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Dissociating Spatial Attention and Awareness in Emotion-Induced Blindness

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Abstract

Emotional stimuli attract spatial attention, sometimes improving perception at their location. But they also can disrupt awareness of targets at their location, a phenomenon known as *emotion-induced blindness*. Such discrepant findings might reflect the impact of emotional stimuli on different perception mechanisms. We dissociated spatial attention and awareness by investigating the spatial distribution of emotion-induced blindness. Participants searched for a target within two simultaneous rapid streams of pictures, one of which could also contain a preceding emotional distractor. When targets were followed by additional stream items, emotion-induced blindness occurred only at the location of the distractor. However, when no items appeared after the target, so that it could persist in iconic memory and its temporal position was easily discernible, emotional disruption of target perception was more robust away from the distractor's location than at the distractor's location. The results suggest that although emotional distractors attract spatial attention, they inhibit identification of competing items potentially linked to the same spatiotemporal position.

Keywords

emotion-induced blindness, spatial attention, visual awareness, attentional competition, emotion, perception

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Emotional stimuli are often perceived better than nonemotional stimuli (e.g., Anderson & Phelps, 2001; Öhman, Flykt, & Esteves, 2001), but how do they affect perception of the stimuli around them? On one hand, attention to emotional stimuli has been found to carry over, such that targets appearing in the same place as emotional stimuli elicit quicker and more accurate responses than targets at other locations (e.g., Fox, Russo, Bowles, & Dutton, 2001; MacLeod, Mathews, & Tata, 1986; Mogg & Bradley, 1999; Van Damme, Crombez, & Notebaert, 2008). However, emotional stimuli also have been found to disrupt target awareness even when all items appear in the same location. For example, when participants viewed rapid streams of upright landscape photos and searched for one landscape within each stream that was rotated 90°, target detection suffered when targets were preceded in the stream by a task-irrelevant emotional picture, an effect labeled *emotion-induced blindness* (e.g., Most, Chun, Johnson, & Kiehl, 2006; Most, Chun, Widders, & Zald, 2005; Most & Jungé, 2008; Most, Smith, Cooter, Levy, & Zald, 2007; Smith, Most, Newsome, & Zald, 2006).[1]

The discrepant findings from such studies might be due to differences in the perception mechanisms that are tapped by the experimental procedures. The studies showing facilitation at an emotional stimulus's location index spatial attention, which is often measured via response time and appears to be dissociable from awareness (e.g., McCormick, 1997; Woodman & Luck, 2003). In contrast, studies of emotion-induced blindness typically use rapid serial presentations, and failures of visual awareness under such conditions have been linked to a range of perception mechanisms besides spatial attention. For example, dominant models of the *attentional blink* (AB)—a deficit in reporting the second of two temporally proximal targets within a rapid stream—attribute the AB to central processes such as bottlenecks gating access to working memory (e.g., Chun & Potter, 1995; Potter, Staub, & O'Connor, 2002), errors in target retrieval from memory (Shapiro, Raymond, & Arnell, 1994), or lapses of attentional control (Di Lollo, Kawahara, Ghorashi, & Enns, 2005).

Failures of visual awareness during rapid serial presentations have also been linked to relatively early factors, such as neural competition elicited by stimuli that overlap in time and space (Keysers & Perrett, 2002). For example, visual cortical neurons that exhibit heightened activity in response to one

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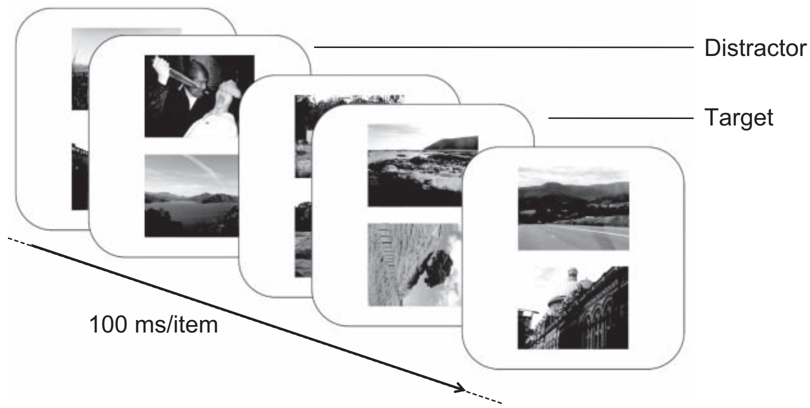

