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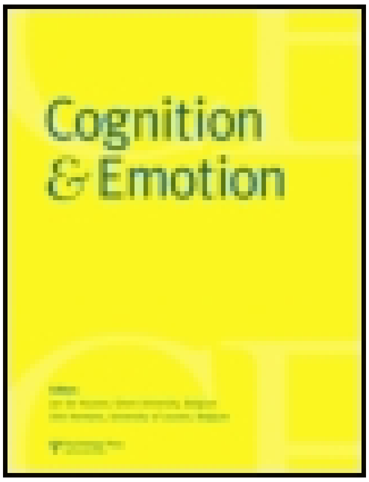

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Blaming the victims of your own mistakes: How visual search accuracy influences evaluation of stimuli

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Blaming the victims of your own mistakes: How visual search accuracy influences evaluation of stimuli

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Even without explicit positive or negative reinforcement, experiences may influence preferences. According to the *affective feedback in hypotheses testing* account preferences are determined by the accuracy of hypotheses: correct hypotheses evoke positive affect, while incorrect ones evoke negative affect facilitating changes of hypotheses. Applying this to visual search, we suggest that accurate search should lead to more positive ratings of targets than distractors, while for errors targets should be rated more negatively. We test this in two experiments using time-limited search for a conjunction of gender and tint of faces. Accurate search led to more positive ratings for targets as compared to distractors or targets following errors. Errors led to more negative ratings for targets than for distractors. Critically, eye tracking revealed that the longer the fixation dwell times in target regions, the higher the target ratings for correct responses, and the lower the ratings for errors. The longer observers look at targets, the more positive their ratings if they answer correctly, and less positive, following errors. The findings support the affective feedback account and provide the first demonstration of negative effects on liking ratings following errors in visual search.

Keywords: Conjunctive visual search; Error monitoring; Preferences; Conflict; Affective feedback; Fixation dwell times.

Even in the absence of positive or negative reinforcement our experiences may influence our preferences. A well-known example of this is the mere (repeated) exposure effect, involving increased liking of previously perceived stimuli (Bornstein & D'Agostino, 1992; Zajonc, 1980). However, a number of findings show that the link between exposure and preferences is subtler than this. Muth and Carbon (2013) demonstrated that repeated presentation of degraded Mooney faces led to an increase in liking only when observers managed to detect a face. This "perceptual insight"

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produced an increase in preferences that remained relatively stable over following presentations. Similarly, Chetverikov (2014) showed that recognition accuracy moderated mere exposure influences. More frequent exposure led to more positive evaluations only when stimuli were correctly recognised. When they were not recognised, the exposure effect was absent or even negative. This suggests that participants in preference studies should not be treated as passive observers, because their efficacy in solving the task using past or present experience may be no less important for preferences than the actual experience.

Chetverikov (Chetverikov, 2014; Chetverikov & Filippova, 2014) used the *affective feedback in hypotheses testing* account to explain these findings: affect is a subjective experience of positive or negative feedback on cognitive hypotheses (or predictions). The proposal that information processing involves hypotheses testing is not new (Bartlett, 1932; Bruner, 1957; Clark, 2013; Gregory, 1968; Hohwy, 2012; Neisser & Becklen, 1975) nor is the idea that the violation of expectations can be a source of negative affect (Huron, 2006; Reber, Schwarz, & Winkielman, 2004; Whittlesea, 1993). However, these two lines of research and theoretical work have largely been isolated from one other. In a typical study of expectation-related affect, the experimenter first creates some expectation (e.g., by presenting a sequence of tones or a beginning of a sentence) and then presents a stimulus that either confirms or breaks these expectations (Forster, Leder, & Ansorge, 2013; Huron, 2006; Reber, Winkielman, & Schwarz, 1998; Whittlesea, 1993). Violation of these expectations evokes negative affect, and confirmation—positive affect. The *affective feedback in hypotheses testing* account further suggests that without external feedback people monitor the accuracy of their hypotheses by testing a selected hypothesis by different "modules". For example, a number of parallel feature detectors can be used to test a hypothesis that a particular object belongs to a specific category, thus allowing fast categorisation decisions (Delorme, Richard, & Fabre-Thorpe, 2000; Fabre-Thorpe, Delorme, Marlot, & Thorpe, 2001; VanRullen & Thorpe, 2001). This parallel testing process is further assumed to be one of the sources of feedback about the accuracy of hypotheses, and hence a source of positive or negative affect. When the testing results are coherent and support the hypothesis, the hypothesis is accepted which evokes positive affect. When the results are incoherent or do not support the hypothesis, it is rejected, evoking negative affect. From this viewpoint, the proposed model has similarities with models that link stimulus and response conflict to aversive tendencies (Aarts, De Houwer, & Pourtois, 2012, 2013; Botvinick, 2007; Dreisbach & Fischer, 2012; Fritz & Dreisbach, 2013; Schouppe, De Houwer, Ridderinkhof, & Notebaert, 2012).

