Perception of facial expression depends on prior attention

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Abstract Attending versus ignoring a stimulus can later determine how it will be affectively evaluated. Here, we asked whether attentional states could also modulate subsequent sensitivity to facial expressions of emotion. In a dual-task procedure, participants first rapidly searched for a gender-defined face among two briefly displayed neutral faces. Then a test face with the previously attended or ignored face's identity was presented, and participants judged whether it was emotionally expressive (happy, angry, or fearful) or neutral. Intensity of expression in the test face was varied so that an expression detection threshold could be determined. When fearful or angry expressions were judged, expression sensitivity was worse for faces bearing the same identity as a previously ignored versus attended face. When happy expressions were judged, sensitivity was unaffected by prior attention. These data support the notion that the motivational value of stimuli may be reduced by processes associated with selective ignoring.

Keywords Face perception · Attention · Distractor devaluation · Face expression

Recently, several studies have shown that selective visual attention can influence the subsequent affective evaluation of abstract patterns (Raymond, Fenske & Tavassoli, 2003) and simple objects (Griffiths & Mitchell, 2008; Veiling, Holland & van Knippenberg, 2007) and the social appraisal of faces (Fenske, Raymond, Kessler, Westoby & Tipper, 2005; Goolsby, Shapiro, Silvert, Kiss, Fragopanagos, Taylor & Raymond, 2009; Kiss, Goolsby, Raymond,

Shapiro, Silvert, Fragopanagos & Eimer, 2007). Many of the studies reporting these effects used a dual-task procedure in which participants first engaged in a simple two-item visual search task (attention task) that was immediately followed by an explicit affective evaluation of the item that had been the previously attended item (target), the previously ignored item (distractor), or neither. Typically, prior distractors have been evaluated more negatively than prior targets, and evaluation of prior targets has remained unaffected by attention. Interestingly, this *distractor devaluation* effect has been found to be feature based (Goolsby et al., 2009). When the attention task required selection among two same-category items (e.g., houses) on the basis of a feature (e.g., a transparent overlay color), distractor devaluation was found for items from an unrelated category (faces) if they shared the previously ignored feature (overlay color). This and other behavioral (e.g., Fenske et al., 2005; Fenske, Raymond & Kunar, 2004), electrophysiological (Kiss et al., 2007), and neuro-imaging (Doalla, Raymond, Shapiro, Eimer & Nobre, 2011) findings support the proposal that distractor devaluation results from task-specific attentional inhibition that becomes associated with the distracting feature. When this feature is presented later in the to-be-evaluated stimulus, inhibition becomes reinstated and modulates affective responses.

However, how affective responses are modulated remains unclear. One possibility is that reinstated inhibition generates negative affect for the ignored feature, causing subsequently presented stimuli bearing this feature to be evaluated more negatively than if that feature had been previously attended. If this is correct, devaluation effects (i.e., more negative evaluations) should be independent of the emotional valence (positive or negative) of the to-be-evaluated stimuli, requiring only that they possess the previously ignored feature. Making different predictions is

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another explanation derived from notions of emotional regulation (Ochsner, Bunge, Gross & Gabrieli, 2002). In this view, reinstated inhibition suppresses affective responses to stimuli bearing the inhibited feature, making positive stimuli appear more negative and negative stimuli appear more positive.

Raymond (2009) proposed a third explanation, derived from notions of value prediction and motivation, that predicts yet a different pattern of outcome when emotionally valenced stimuli are judged after prior ignoring. Recent studies have shown that an extensive neural network involving the ventral striatum, the prefrontal cortex, (including the orbitofrontal cortex [OFC]) and the amygdala (among other areas) is used to predict the value of interacting with specific stimuli (O'Doherty, 2004). Stimuli predicting high-value outcomes motivate behavioral engagement, whereas those predicting low-value or negative outcomes do not. Consider that in a typical distractor devaluation experiment, distractors in a search array signal potential errors (implicit negative outcomes). This should reduce the predicted value of the ignored feature, lowering motivation to engage with stimuli sharing that feature when encountered in the evaluation task. In this way, memory for prior attentional inhibition of a feature could be stored as a negative change in that feature's predicted value. Like the affective suppression notion, reduced motivation should dampen affective responses. However, unlike affective suppression, a motivation-based account allows other, especially affective, features in the to-be-evaluated stimuli to moderate the effects of prior ignoring. By proposing that an object's value prediction is a weighted sum of the predicted value of all its features, this view allows motivational states toward stimuli to flexibly incorporate past and current experience.