Fig. 1. Schematic representation of a partial trial. Two simultaneous, rapid streams of pictures were presented, one above the other (presentation rate of 100 ms/picture), and participants reported the orientation of a single target that could appear in either stream (here, the target is rotated 90° clockwise). On most trials, a critical distractor (either an emotionally negative or a neutral picture) appeared two items before the target, either in the same stream as the target or in the opposite stream. Here, the critical distractor is emotionally negative and appears in the stream opposite from the target.

stimulus are less responsive when a second, competing stimulus simultaneously occupies their receptive fields; attention to either of the stimuli leads to a neural response similar to that observed when the attended item appears alone (e.g., Chelazzi, Miller, Duncan, & Desimone, 2001). Although items within rapid serial presentations appear one after another, they can elicit neural responses that overlap temporally, thereby giving rise to similar competition for dominance at a given spatiotemporal position (Keysers & Perrett, 2002). In sum, mechanisms underlying the impact of emotion on conscious perception likely are distinct from spatial attention, even though the latter has been the focus of most attention-emotion studies; the challenge in characterizing the impact of emotion on perception stems from the fact that visual awareness emerges via a complex symphony of processes.

In two experiments, we elucidated mechanisms driving emotion-induced blindness by examining the degree to which it is spatially localized. If emotional distractors disrupt perception via central mechanisms, as has recently been suggested (Bocanegra & Zeelenberg, 2009), then emotion-induced blindness should occur regardless of the spatial relationship between targets and emotional distractors. Alternatively, if emotion-induced blindness stems from competition for dominance at a given spatiotemporal position, then emotion-induced blindness should occur only when a target is at the same location as an emotional distractor. A third possibility is that emotion-induced blindness is not dissociable from spatial attention, in which case target detection should be worse when a target and distractor are at different locations than when they are at the same location.

Experiment 1

In our first experiment, participants monitored two simultaneous rapid streams of pictures in order to detect a single target, which could appear in either stream. On most trials, a critical distractor—an emotionally neutral or negative picture—preceded the target, either in the same stream or in the opposite stream (Fig. 1).

Method

Participants. Seventeen undergraduates (mean age = 19.9 years; 8 female, 9 male) participated in this experiment.

Materials and procedure. Stimuli were color photographs measuring 12 cm by 9 cm. Distractors were 56 neutral and 56 emotionally negative pictures, drawn mostly from the International Affective Picture System (Lang, Bradley, & Cuthbert, 2001) and supplemented by similar pictures from publicly available sources. The distractors portrayed people or animals, with the negative set including depictions of violence, distress, and medical trauma; using 9-point scales, a separate group of 12 individuals had rated the negative pictures as more unpleasant and arousing than the neutral pictures ($ps < .001$). Targets were 84 landscape and architectural photos, each of which appeared once with a 90° clockwise rotation and once with a 90° counterclockwise rotation. The filler stimuli were 252 upright landscape and architectural scenes.

Each trial consisted of the presentation of two simultaneous streams of 17 images; the two streams were separated by a vertical gap of 1.6 cm, and each image appeared for 100 ms before being immediately replaced by the next. In the distractor conditions, the 4th, 6th, or 8th stimulus in one of the streams was an emotionally negative (56 trials) or emotionally neutral (56 trials) picture. In the baseline condition, there was no distractor (56 trials). The target appeared 2 serial positions after the distractor (or in the 6th, 8th, or 10th serial position on baseline trials). In the distractor conditions, the target appeared

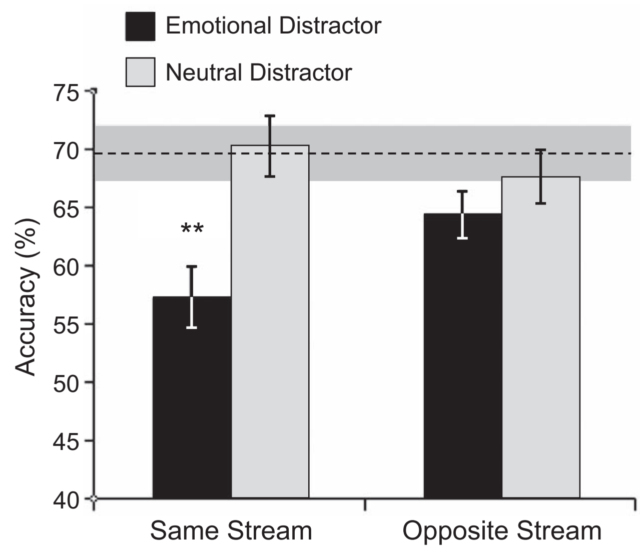

Fig. 2. Results from Experiment 1: mean accuracy as a function of stream (target and distractor in same vs. opposite streams) and distractor type (emotional vs. neutral). Error bars indicate standard errors of the mean. The asterisks indicate a significant difference between distractor types (**$p < .01$). The horizontal dashed line indicates mean accuracy in the baseline condition, in which no distractor was present; the surrounding gray area indicates the standard error in that condition.