According to the *affective feedback in hypotheses testing* account both pre-decisional information processing in simple cognitive tasks and the decision itself can be thought of as a hypotheses testing process. An important consequence of this approach is that for errors, hypotheses testing should yield results that are more inconsistent with the hypothesis, thus creating more negative affect. If decisions are treated as hypotheses, then we suggest that the degree to which they are confirmed should produce positive or negative affect as for more simple hypotheses. From an external point of view, erroneous hypotheses are less consistent with the data than correct ones. Thus, even in the absence of external feedback, a parallel testing process should provide less consistent results for errors. Consequently, erroneous hypotheses should be evaluated as unconfirmed and lead to negative affect. Observers might therefore, be able to assess the accuracy of their hypotheses using parallel testing even without experimenter feedback. This creates a link between the affective feedback account and models that emphasise the role of conflict and emotions in error processing (Hajcak & Foti, 2008; Hajcak, McDonald, & Simons, 2004; Luu, Collins, & Tucker, 2000; Olvet & Hajcak, 2012; Wiswede, Münte, Goschke, & Rüsseler, 2009; Yeung, Botvinick, & Cohen, 2004).

So far the proposed model has been tested on recognition tasks (Chetverikov, 2014) and perceptual categorisation (Chetverikov & Filippova, 2014). Here we describe two experiments demonstrating that similarly to recognition and categorisation tasks, decisions in visual search lead to an increased liking of targets following correct answers and decreased liking of targets following errors.

From a prediction point of view, visual search can be considered a comparison of incoming sensory information with existing templates. These templates can be based on a-priori knowledge of target features in everyday experience (when searching for a zebra, attend to stripes), pre-set criteria (look for a zebra with blue eyes) or previous experience (all previous zebras appeared to your right). To take an example, according to the Guided Search model (Wolfe, Cave, & Franzel, 1989; Wolfe, 1998, 2007), preattentive processing creates a salience map that guides search to the locations of potentially task-relevant objects, which are then compared with a target template. We can assume that the hypothesis in this case is that each such salient object is a target. Matches between target templates and the object should then serve as source of positive feedback and the better the match, the more positive the affect. We therefore expect that for correct answers ratings of targets should be more positive than ratings of distractors. This effect has consistently been observed in previous studies (Kiss et al., 2007; Raymond, Fenske, & Westoby, 2005). The effects of errors are less well understood, but Chetverikov (2014) demonstrated that errors lead to decreased preferences for targets in a recognition task. Moreover, increasing the amount of data available for the correct decision (operationalized as the total time of target exposure) leads to more negative ratings following errors. According to our proposal, more data (such as through longer fixation on a candidate target) means more conflict when the incorrect decision is made. In visual search we expect a similar pattern: following errors, targets should be liked less and with more data the liking should become even more negative.[1]

To test this hypothesis we conducted two experiments using a conjunction visual search task. In Experiment 1 we show that errors lead to decreased liking of target stimuli while in Experiment 2 we replicate those findings. Moreover, eye-movement analyses provided estimates of the data available for the decision by measuring for how long observers looked at each particular item. These estimates show that more data leads to more positive ratings following correct answers, and less positive ratings following errors.

EXPERIMENT 1

Experiment 1 was conducted over the Internet using experimental software written in JavaScript. Internet-based experimentation can be a powerful way of obtaining experimental data (Keller, Gunasekharan, Mayo, & Corley, 2009; Lewis, Watson, & White, 2009; Reimers & Stewart, 2007) and can compensate for greater noise through larger observer numbers.

Method

Participants

One hundred and twenty-seven observers (94 female, age range: 18–51 years, Mdn = 21 year) voluntarily participated. They were recruited by advertising the experiment on online social networks. Participants received no compensation.

Procedure

The experiment consisted of 20 time-limited search trials, each of which was followed by 5 liking trials (see Figure 1). Search trials started with the presentation of a fixation cross for 1000 ms. The stimuli were nine faces (100 × 120 pixels) positioned in a circular array with 250 pixel radius, presented for 600 ms with 250 ms pre-masks and

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[1] In fact, the opposite post-decisional effect should be present for correct decisions as well. Thus, positive ratings for targets after correct answers probably confound the positivity stemming from the match between target template and object and the positivity stemming from the correct decision. The present study does not distinguish between the two, however.