Considering this, the motivation view, unlike the other accounts, predicts very little or no devaluation when stimuli possess a recently ignored feature but are otherwise especially attractive (as in smiling faces), because the latter should outweigh the former. It also predicts that aversive stimuli (e.g., angry faces) should appear less negative if they share a recently ignored versus attended feature, because the aversive feature should exacerbate the effect of prior ignoring, further suppressing affective responses. To test these ideas, we used the basic distractor devaluation paradigm but replaced the affective evaluation task with a task requiring detection of subtle positive or negative facial expressions in faces that had just previously been seen bearing neutral expressions in a gender-defined visual search task.

We reasoned that detection of a subtle facial expression should depend on the social motivation to engage with the person bearing that expression. If motivation is low, sensitivity to facial expression should also be low.

Assuming that attentional inhibition reduces subsequent motivation to engage, sensitivity to facial expression in a previously ignored versus attended face should be reduced. Reduced sensitivity to facial expression should be especially evident when negative expressions are judged, because such expressions should further reduce motivation. However, positive expressions might mitigate sensitivity losses because they enhance social motivation (O'Doherty, Winston, Critchley, Perrett, Burt & Dolan, 2003) and could thus countermand the effects of prior ignoring. These predictions can be contrasted to those offered by the negative affect and affective suppression accounts of distractor devaluation. The former predicts that sensitivity to facial expression should be enhanced for negative expressions and reduced for positive expressions, because, in all cases, the faces should seem more negative (more angry, more fearful, less happy). The latter predicts that sensitivity should be reduced regardless of the valence of facial expression, because, in all cases, emotional salience of the face should be suppressed.

To test these predictions, we briefly presented pairs of opposite-gender, neutrally expressive faces, each with a different color transparent overlay, and asked participants to report the color of a gender-defined target as quickly as possible. Participants then judged whether the expression of a single test face (previous target or distractor) was emotionally expressive or neutral. Critically, test faces varied in the intensity of their expression so that a psychometric function could be generated and an expression detection threshold interpolated for each prior attention condition. Different participants judged happy, angry, or fearful test face expressions.

Not only was our experiment designed to resolve how attentional inhibition leads to distractor devaluation, it was also aimed at demonstrating that top-down effects of attention could modulate sensitivity to emotional expressions in faces. Although numerous studies have shown that activation of neural networks responsive to faces can be modulated by attention (e.g., Vuilleumier, Armony, Driver & Dolan, 2001), the effects of attention on sensitivity to facial expression have not been previously reported.

Method

Participants

Forty-two students (35 females; mean age = 20 years, $SD = 1.1$ years) reporting normal or corrected-to-normal vision completed the experiment in exchange for course and printer credits. Informed consent was obtained prior to participation.

Apparatus

Stimuli were displayed on a 22-in. Mitsubishi DiamondPro 2060u monitor (32-bit true color; resolution, $1,280 \times 1,024$ pixels) viewed binocularly from a distance of 60 cm. E-Prime software (Version 1.0) generated stimuli and recorded responses acquired via a keyboard.

Stimuli and design

A methodological necessity for measuring sensitivity to facial expressions per se (independently of face identity and emotion valence) is a set of iso-intense stimuli that vary by equal increments in expression intensity for different face identities and emotions. To do this, we first generated sets of images (morphs), using digital morphing software that reflected a gradual transition between neutral and highly expressive faces for several different people expressing different emotions, all selected from the Karolinska Directed Emotional Faces set (Lundqvist, Flykt & Öhman, 1998). Then, in a separate pilot study,¹ we measured the proportion of trials on which each morph was judged *expressive* versus *neutral* and plotted the *z*-transformed probability of an *expressive* response as a function of morph intensity (% of the fully expressive face) for each identity and emotion. The psychometric function thus derived for each emotion–identity combination was used to interpolate the specific %-morph values needed theoretically to yield five different probabilities of *expressive* response (i.e., five different expression intensities). These were .16, .31, .50, .69, and .84, each corresponding to equally spaced *z*-transforms of -1.0, -0.5, 0.0, 0.5, and 1.0 *z*-units, respectively. These interpolated %-morph values were then used to create five new morphs (called *z*-morphs) for each emotion–identity combination (see Fig. 1a for an example). Each expression intensity was labeled by the *z*-value of its predicted response (“*z*-morph” value). Negative *z*-morphs had so little expression that such faces were expected to be judged as *neutral* most of the time; positive *z*-morphs had enough expression to expect that they would be judged *expressive* most of the time.