equally often in the same stream as the distractor and in the opposite stream, and in the baseline condition, the target appeared equally often in each stream. After each trial, participants indicated the target's rotation (clockwise or counter-clockwise) via key press. Participants were instructed to ignore pictures of people or animals and were told that there was no predictive relationship between the locations of targets and the locations of distractors.

Results and discussion

Data from 1 participant who performed below chance were eliminated. A 2 (distractor type: negative vs. neutral) × 2 (stream: target and distractor in same vs. opposite streams) within-subjects analysis of variance (ANOVA) revealed a main effect of distractor type, $F(1, 15) = 10.90$, $p = .005$, $\eta_p^2 = .421$; performance was worse following an emotionally negative distractor than following a neutral distractor. There was no main effect of stream, $F(1, 15) = 1.76$, $p = .204$, $\eta_p^2 = .105$. A two-way interaction, $F(1, 15) = 4.82$, $p = .044$, $\eta_p^2 = .243$, revealed that emotionally negative distractors were more disruptive relative to neutral distractors when targets and distractors appeared in the same stream (negative: $M = 57.37\%$, $SD = 10.14\%$; neutral: $M = 70.31\%$, $SD = 9.99\%$), $t(15) = 3.57$, $p = .002$, than when they appeared in opposite streams (negative: $M = 64.51\%$, $SD = 7.43\%$; neutral: $M = 67.63\%$, $SD = 8.98\%$), $t(15) = 1.06$, $p = .307$ (Fig. 2).

For targets following emotional distractors, performance was worse than baseline ($M = 69.75\%$, $SD = 9.21\%$) both when targets and distractors appeared in the same stream, $t(15) = 3.93$, $p = .001$, and when they appeared in opposite streams, $t(15) = 2.81$, $p = .013$. In contrast, accuracy following neutral distractors was comparable to baseline regardless of stream (*p*s > .46).

Thus, emotion-induced blindness seems to be localized in space, but the pattern of results contrasts with evidence that by attracting spatial attention, emotional distractors typically induce greater processing impairments for targets appearing away from the distractor location than at the distractor location. In addition to highlighting a distinction between mechanisms of emotion-induced blindness and spatial attention, the localized nature of the effect suggests that emotion-induced blindness does not reflect the type of central processes often thought to underlie the AB, such as visual working memory consolidation. Instead, emotional distractors might have a dual impact, attracting spatial attention while inhibiting target representations linked to the same spatiotemporal position (e.g., see Keysers & Perrett, 2002). Such a mechanism would be consistent with previous findings that target perception is preserved when targets are temporally removed from distractors (e.g., Most et al., 2005).

In Experiment 2, we maintained the onset asynchrony between targets and distractors but eliminated posttarget items from the streams in half the trials, reasoning that the resulting persistence of targets in iconic memory would aid in disambiguating their temporal positions. We hypothesized that emotion-induced blindness would diminish under such conditions[2] and that the decrease in spatiotemporal competition would result in a pattern of target processing impairment more in line with typical spatial attention effects. That is, we expected target processing to be more impaired when targets and emotional distractors were in opposite streams than when they were in the same stream—a reversal of the pattern obtained in Experiment 1.

Experiment 2

Experiment 2 was generally identical to Experiment 1 with the following critical exception: In half the trials, the target was followed by several items in each stream (as in Experiment 1), but in the remaining trials, the streams stopped immediately upon the offset of the target, rendering it the last item in its stream. We refer to these as *trailing* and *nontrailing* trials, respectively. Additional changes from Experiment 1 included an absence of a baseline condition and a slight change in the serial positions of distractors and targets.

Method

Participants. Twenty-four undergraduates (mean age = 19.7 years; 17 female, 7 male) participated in Experiment 2.