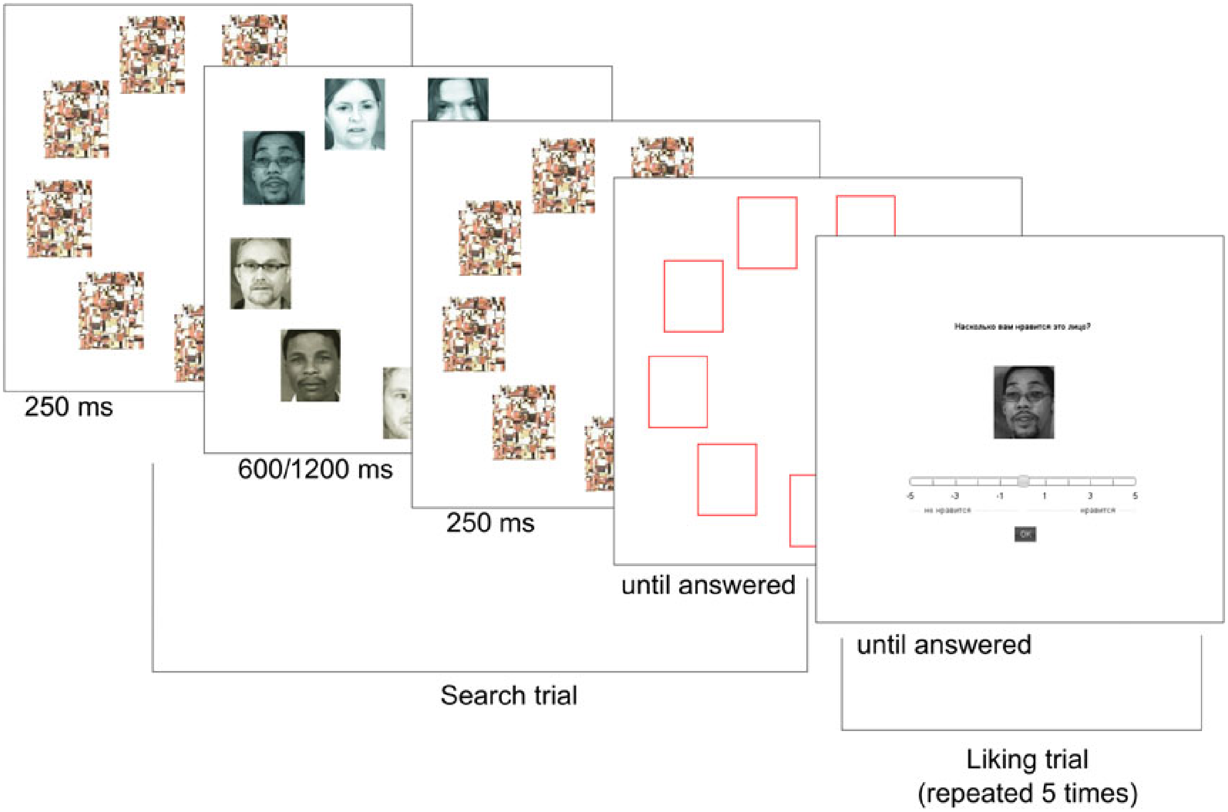

Figure 1. *Event sequence for each trial in Experiment 1. Faces were tinted blue or yellow during search (see colour version online) Each sequence was preceded by a fixation cross for 1000 ms (omitted here). Premasks were then presented for 250 ms, followed by targets and distractors for 600 or 1200 ms, and a 250 ms post-mask. Rectangles then appeared until observers clicked on the rectangle where they thought the target had been. The liking task followed (see text for details). The faces in this example are from MUCT database (Milborrow, Morkel, & Nicolls, 2010). The depicted subjects have agreed to the images being used.*

250 ms post-masks.[2] The pre-masks and post-masks consisted of random patched noise and were of the same size as stimuli (see Figure 1). Target and distractor positions were chosen randomly. After their disappearance, observers indicated the position of targets by clicking on one of the rectangles presented at previous target and distractor positions.

The stimuli were chosen randomly from the FEI database (Thomaz & Giraldi, 2010), converted to grey-scale and pre-processed to have roughly equal luminance, resolution and face area. Faces were tinted either yellow (RGB: 222/222/197) or blue (RGB: 197/222/222). Targets were defined by a conjunction of tint colour and gender (blue-tinted male faces, blue-tinted female faces, yellow-tinted male faces and yellow-tinted female faces). For each participant the target conjunction was the same on all search trials and explained in the instructions. Target colour and gender were counterbalanced between observers. Half of the distractors on each trial were of the same gender but had different colour, the other half had the same colour but were of the other gender. No feedback was provided about response accuracy after the search trial but after the experiment observers were given feedback about their own performance compared with other participants.

On liking trials the stimuli were presented for rating in random order and the observers evaluated

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[2] In Experiment 1 there was also a group of participants for whom target and distractors were presented for 1200 ms instead of 600 ms. In this group the low number of errors (14% of all answers, 2 errors per observer) did not allow a proper analysis of target liking following errors. Thus, this group was excluded from analyses and is not described here.

five faces from the preceding search trial on a left-to-right 11-point scale from "don't like" to "like". If they answered correctly on the search trial, they rated the target and four distractors located at different distances from the target. If they made an error, they rated the target, the chosen distractor, the distractor located near the target (at the next position in the circle, either clockwise or counter-clockwise), a distractor located near the chosen distractor and one randomly chosen distractor. Tint was removed both for targets and for distractors on the liking trials.

Results

Visual search performance

Observers answered correctly on 58% of trials. A binomial mixed-effects regression indicated no significant effects of target gender or target colour (all *p*s > .3). Importantly, target attractiveness (measured as a mean liking rating for each stimulus excluding the observer's own rating) did not influence search accuracy, *p* > .1, and is therefore unlikely to lead to any differences in liking ratings.

Liking and search accuracy

Analyses of liking were performed on *Z*-transformed liking ratings using linear mixed-effects regression controlling for several confounding effects: individual differences in liking for correct and incorrect answers and for targets and distractors, differences in mean liking of stimuli, effects of face gender, observer gender and of search response time.[3] The analysis was conducted with the *lme4* package in *R* (Baayen, Davidson, & Bates, 2008; Bates, Maechler, Bolker, & Walker, 2013).

