it becomes a target color in the distractor-to-target and switch conditions.

Differences in liking were observed for distractor-related expectancies. Similar effects are likely for target-related predictions with different tasks requirements, which can modulate target activation and distractor inhibition in visual search (Geyer, Müller, & Krummenacher, 2006; Kristjánsson et al., 2013; Lamy et al., 2008). Since our task included many easily distinguishable distractors, it could be solved through distractor inhibition. Tasks not easily solved through distractor inhibition might then lead to target-related differences in liking.

Conclusions

Expectancies formed by between-trial repetition that typically have large effects on search lead to choice biases and evaluative effects for the search items. Targets are devalued after distractor-to-target transitions, whereas choice biases follow distractor repetition. Combining bias and liking analyses allows for separate assessments of different top-down

mechanisms (cf. Enns & Lleras, 2008; Summerfield & Egner, 2009). Importantly, the present findings demonstrate differences between “unexpected” stimuli, such as a novel color, and stimuli that violate previous expectations, such as a distracting color that becomes a target. This poses a problem for prediction-related approaches (e.g., predictive coding; Bar, 2009; Friston, 2010; Hohwy, 2012), because two different types of prediction errors must be distinguished: There appears to be a difference between predicting an event that did not occur (“blue is the target” while blue is absent) and inaccurately predicting an event that nevertheless occurred (“red is the distractor” while the target is red). Our findings add to a growing literature linking affect to processing accuracy in simple cognitive tasks (Chetverikov, 2014; Hajcak et al., 2004; Muth & Carbon, 2013; Wiswede et al., 2009).

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Appendix

The results of each experiment are described separately.

Experiment 1A

Observers found the target on 99.5% of trials (99.6% on critical trials). Error trials were not analyzed.

Search times Search times decreased from the first to the fourth trial. A repeated measures ANOVA showed a significant effect of position in sequence both when first trial was included, $F(1, 23) = 95.25, p < .001, \eta_G^2 = .806$, and when only trials from two to four were analyzed, $F(1, 23) = 10.46, p = .004, \eta_G^2 = .313$.

We found significant effects of target repetition, $F(1, 23) = 39.19, p < .001, \eta_G^2 = .130$, and distractor repetition, $F(1, 23) = 6.98, p = .015, \eta_G^2 = .022$, but not an interaction, $F(1, 23) = 3.02, p = .096, \eta_G^2 = .008$, and no effect of distractor-to-target role reversal, $F(1, 23) = 0.89, p = .356, \eta_G^2 = .008$, nor of target-to-distractor role reversal, $F(1, 23) = 0.00, p = .999, \eta_G^2 = .000$.

Liking No significant effect of target repetition, $F(1, 23) = 1.47, p = .238, \eta_G^2 = .016$, or distractor repetition, $F(1, 23) = 0.59, p = .449, \eta_G^2 = .005$, was observed, nor was their interaction, $F(1, 23) = 2.60, p = .121, \eta_G^2 = .027$. In all factor

combinations, target ratings were not significantly different from zero (all $ps > .1$). The role-reversal analysis showed a tendency-level effect of distractor-to-target role reversals, $F(1, 23) = 3.96$, $p = .059$, $\eta_G^2 = .067$, but not of the target-to-distractor role reversal, $F(1, 23) = 1.25$, $p = .276$, $\eta_G^2 = .018$. Separate t tests indicated that targets in the distractor-to-target condition were liked less than were old distractors: $M = -0.34$ $[-0.56, -0.11]$, $t(23) = -3.06$, $p = .006$, $d = 0.62$, when the distractor was novel, and $M = -0.21$ $[-0.38, -0.05]$, $t(23) = -2.67$, $p = .014$, $d = 0.54$, when it had been a target before.

Choice biases There was a significant effect of distractor repetition, $F(1, 23) = 11.00$, $p = .003$, $\eta_G^2 = .068$, but not of target repetition, $F(1, 23) = 0.27$, $p = .611$, $\eta_G^2 = .003$, nor an interaction, $F(1, 23) = 0.25$, $p = .62$, $\eta_G^2 = .003$. The target was chosen before the distractors when both the target and distractor were the same as on previous trials, $M = 0.15$ $[-0.02, 0.32]$, $t(23) = 1.85$, $p = .078$, $d = 0.38$, and when the target was replaced with a novel color but the distractors stayed the same, $M = 0.24$ $[0.09, 0.38]$, $t(23) = 3.38$, $p = .003$, $d = 0.69$.