Materials and procedure. Participants completed four blocks, each containing a randomized sequence of 64 trials constituting a 2 (distractor type: negative vs. neutral) × 2 (stream: target and

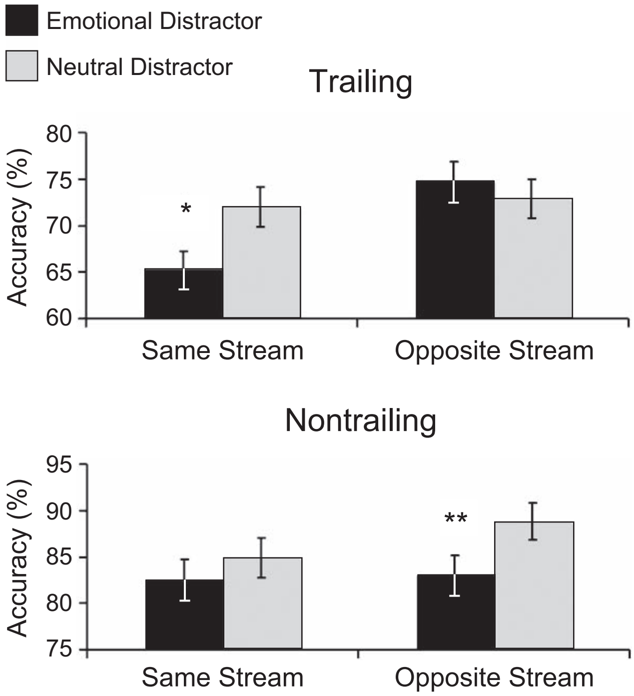

Fig. 3. Results from Experiment 2: mean accuracy as a function of stream (target and distractor in same vs. opposite streams) and distractor type (emotional vs. neutral), separately for trailing and nontrailing trials. Error bars indicate standard errors of the mean. Asterisks indicate significant differences between distractor types (*p < .05, **p < .01).

distractor in same vs. opposite stream) × 2 (trial type: nontrailing vs. trailing) design. Across all conditions, the distractor appeared equally often in the 5th and 10th serial positions, and the target appeared 2 serial positions afterward.

Results

A 2 (distractor type) × 2 (stream) × 2 (trial type) within-subjects ANOVA revealed main effects of distractor type, $F(1, 23) = 7.94$, $p = .010$, $\eta_p^2 = .257$; trial type, $F(1, 23) = 64.55$, $p < .001$, $\eta_p^2 = .737$; and stream, $F(1, 23) = 20.95$, $p < .001$, $\eta_p^2 = .477$. Performance was worse following emotionally negative distractors than following neutral distractors, was worse in the trailing condition than in the nontrailing condition, and also was worse when targets and distractors appeared in the same stream than when they appeared in opposite streams.

Critically, a significant three-way interaction, $F(1, 23) = 10.85$, $p = .003$, $\eta_p^2 = .321$, revealed that emotion-induced blindness was localized to the distractor's location only in the trailing condition (Fig. 3). A 2 (distractor type) × 2 (stream) ANOVA within the trailing condition replicated the two-way interaction in Experiment 1, $F(1, 23) = 7.19$, $p = .013$, $\eta_p^2 = .238$: Emotional distractors caused greater disruption than neutral distractors when targets and distractors appeared in the same stream (negative: $M = 65.36\%$, $SD = 9.03\%$; neutral: $M = 72.01\%$, $SD = 10.49\%$), $t(23) = 2.65$, $p = .014$, but not when they appeared in opposite streams (negative: $M = 74.87\%$, $SD = 9.90\%$; neutral: $M = 72.92\%$, $SD = 10.21\%$), $t(23) = 0.71$, $p = .483$. In contrast, the opposite pattern emerged in the nontrailing condition. Although the interaction in the nontrailing condition fell somewhat short of significance, $F(1, 23) = 2.37$, $p = .138$, $\eta_p^2 = .093$, a closer examination of nontrailing trials revealed that emotional distractors were significantly more disruptive than neutral distractors when distractors and targets appeared in opposite streams (negative: $M = 83.07\%$, $SD = 10.05\%$; neutral: $M = 88.80\%$, $SD = 9.66\%$), $t(23) = 4.32$, $p < .001$, but not when they appeared in the same stream (negative: $M = 82.55\%$, $SD = 10.78\%$; neutral: $M = 84.90\%$, $SD = 10.45\%$), $t(23) = 1.37$, $p = .185$. This pattern is consistent with the possibility that emotional distractors in the opposite stream held spatial attention away from the target's location (e.g., Fox et al., 2001; Van Damme et al., 2008).

General Discussion

Emotional stimuli often impair awareness of subsequent targets, an effect termed emotion-induced blindness (Most et al., 2005). Notably, such findings contrast with previous findings that emotional stimuli can facilitate processing of targets at their location (e.g., MacLeod et al., 1986; Mogg & Bradley, 1999). Our data help reconcile these discrepant patterns by suggesting that they reflect the impact of emotion on separable perception mechanisms.