Analyses of liking ratings revealed a significant interaction effect of object type (target vs. distractor) and answer accuracy, *F*(1, 4814) = 4.41, *p* = .036, a tendency-level main effect of target, *F*(1, 238) = 2.35, *p* = .098, and no significant effect of accuracy, *F*(1, 261) = 2.28, *p* = .104. Pairwise comparisons indicated that targets were rated significantly more positively following correct answers than errors, *t*(570) = 2.00, *p* = .046. However, ratings for targets following correct answers were not different from ratings for distractors, *t*(129.6) = 1.54, *p* = .127. Following errors, targets were rated numerically lower than distractors, but this effect was not significant, *t*(150.7) = 0.95, *p* = .344.

We reasoned that engaging in several consecutive liking trials may distort liking ratings and repeated the analysis, this time including liking trial position (from 1 to 5) as predictor. This time, we found significant effects of accuracy, *F*(1, 2885) = 7.14, *p* = .008, trial position, *F*(1, 10939) = 5.09, *p* = .024, an accuracy and object type interaction, *F*(1, 10893) = 8.78, *p* = .003,

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[3] Our study followed a quasi-experimental design. Thus, liking ratings can be confounded both by between-stimulus differences (one face can be more attractive than another) and by between-observer differences (one observer can be in a better mood than another and provide higher ratings). In addition, observers may differ in their interpretation of the scale: some may try to use the full range of the provided scale, while others may consider most stimuli neutral and use only a small range of the possible values (liking rating *SD*s measured for each observer in Experiment 1 varied from 0.28 to 3.10). Usually, a by-subject aggregation is used to control for between-subject differences, but it does not allow for controlling the within-trial variables, such as target sex or trial position nor for between-stimulus differences. To avoid this problem, liking ratings were first *Z*-standardised individually for each observer. The standardisation allows comparing data from different distributions, thereby diminishing the effects of between-subject differences in strategies used to rate the stimuli. Second, we conducted linear mixed-effects regression with random effects of stimuli and random within-subject effects of answer accuracy and object type (Judd, Westfall, & Kenny, 2012). Random effects for stimuli provided control for the differences in mean ratings of stimuli. Random within-subject effects of answer accuracy and object type controlled for the possible difference in individual reactions to correct and incorrect answers and to targets and distractors. Finally, we also added stimulus gender (male vs. female), subject gender (male vs. female), their interaction, and response time during the search as covariates to control for their possible confounding influence (the effect of these variables is not reported for the sake of brevity). This analysis also allows the inclusion of dwell times and is therefore preferable for consistency of analytic approaches in Experiment 1 and Experiment 2. For the ease of understanding, results are presented as Type III F-tests using a Satterthwaite approximation of the degrees of freedom.

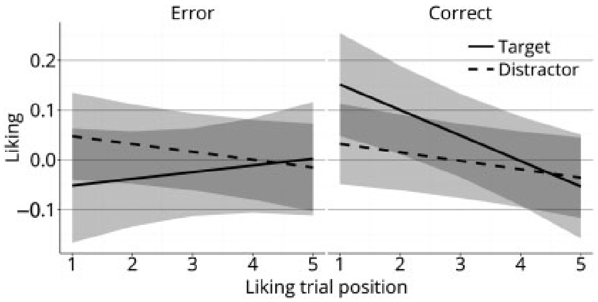

Figure 2. *Standardised liking ratings as function of answer accuracy, object type, and liking trial position relative to the visual search task. The first liking rating following the visual search has position 1, the second—position 2, etc. Shaded areas show 95% confidence intervals. Liking ratings are obtained with a linear mixed effects regression model (see text).*

an accuracy and trial position interaction, $F(1, 10931) = 5.30$, $p = .021$, and a three-way interaction of accuracy, object type and trial position, $F(1, 10931) = 5.30$, $p = .021$. Figure 2 summarises the results of this analysis. There was a general trend for decreasing ratings with higher trial position following correct answers. Initial ratings for targets were, however, more positive than ratings of distractors. On the other hand, initial ratings for target items after errors were more negative than the ratings of distractors. After several liking trials this difference disappeared, as was the case for correct answers. When the first three liking trials were analysed separately, we confirmed that targets were rated more positively than distractors following correct answers, $t(120) = 1.99$, $p = .048$, but more negatively following errors, $t(176.9) = 2.10$, $p = .037$. No effects were significant when the last two liking trials in each sequence were analysed.

Discussion

Experiment 1 demonstrates that following correct answers, observers rate targets more positively than following errors. Our initial analyses did not show the expected differences between targets and distractors neither following correct answers nor errors. However, when the position of liking trials relative to the visual search trial was taken into account, the ratings were more negative for targets than for distractors following errors, but only during the first three liking ratings. Importantly, the difference between targets and distractors following correct answers was short-lived as well. Thus, although an analysis of liking trial position was a post-hoc decision, the observed pattern is consistent both for correct answers and for errors.

The first goal of Experiment 2 was to replicate the obtained findings in a more controlled laboratory setting. The results of Experiment 1 suggest that liking effects are short-lived since the effect of errors on liking ratings were only observed immediately following the search trial. Each search trial in Experiment 2 was therefore followed by only two liking trials instead of five in Experiment 1. The second and the most important goal of Experiment 2 was to test the hypothesis that the amount of data (as measured by fixation dwell times on candidate targets) available for the decision will lead to higher ratings for targets following correct decisions and lower ratings following errors.