For the present study, six male and six female identities expressing three emotions (happy, angry, fearful) were selected from this set. Images were presented in grayscale, cropped, and enclosed in a rectangular frame ($5.84^\circ \times 7.99^\circ$). Search array faces were always neutral, presented in pairs (centred 4.83° to the left and right of fixation), and overlaid with different transparent colors (yellow, blue, or

green), using JASC Image Robot (hue = 40, 150, or 70, respectively; saturation = 75, 50, or 50, respectively). Similarly tinted, grayscale place images (six houses, six buildings) matched in size to the faces were used in search arrays on baseline trials. For the expression task, a single grayscale face with no color overlay was centrally presented. Five expression intensity morphs (-1.0, -0.5, 0.0, 0.5, 1.0 *z*-morphs) for each identity and expression (180 images) were used. Alphanumeric stimuli appeared in 18-point Courier New font.

Procedure

On each trial, participants performed a visual search task followed by an expression judgment task (Fig. 1). Each trial began with a central fixation cross (1,000 ms), followed by a two-item search array (200 ms), with each item having a different transparent color overlay. On face search trials, one male and one female face (both with neutral expressions) were presented; on place search trials, one house and one building were presented. Search type (face, place) and target category (male, female, house, or building) varied between blocks of trials, being prespecified at the beginning of each block. The task was to report the target’s color (blue, yellow, or green) by depressing one of three keys as quickly as possible. Accuracy and response time (RT) were recorded. After response, a blank screen (150 ms) and then a fixation cross (1,000 ms) were presented. Finally, a test face was presented for 300 ms. Participants judged the face as *expressive* or *neutral*, indicating response via the keyboard (nonspeeded).

Each face identity was presented equally often as target or distractor in the search array. Half of the targets appeared on the right, and half on the left. A third of the trials presented targets in each color; corresponding distractors were equally likely to be in one of the other two colors. Target location, identity, and color combinations were presented in a pseudorandom order within each block. In two different attention conditions, (attended, ignored; randomly presented within each face search block), the test face shared the identity of the target or distractor, respectively. In a third condition (baseline), tested in separate place search blocks, the test face was not seen during the attention task. Experimental trials were conducted in six blocks of 180 trials (1,080 trials in total), consisting of two blocks with male targets, two with female targets, one with house targets, and one with building targets. To ensure that all critical stimulus conditions were equally probable, half the blocks (one male, one female, and either a house or a building block) were constructed using a subset of three female and three male face identities. Within each of these blocks, each combination of face identity and expression intensity morph was

¹ Using the method of constant stimuli, we asked five healthy young adults to judge six morphed images of 14 identities displaying anger, happiness, or fear. Each morph was presented eight times for 300 ms in a random order, blocked for emotional expression. Face images were as described here.

Fig. 1 **a** An example of the z-morph expressive faces used in the main study. Going from left to right, each face increments in intensity by 0.5 z-units (see the text). The middle face in each row produces an *expressive* response on approximately 50% of trials requiring an *expressive* versus *neutral* judgment when presented for 300 ms. From top to bottom, anger, happiness, and fear expressions are shown. Faces in each column can be considered iso-intense. **b** A schematic illustration of the dual-task trial sequence used in the experiment.

Each trial began with a fixation display, followed by the search array. The first task was to report the color tint of the gender-defined target in the search array as quickly as possible. The second task was to judge whether the test face (presented 1,150 ms after response to the search array) was expressive or neutral. On different trials, the test face had the same identity as the previous target face, the previous distractor face, or, on baseline trials, neither face. In the latter case, the search arrays items were a building and a house image

presented equally often as test, in a pseudorandom order. Remaining blocks used the remaining face identities. In this way, each face appeared 30 times each as target and distractor. Each expression intensity morph for each

identity was presented 4 times in each attention condition (attended, ignored, and baseline). After receiving task instructions, participants completed four 12-trial practice blocks (one for each target type). The emotional nature of

the possible expression on the test face remained constant for each participant but varied among participants, creating three emotion groups (happy, $n = 14$; angry, $n = 13$; fearful, $n = 14$).

Data analysis

Expression task data were excluded if the preceding search trial yielded an incorrect response (8%). Data were also excluded if an anticipation error ($RT < 200$ ms) or an unusually slow response ($RT > 3$ SDs above the participant's condition mean) was made in either task (6% of remaining data).