On one hand, emotional stimuli attract spatial attention. In the nontrailing condition of Experiment 2, in which no items followed the targets, emotional disruption was evident only when targets were not at the distractor's location; this fits well with findings that emotional distractors typically draw or hold spatial attention away from targets at other locations. Thus, it is notable that such previous findings come largely from experiments in which targets were not followed by stimuli that cut short their perceptual availability. In contrast, in our trailing conditions, in which items continued to appear after the target, emotional disruption was evident only for targets in the location of the emotional distractor. Perceptual impairment in the location of an emotional distractor is a hallmark of emotion-induced blindness, and this localization suggests that the impairment does not stem from a central bottleneck, such as disrupted maintenance of a target template or competition for consolidation into visual working memory. Instead, by truncating target processing time and increasing the proportion of temporal overlap between target- and distractor-related responses within the visual system, posttarget items might increase the likelihood that the perceptual system will link the target and the distractor to a common spatiotemporal position; in this scenario, spontaneous prioritization of emotional stimuli could inhibit formation of other representations linked to the same time and place (see Keysers & Perrett, 2002, for a relevant review; also see Chelazzi et al., 2001; Mounts & Gavett, 2004). Thus, emotional stimuli appear to have a dual impact on perception mechanisms, grabbing spatial attention but inhibiting competing episodic representations at their location.

Note that, taken separately, the results of the nontrailing and trailing conditions each could be attributable simply to spatial attention. For example, the results of the trailing conditions might reflect inhibition of return, in which reflexive orienting to a location is followed by involuntary withdrawal of spatial attention (e.g., Posner & Cohen, 1984). However, emotion-induced blindness is inconsistent with this account, as it is robust with a shortened, 100-ms onset asynchrony between target and emotional distractor (Most & Jungé, 2008), a time course typically associated with the benefits of spatial orienting rather than the costs of inhibition of return. Furthermore, such an account is incongruent with the results for the nontrailing condition.

On the surface, emotion-induced blindness resembles a spontaneous AB, but distinctions between our findings and predictions stemming from major models of the AB suggest that emotion-induced blindness and the AB may involve different mechanisms, providing fertile ground for delineating potentially unique means through which emotion and perception interact. Indeed, the AB itself may be a heterogeneous phenomenon; for example, whereas—consistent with central accounts of the AB—some evidence suggests that the AB involves equivalent perceptual impairment across the visual field (e.g., Lunau & Olivers, 2010; Shih, 2000), one unique AB study uncovered evidence of a spatially localized perceptual impairment, suggesting that under some conditions the AB reflects relatively early suppression of attention (Kristjánsson & Nakayama, 2002). Thus, emotion-induced blindness might share overlapping mechanisms with some forms of the AB but not with others. Notably, the mechanisms driving emotion-induced blindness may also be heterogeneous. For example, although the emotional pictures in our experiments induced spatially localized effects, stimuli with greater emotional intensity (or the same stimuli if presented to clinically anxious populations) might disrupt more central processing as well (e.g., see Pessoa, 2009). Much might be gleaned from future research examining whether mechanisms underlying perception-emotion interactions are modulated by situational and individual differences variables.

As it stands, our experiments provide a linchpin within the attention-emotion literature, helping to resolve problematic discrepancies by linking seemingly contradictory findings to separable perception mechanisms. We dissociated the impact of emotional stimuli on spatial attention from their impact on perceptual processes that might be more intimately associated with visual awareness. Going further, our data suggest that emotion-induced blindness might not reflect disruption of central bottlenecks, but instead stem from stages involved in linking episodic representations to spatiotemporally distinct aspects of the visual environment: When targets and emotional distractors vie for dominance at overlapping points in time and space, spontaneous prioritization of emotional stimuli leads to inhibition of spatiotemporally competing information.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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Notes

1. Experiments including scrambled emotional distractors have shown that emotion-induced blindness cannot be attributed to low-level visual properties, such as distractors' color or brightness (e.g., Most et al., 2005, 2007; Most & Jungé, 2008).
2. The absence of posttarget items has been shown to reduce the standard AB; however, this reduction has been attributed to relatively central mechanisms underlying the AB (e.g., Giesbrecht & Di Lollo, 1998). With the results of Experiment 1 suggesting that emotion-induced blindness might not stem from a central bottleneck, it was not a foregone conclusion that the absence of posttarget items would affect emotion-induced blindness.

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