Experiment 2 consisted of two parts. The first part was a behavioural-only study, and the second part involved both behavioural and eye-movement measures. The latter allowed us to estimate the fixation duration on each stimulus providing estimates about the amount of data about the object available for decision. Eye movements generally follow attention if no instruction to do otherwise is given (Deubel & Schneider, 1996; Hoffman & Subramaniam, 1995; Kristjánsson, 2007; 2011). We may therefore assume that if an observers' gaze has lingered on one stimulus above others that it was, other things being equal, preferentially processed. We therefore expected that the longer observers look at the target, the more positive target liking ratings following correct decisions would be, and the less positive they would be following errors. Different observers participated in the first and the second part. The behavioural-only part of the study allowed us to gather more data for the behavioural analysis of errors to see if the effect of errors on target ratings can be reliably observed in behaviour-only studies.

EXPERIMENT 2

Method

Participants

Thirty-seven psychology students (27 females, 10 males, 18–23 years, Mdn = 20 years) at Saint Petersburg State University participated in the behavioural part of the experiment and 20 volunteers (14 female, 21–53 years, Mdn = 29.5 years) at the University of Iceland participated in the eye-tracking part of the experiment. They were not paid for participation. All reported normal or corrected-to-normal visual acuity.

Procedure

The procedure generally followed Experiment 1 (see Figure 1). The experiment consisted of 100 time limited search trials, each of which was followed by two liking trials. The number of liking trials was decreased as Experiment 1 showed that the observed effects are short-lived. Note that the increased number of search trials may compensate for smaller number of subjects.

The stimuli were faces chosen randomly from a set created using Facial Recognition Technology (FERET; Phillips, Moon, Rizvi, & Rauss, 2000; Phillips, Wechsler, Huang, & Rauss, 1998)[4] and Milborrow/University of Cape Town (MUCT) databases (Milborrow, Morkel, & Nicolls, 2010). We used different faces from Experiment 1, because the number of trials increased and more stimuli were needed. Faces in these two databases were similar to each other in overall image quality, so we decided to use them instead of the faces in Experiment 1. All stimuli were converted to greyscale and pre-processed to achieve roughly equal luminance, resolution and face size. During the behavioural part of the experiment all stimuli were presented on a 19 inch Acer V193 LCD monitor using PsychoPy software (Peirce, 2007). Search trials started with a fixation cross (1° × 1°) which disappeared when observers clicked on it to ensure central fixation. Nine faces (2.4° × 2.88°) were then presented in a circular array at 6° eccentricity from central fixation for 650 ms followed by a 250 ms mask.[5] Observers then clicked on one of the rectangles that replaced the stimuli to indicate target position. Targets were again defined by a conjunction of tint—yellow (RGB: 222/222/197) or blue (RGB: 197/222/222)— and gender. Target parameters were identical throughout the experiment for each observer and were counterbalanced between observers. Half of the distractors were of the same gender but had different colour; the other half had the same colour but different gender. Target and distractor positions were chosen randomly. Again, no feedback was provided regarding search accuracy.

On liking trials, observers evaluated two faces from the preceding search trial. Tint was removed both from targets and distractors. Observers evaluated the target and a distractor located near it during the search on a left-to-right scale from “don’t like” to “like” without numbers or ticks dragging the scale marker with a mouse. When observers erroneously chose a distractor located near the target, a distractor located on an adjacent position was shown for evaluation instead. This was done to exclude erroneously chosen distractors and to equate the distance between the chosen distractor and target and between the chosen distractor and evaluated distractor. The position of the marker was translated to a −1 to 1 rating with higher ratings indicating more liking. Rating order (first target then distractor or vice versa) was random.

During the eye-tracking part of the study the procedure was the same except for a few modifications. Observers’ heads were stabilised with chin rests and headrests. Viewing distance was 56 cm. A high-speed (250 Hz) monocular eye tracker based

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[4] Portions of the research in this paper use the FERET database of facial images collected under the FERET programme, sponsored by the DOD Counterdrug Technology Development Program Office.

[5] During pilot testing no effect of premasks was found, so they were removed to shorten experiment duration.

on infrared reflection technology with a tracking accuracy from 0.125° to 0.25° and a horizontal range of ±40° from Cambridge Research Systems (2006) monitored eye position (see Jóhannesson, Ásgeirsson, & Kristjánsson, 2012; Jóhannesson & Kristjánsson, 2013 for details). The experimental software was rewritten in Matlab using Psychtoolbox (Brainard, 1997; Kleiner, Brainard, & Pelli, 2007; Pelli, 1997) as PsychoPy lacks support for the CRS eye tracker. The experiment was split into two blocks; in the first there were 55 trials of which the first 5 were practice trials, not included in statistical analyses. In the second block there were 50 trials. Observers could rest as needed between blocks.

Results

One observer was removed from the analysis in the behavioural part because 150 out of 200 liking ratings were set to −1, and another one because 160 out of 200 liking ratings were set to 0. No observers in the eye-tracking part of the study were excluded.

Unlike Experiment 1, mixed effects regression would not allow correct estimation of the random effects of stimuli because the number of stimuli was much higher and the number of ratings per trial was lower. Thus, random effects for stimuli were excluded from the model. Apart from this, the same analysis procedure was used. We first present the combined behavioural data from both parts of the experiment and then the eye-movement data.