For each participant and attention condition, the mean proportion of *expressive* responses for each expression intensity value (collapsing across face identity) was calculated, z -transformed, and then plotted as a function of expression intensity (z -morphs). A least squares line was then fit to each plot, excluding extremes where functions flattened. Threshold was defined as the interpolated z -morph needed to yield an *expressive* response on 60% of the trials. If the method of creating the iso-intense z -morphs was valid, mean baseline threshold should have been approximately 0.25 z -morphs for all emotions. As can be seen in Table 1, this result was obtained.

A mixed design analysis of variance (ANOVA) was conducted on expression detection thresholds, using attention condition (attended, ignored, baseline) as a within factor and emotion (happy, angry, fearful) as a between factor. Planned comparisons used within or between t -tests, as appropriate. Alpha levels were set at .05.

Results

Facial expression thresholds

As was expected from our use of iso-intense z -morphs, the main effect of emotion was nonsignificant, $F < 1$. Although there was a main effect of attention condition, $F(2, 76) = 36.24$, $p < .001$, $\eta_p^2 = .49$, this effect significantly depended on the emotion being expressed on the test face, $F(4, 76) = 5.54$, $p < .001$, $\eta_p^2 = .23$, an effect contrary to the prediction made by the affective suppression account of distractor devaluation. Separate ANOVAs for each emotion

group revealed significant main effects of attention in all cases ($p < .02$ in all cases). Thresholds for facial expression in faces seen previously in the search array (attended, ignored) were generally lower than those for the baseline condition. For all three emotions, expression thresholds were significantly below baseline in the attended condition ($p < .01$ in all cases), although the magnitude of this effect was significantly larger for the fearful than for the angry or happy group ($p < .01$ in both cases). Lowering of threshold below baseline was also found for Ignored faces, but only in the fearful and happy groups ($p < .02$ in both cases), being absent in the angry group.

To isolate the effects of prior attention, as opposed to prior exposure, we subtracted thresholds obtained in the baseline condition from those obtained in the attended and ignored conditions (Fig. 2). For the happy group, the benefit of preexposure in the search array was equal in magnitude for both attended and ignored faces, consistent with the motivational value account of distractor devaluation. For both negative emotion groups (fearful and angry), this benefit was significantly larger for the attended versus ignored condition ($p < .02$ in both cases), a result also consistent with the motivational value account of distractor devaluation.

Analyses of the slopes of the psychometric functions used to derive threshold estimates showed nonsignificant main effects of emotion and attention and a nonsignificant interaction effect (all $ps > .10$). This shows that attentional processes did not serve to sharpen discrimination of expressive versus neutral expressions but, rather, shifted

Fig. 2 Group mean change in threshold for detection of a facial expression (baseline – attended; baseline – ignored) for each attention condition and emotion group. Threshold is defined as the expression intensity (expressed in z -morph units; see the Stimuli and Design section) needed to produce *expressive responses* on 60% of the trials. Positive numbers on the vertical axis indicate an improvement in sensitivity or a lowering of threshold. Open and filled bars represent the group mean threshold for perceiving expression in faces that had been seen just previously as distractors or targets, respectively. Vertical lines represent ± 1 SE

Table 1 No-exposure (baseline) thresholds (expressed in z -units) for each emotion group

Expression	Threshold <i>M</i> (<i>SE</i>)
Angry	.30 (.07)
Happy	.22 (.08)
Fearful	.30 (.10)

the psychometric functions laterally. Differences in mean proportion of *expressive* responses for the lowest expression intensity morph obtained in attended versus ignored conditions were nonsignificant for all the emotion groups (all $ps > .35$), indicating that criterion shifts did not occur.

Attention task

A mixed design ANOVA of mean RTs on correct search trials, using two of the attention conditions (attended, ignored) and expression intensity (five z -morphs) as within factors and emotion as a between factor, showed that all main and interaction effects were nonsignificant (all $ps > .25$). Error rates were similarly unaffected. Mean RTs for each trial type and emotion group are presented in Table 2. Mean RT for the baseline search task (that used place instead of face images) was faster than that for the attended and ignored conditions ($ps < .01$). This most likely reflects differences in task difficulty related to the different types of search arrays but is of little interest here, because our primary concern was with how attention in the face search task would affect subsequent sensitivity to expression.