For role reversals, none of the effects were significant: $F(1, 23) = 0.06$, $p = .816$, $\eta_G^2 = .001$, for target-to-distractor role reversals, and $F(1, 23) = 1.25$, $p = .276$, $\eta_G^2 = .018$, for distractor-to-target role reversals.

Experiment 1B

Observers correctly found the target on 99.4% of trials (99.5% on critical trials).

Search time Repetition effects (see Fig. 3) were significant, both when the first trial was included, $F(1, 34) = 431.44$, $p < .001$, $\eta_G^2 = .927$, and when only Trials 2 to 4 were analyzed, $F(1, 34) = 39.65$, $p < .001$, $\eta_G^2 = .538$.

We found significant effects of target, $F(1, 34) = 81.83$, $p < .001$, $\eta_G^2 = .139$, and distractor color repetition, $F(1, 34) = 27.26$, $p < .001$, $\eta_G^2 = .051$, but no interaction, $F(1, 34) = 0.22$, $p = .642$, $\eta_G^2 = .000$. There was no additional effect of distractor-to-target role reversal, $F(1, 34) = 0.33$, $p = .569$, $\eta_G^2 = .001$, nor of switch, $F(1, 34) = 0.37$, $p = .548$, $\eta_G^2 = .002$. The results therefore differed from those of Experiment 1A only in that the effects of replacing a distractor color with a novel one were similar for both old and new target colors.

Liking Liking results were similar to those from Experiment 1A, with a tendency-level effect of distractor-to-target role reversal, $F(1, 34) = 3.90$, $p = .056$, $\eta_G^2 = .034$ (novel target color vs. distractor-to-target color), but not of an additional target-to-distractor role reversal, $F(1, 34) = 0.29$, $p = .595$, $\eta_G^2 = .003$ (distractor-to-target vs. switch). Critically, separate t

tests indicated that targets in the distractor-color-to-target-color condition were liked less than were old distractors: $M = -0.27$ $[-0.44, -0.11]$, $t(34) = -3.32$, $p = .002$, $d = 0.56$, when the distractors had a novel color, and $M = -0.22$ $[-0.42, -0.02]$, $t(34) = -2.22$, $p = .033$, $d = 0.37$, when they had a previous target color. There were neither target color, $F(1, 34) = 0.95$, $p = .335$, $\eta_G^2 = .005$, nor distractor color, $F(1, 34) = 1.07$, $p = .307$, $\eta_G^2 = .008$, repetition effects, nor an interaction, $F(1, 34) = 0.08$, $p = .776$, $\eta_G^2 = .000$. For all factor combinations, target ratings were not significantly lower than old-distractor ratings (all $ps > .1$).

Choice biases A significant effect of repeating distractor colors on choice biases was apparent, $F(1, 34) = 7.28$, $p = .011$, $\eta_G^2 = .048$, but not of repeating target color, $F(1, 34) = 0.29$, $p = .591$, $\eta_G^2 = .002$, nor an interaction, $F(1, 34) = 0.01$, $p = .914$, $\eta_G^2 = .000$. As in Experiment 1A, targets were chosen before the distractors when both the target and distractor colors repeated, $M = 0.13$ $[-0.01, 0.26]$, $t(34) = 1.93$, $p = .062$, $d = 0.33$, and when the target color was replaced with a novel one but distractor colors were constant, $M = 0.16$ $[0.06, 0.26]$, $t(34) = 3.24$, $p = .003$, $d = 0.55$. No role-reversal effects were significant: $F(1, 34) = 0.03$, $p = .854$, $\eta_G^2 = .000$, for distractor-to-target versus novel distractor, and $F(1, 34) = 0.29$, $p = .595$, $\eta_G^2 = .003$, for distractor-to-target versus switch.

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