Visual search performance

On average, observers correctly detected 61% of targets. No significant effects of target colour or gender on the accuracy of search were found nor were there any significant differences in accuracy between the behavioural and eye-tracking parts.

Liking ratings

A two-factor LMER with accuracy and stimulus type as predictors revealed an interaction effect, *F*(1, 137) = 11.24, *p* = .001, and a significant main effect of response accuracy, *F*(1, 59) = 8.98, *p* = .004, but not of stimulus type *F*(1, 55) = 0.02, *p* = .882. This interaction is shown in Figure 3. Follow-up comparisons indicated that targets were rated more positively than distractors following correct answers, *t*(52.5) = 2.16, *p* = .036. Following errors, targets were rated more negatively than distractors although only at a tendency level, *t*(89.2) = 1.86, *p* = .066.

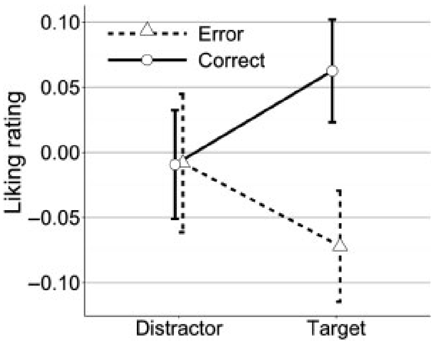

Figure 3. *Behavioural data on liking ratings in Experiment 2.*

Eye movement analyses

We next turn to eye gaze measures, the main measure in this experiment. First, we analysed eye movement patterns as a function of stimulus type and whether the answers were correct or incorrect. We used square regions of interest (ROI) with width and height equal to stimulus height plus 0.5°. Where ROIs overlapped, the area belonged to the region with nearest centre. Total dwell time in the ROI was the dependent variable.

On average, observers looked at 3.3 ROIs during stimulus presentation (650 ms) on each trial. Mean dwell times are shown in Table 1. As

Table 1. *Total dwell time, in milliseconds, (and standard deviations) by ROI type, adjusted for the number of ROI of each type*

	Distractor	*Target*
Errors	118 (32)	117 (114)
Correct	86 (45)	234 (154)

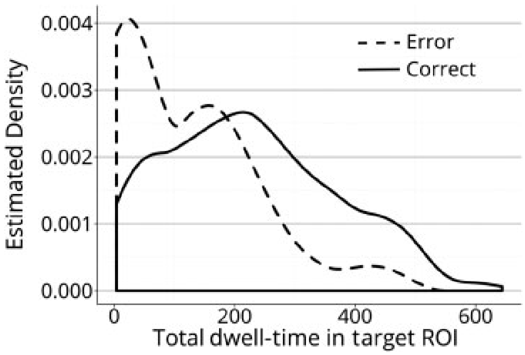

Figure 4. *Density of the distribution of dwell times in target ROI. Note that both when observers correctly identified the target and when they made an error, total dwell time in target ROI varies broadly.*

illustrated in Figure 4, even when observers failed to correctly identify the targets, there were trials on which they had long dwell times in the target ROI. Observers make mistakes both when they look at the target and when they do not.

We next analysed the relationship between dwell time, per cent correct and liking. Using liking as the dependent variable, we tested for the influence of answer accuracy, object type and dwell time in the ROI associated with a rated item. Mixed effects regression showed a two-way interaction of dwell time and object type, $F(1, 4157) = 7.57$, $p = .006$, qualified by a significant three-way interaction, $F(1, 4157) = 13.45$, $p < .001$. Figure 5 elucidates the observed interaction. As dwell time increased, there was a sharp decline in liking for targets following errors in contrast to a more shallow increase in liking for targets following correct answers. Interestingly, there was a positive correlation between dwell time and distractor liking following errors.

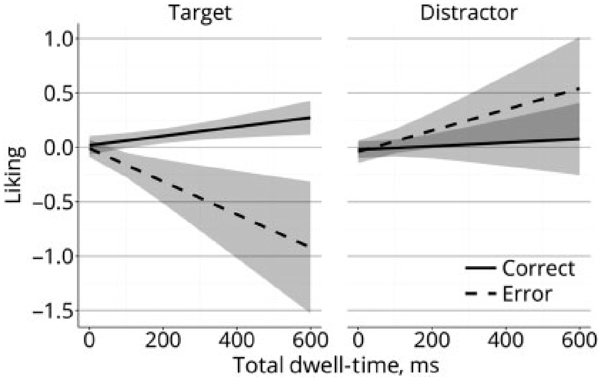

Figure 5. *Linear approximation of liking ratings as function of total dwell time. Shadowed areas and error bars indicate 95% confidence intervals.*

These observations were confirmed by a separate analysis of targets and distractors. For targets, there was a significant interaction of accuracy and dwell time, $F(1, 2069) = 12.00$, $p < .001$. The effect of dwell time on the liking of targets was significant both following correct answers, $F(1, 1310) = 5.85$, $p = .016$, and errors, $F(1, 772) = 7.19$, $p = .007$. For distractors, on the other hand, the interaction of dwell time and accuracy was only marginally significant, $F(1, 2072) = 2.87$, $p = .090$. The effect of dwell time on ratings of distractors was significant and positive following errors, $F(1, 769) = 5.63$, $p = .018$, but almost absent following correct answers, $F(1, 1271) = 0.03$, $p = .865$.