Discussion

This experiment shows that after a simple visual search task involving neutral faces, distractor devaluation effects are manifest as changes in sensitivity to emotional facial expressions. Specifically, ignoring, as compared with attending, a neutral face reduces subsequent sensitivity to the presence of a negative expression on that face but has no effect on sensitivity to the appearance of a positive expression. These results are important for two reasons: First, they provide clear support for a motivation-based account of distractor devaluation, and second, they demonstrate that perception of expression in faces can be influenced by top-down processes.

Distractor devaluation is thought to occur because selectively attending a target in the presence of a distractor causes inhibition to become associated with the relevant distractor feature. When that feature is reencountered, the associated inhibition is reinstated, depressing affective

appraisal (Raymond et al., 2003). Three different accounts of how inhibition could modulate affective evaluation were tested here. The first is that attentional inhibition imbues ignored stimuli with negative attributes. It predicts that sensitivity should be enhanced for negative expressions but reduced for positive expressions. However, this result was not obtained. The second view proposes that inhibition suppresses affective response, predicting that expression sensitivity should be reduced for faces in the ignore versus attend conditions regardless of emotion. Again, this result was not found. The third account is that inhibition lowers a distracting feature's predicted value, reducing motivation to engage with it (Raymond, 2009). The idea here is that the distractor feature predicts potential errors and, thus, acquires negative predicted value, reducing motivation to interact with stimuli that possess this feature. Importantly, in this view, the emotional expression on the test face should modulate the negative motivational effect of prior ignoring, because it provides a separate, additional motivation signal. A negative facial expression on the test face should serve to further reduce its predicted value, whereas a positive expression should improve it (Custers & Aarts, 2005; O'Doherty et al., 2003). Such expression information could be rapidly acquired via thalamic routes to the amygdala, which, in turn, could modulate conscious visual processes directly or via frontal (OFC) feedback. The end result of such motivationally based modulation would be a decline in explicit sensitivity to negative expressions for distractors (relative to that for targets) and a nulling of any distractor "devaluation"-like effects for distractor faces with positive expressions. Indeed, the pattern of result reported here is consistent with this account. Sensitivity to negative facial expressions was worse for prior distractors, as compared with prior targets. However, sensitivity to happy expressions was unaffected by prior attention.

Another alternative explanation for the effects found here is that selective attention for target faces in the visual search task allowed face analysis mechanisms to preferentially engage with the attended face, facilitating its representation in visual working memory (WM) over that for the ignored face. If comparisons between the stored WM representation and the subsequently presented test face could be used to enhance expression detection, sensitivity to expression in the attended face should have been better than that for the ignored face (as was found for negative expressions). Indeed, such a process may underlie our finding of enhanced sensitivity for faces preexposed in the search task (attended or ignored), as compared with that for faces in the baseline condition, where no WM representation would have been available to facilitate expression detection. However, this WM-based account cannot explain the lack of an effect for positive expressions. Regardless of the emotional expression in the test face, the search array information (always neutral faces) and task were

Table 2 Group mean reaction time (and *SE*) for each attention condition for each emotion

Expression	Baseline (Places) <i>M (SE)</i>	Target (Faces) <i>M (SE)</i>	Distractor (Face) <i>M (SE)</i>
Angry	733 (29)	782 (31)	785 (31)
Happy	688 (29)	735 (31)	734 (31)
Fearful	777 (29)	812 (31)	811 (31)

identical across emotion conditions, giving no reason to expect emotional expression in the test face to produce differences in the quality or resolution of representations already held in WM. Moreover, the absence of any systematic effect of emotion on search task performance casts doubt on this possibility.

Our finding that test face emotion interacts with prior attention to determine expression thresholds shows clearly that differential encoding of target and distractor faces during the search task is unable to account for the alterations in expression sensitivity reported here. Similarly, differences in the sensory data present in the test face cannot explain these results, because the sensory data were identical for all attention conditions. Instead, a combination of top-down processes that incorporate past information (from the search task events) with current sensory and motivational information inherent in the test face must combine to determine explicit sensitivity to emotional expression in human faces. Value prediction mechanisms provide a plausible framework with which to explain these experimental outcomes. Although faces in the search array in the present experiment were not explicitly assigned value, their role in yielding implicit rewards and punishments may have been sufficient to alter motivation for subsequent perceptual engagement, consequently leading to modulation of sensitivity to facial expressions. These results show that “reading” the emotion expressed in a face depends not only on the physical information in the face, but also on one’s immediate prior experience.

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