To make sure that the observed effects are not due to the initial attractiveness or unattractiveness of the face, for each observer we used liking ratings provided by other observers as predictors of dwell time. The effect of attractiveness on dwell time was neither significant when targets and distractors were analysed together, $F(1, 3688) = 1.41$, $p = .235$, nor when targets, $F(1, 1905) = 0.08$, $p = .777$, or distractors, $F(1, 1737) = 1.42$, $p = .233$, were analysed separately.

Discussion

Liking ratings in Experiment 2 follow the same pattern as in Experiment 1: following correct answers, targets were rated more positively than distractors, and following errors they were rated more negatively. However, for the behavioural data the difference in liking between distractors and targets after errors was only marginally significant.

Eye-movement analysis provided further evidence that following errors, liking ratings of targets decrease. Moreover, this effect cannot be explained by a simple lack of attention to the target items. On the contrary, the lower the liking ratings for target items on error trials, the longer observers gaze dwelt on a target. Conversely, a positive effect of overt attention on liking was observed for target items following correct answers and for distractors in the case of errors. There were no erroneously chosen distractors among the distractors in question, indicating that positive effects of overt attention on liking are not related to the misclassification of distractors.

The fixation dwell time results can explain the marginal significance of the results at the behavioural level. Errors can be divided into two categories: Firstly, random errors that occur when observers cannot analyse the target item, or do not attend to it. These errors are unlikely to have any evaluative effect at all, as there is simply no data to base predictions on. And this is what is seen in the analyses of targets liking when the total dwell time is close to zero. The second kind—misclassification errors—is observed, when observers do analyse the target but erroneously classify it as a distractor. This second kind of error should lead to decreased liking ratings, because there is a conflict created by the incorrect classification. This division has intuitive appeal. For example, imagine that a search display flashes for 1 ms and observers are forced to indicate the position of a target. Their answers will, most likely, be complete guesses, and the items will therefore not be devalued. Given that the dwell time is also a predictor of correct answers, the number of misclassification errors is small and in a behavioural study, without eye tracking, it might be difficult to measure their influence. It is therefore not surprising that on a behavioural level we obtained only marginally significant results when targets are compared to distractors following errors.

In sum, the results support the hypothesis that both correct and incorrect perceptual hypotheses are followed by affective feedback, with increased liking following correct classification and decreased liking following erroneous misclassification of analysed targets, but not following random errors.

GENERAL DISCUSSION

Our results consistently show that when observers correctly locate a target face, they rate it more positively than distractors. When they do not, they rate targets more negatively. The latter effect was especially clear when observers gaze was tracked during the searches. Dwell times in the target region of interest were negatively correlated with liking ratings for targets following errors. In contrast, following correct answers, this correlation was positive, that is, targets were rated higher with longer dwell times. The longer observers look at the targets, the more positive their ratings of these targets if they answer correctly, and the less positive, if they make an error.

To our best knowledge, this is the first demonstration of the negative effect of errors in visual search on liking ratings. From a theoretical perspective, our results provide further evidence for the affective feedback model of hypotheses testing (Chetverikov, 2014; Chetverikov & Filippova, 2014). Similarly to recognition tasks and perceptual categorisation, visual search tasks elicit positive or negative affect depending on the accuracy of the hypotheses observers generate. This affect is revealed by changes in liking ratings for targets and distractors. On a more general level, our results support the idea that affect serves as intrinsic reinforcement for the development of an accurate model of the world (Allakhverdov & Gershkovich, 2010; Ramachandran & Hirstein, 1999).

Potential alternative explanations

Differences in exposure time may seem to be the most obvious explanation for differences in observed liking ratings. Even though the presentation time was kept constant, we can assume that observers do not attend to the display as a whole, but rather process it in parts. Thus, the actual time each item is “exposed” depends on where observers fixate. However, the last experiment demonstrates that positive influences of exposure time for target items (as measured by eye tracking) are only observed for correct responses, whereas the influence is negative for errors. It therefore seems unlikely that exposure time on its own has any influence on ratings in this task.

Recently, it has been proposed that distractors may be devalued through inhibition (Fragopanagos et al., 2009; Raymond, Fenske, & Tavassoli, 2003; Raymond et al., 2005). This idea might potentially explain differences between ratings following correct responses in our experiments. Moreover, targets not recognised as targets can also be inhibited, thus explaining more negative ratings for targets following errors. Note that if the same mechanism explains more negative ratings for targets following errors and for distractors following correct answers, the same pattern of results should be observed in these two cases. For example, Frischen, Ferrey, Burt, Pistchik, & Fenske (2012, Experiment. 4) found that increased exposure leads to stronger devaluation of distractors paralleling our findings of stronger devaluation of targets following errors. However, in Experiment 2 the negative correlation between dwell times and liking was observed only for target items following errors. Distractor ratings following correct answers were not correlated with dwell time. This pattern of results is not consistent with the inhibitory devaluation explanation. Rather, it suggests that there is a positive effect of processing on subsequent ratings, unless there is conflict associated with an incorrect decision.

Another possible alternative explanation concerns affect-related biases. Firstly, visual search can be biased towards attractive faces (Shimojo, Simion, Shimojo, & Scheier, 2003; Simion & Shimojo, 2006, 2007). Consequently, the likelihood of finding an attractive target is higher. Secondly, the decision that objects match target criteria can have a higher threshold for unpleasant objects than for pleasant ones, increasing error rates for unattractive above attractive ones with brief displays. Consequently, errors will be correlated with more negative liking ratings for targets, similar to the *perceptual defence* concept (Bruner & Postman, 1947; Erdelyi, 1974). However, by this account both kinds of biases should be the same independently of stimulus type (target or distractor) and search accuracy. Importantly, as we describe above, this was not the case. For the same reason, it is unlikely that stimulus properties (e.g., uncertainty in gender-defining features) can account for any liking modulations. Moreover, we found no evidence that attractiveness of stimuli influenced the accuracy of visual search, in direct contradiction to the affective biases explanation.

Implications for future studies

Our findings indicate that information about targets and distractors is stored in the form of liking not only following correct identification of targets but also when targets are misclassified as distractors. So, if search is continued or repeated, a negative feedback loop may further inhibit target identification. This may explain pervasive errors observed in change-blindness and related paradigms (Simons & Rensink, 2005). Interestingly, the results of Experiment 2 may also partly explain the logic of errors in visual search in general. Recall that for errors there was a positive correlation between dwell time and ratings of distractors. Following the proposed approach, processing of distractors may be reinforced by positive affect. Even though the processing of such distractors should end following brief analysis, the reinforcement may prolong it. This can either reflect that the distractor contains features similar to the target or because for some reason its processing turns out to be no less rewarding than the processing of the target.

Positive affect elicited by correct identification of targets may, in turn, explain some of the results observed for priming in visual search (Kristjánsson, Saevarsson, & Driver, 2013; Maljkovic & Nakayama, 1994; Sigurdardottir, Kristjánsson, & Driver, 2008; see Lamy & Kristjánsson, 2013 for review). For example, Brascamp, Blake, and Kristjánsson (2011) demonstrated that previous singleton search trials prime the selection of a target item on free-choice trials. If accurate search results in positive affect this could explain choices of previous targets during free-choice.

Furthermore, our results are important for studies of error-monitoring processes in general. Errors in simple tasks are followed within 60–120 ms by a negative deflection in electroencephalography termed an error-related negativity (ERN; Falkenstein, Hoormann, Christ, & Hohnsbein, 2000; Gehring, Goss, Coles, Meyer, & Donchin, 1993; Gehring, Liu, Orr, & Carp, 2012). Recent studies demonstrate that ERN amplitude is positively correlated with negative affect. For example, Wiswede et al. (2009) used pictures to induce short-term affect. Following the presentation of an unpleasant picture, ERN amplitude was higher than following pleasant or neutral ones. Our results suggest that ERNs may not only be associated with negative affect (i.e., negative affect can make the error-monitoring system more "vigilant", thus influencing ERN amplitude) but may also reflect negative affect elicited by error. This affect seems to be mostly associated with targets as the distractors positioned nearby were not rated more negatively following errors. However, affect is known to "diffuse" from one object to another unless special effort is made to attribute it to its source (e.g., Clore & Huntsinger, 2009; Monahan, Murphy, & Zajonc, 2000; Schwarz & Clore, 1983). It is therefore possible that the lack of effects on the ratings of distractors was determined simply by the lack of time for their analysis.

ERNs are enhanced in psychopathology associated with negative affect, such as anxiety disorders, obsessive-compulsive disorder and depression (see Moser, Moran, Schroder, Donnellan, & Yeung, 2013; Weinberg, Riesel, & Hajcak, 2011 for reviews). This is consistent with the idea that negative affect elicited by errors might be more pronounced in these disorders. Especially interesting is the absence of enhanced ERNs in phobias as opposed to generalised anxiety disorder (GAD; Hajcak, McDonald, & Simons, 2003; Moser, Hajcak, & Simons, 2005; Weinberg, Olvet, & Hajcak, 2010; Xiao et al., 2011). In other words, GAD is related to enhanced ERN and negative affect not related to specific objects, while phobias are related to specific objects and lack an enhanced ERN. We suggest that non-specific negative affect in GAD might reflect a deficiency in attribution of ERN affect to its source. That is, while in our results the error-related affect was attributed to targets and not to distractors, subjects with GAD might attribute this affect to other objects as well, leading to a non-specific negative affect.

Similarly, this study converges with studies relating stimulus and response conflict to aversive tendencies (Aarts et al., 2012, 2013; Dreisbach & Fischer, 2012; Fritz & Dreisbach, 2013; Martiny-Huenger, Gollwitzer, & Oettingen, 2013; Schouppe et al., 2012). According to our results, errors involve a special type of conflict when the information regarding correct decisions is available, as for long dwell times on a target item. Further studies may provide insights into the level of processing creating the conflict.

Our studies demonstrate that search accuracy can influence liking, especially when a significant amount of time is spent analysing an object. But why are errors made following relatively lengthy analysis of an object? It is possible, that the error is made during response execution—observers may simply click on the wrong object despite being aware of the target position. The errors may also relate to earlier stages before information about target identity reaches awareness. It will be interesting to test whether such effects can be observed with even longer search and exposure times. Errors in typical time-unlimited visual search studies are seldom thoroughly analysed, but, as evident from the present study, errors can provide interesting information about the mechanisms of visual search, and further studies in this area are clearly warranted.

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