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BRIEF REPORT

Perceptual, not Memorial, Disruption Underlies Emotion-Induced Blindness

Briana L. Kennedy and Steven B. Most
University of Delaware

Emotion-induced blindness refers to impaired awareness of stimuli appearing in the temporal wake of an emotionally arousing stimulus (S. B. Most, Chun, Widders, & Zald, 2005). In previous emotion-induced blindness experiments, participants withheld target responses until the end of a rapid stream of stimuli, even though each target appeared in the middle of the stream. The resulting interval between the targets' offset and participants' initiation of a response leaves open the possibility that emotion-induced blindness reflects a failure to encode or maintain target information in memory rather than a failure of perception. In the present study, participants engaged in a typical emotion-induced blindness task but initiated a response immediately upon seeing each target. Emotion-induced blindness was nevertheless robust. This suggests that emotion-induced blindness is not attributable to the delay between awareness of a target and the initiation of a response, but rather reflects the disruptive impact of emotional distractors on mechanisms driving conscious perception.

Keywords: emotion, perception, attention, emotion-induced blindness

Emotional stimuli appear to have such robust power to capture attention that they can impair awareness even of targets that people look at directly, a phenomenon known as *emotion-induced blindness* (Most et al., 2005; Most, Chun, Johnson, & Keihl, 2006; Most, Smith, Cooter, Levy, & Zald, 2007; Most & Jungé, 2008; Most & Wang, 2011). In a typical emotion-induced blindness task, participants view images appearing within a rapid serial visual presentation (RSVP), at a rate of about 10 per second, and they are instructed to find a single target (a 90-degree rotated image) in the stream. At the end of each trial, they report the target's orientation. Critically, a distractor image also appears within the stream on most trials, and this distractor can be emotionally arousing or neutral. When the target appears soon after an emotional distractor (or sometimes just before it; Most & Jungé, 2008), people are less able to report its orientation than when it appears soon after or before a neutral distractor.

The robustness of this effect has obvious potential consequences for the real world. If, for example, a driver passes the scene of an accident just as the car ahead of him brakes, it is possible that the emotional nature of the accident scene could lead the driver to fail to notice the onset of the brake lights. Likewise, the prevalence of emotionally evocative ads on roadside billboards could constitute a generally underappreciated hazard, even when the advertiser's intention is ironically one of increasing road safety. For example, in an attempt to discourage drivers from speeding in wet weather, a district in New Zealand erected "antispeeding" billboards with pictures of children whose faces emitted red dye when it rained, giving the impression that they were streaked with blood (Dearnaley, 2009). Such efforts might be effective in changing drivers' behavior, but it is important to remain vigilant to the possibility that such billboards could potentially cause perceptual disruptions that in themselves are dangerous.[1]

Of course, one possibility is that emotion-induced blindness reflects a failure to encode or maintain target information in memory rather than a failure of conscious perception. One feature common to all emotion-induced blindness experiments to date is that participants are asked to withhold their responses until the end of each trial, at which point several hundred milliseconds may have passed since the sensory availability of the target. Because of this, it remains possible that participants have fleeting awareness of the target but do not have access to this information after even a very brief interval. If so, then the consequences of emotion-induced blindness for real-world safety are somewhat ameliorated; after all, almost every driver has had the experience of arriving safely at his or her destination, having navigated complex traffic situations without any memory of having done so.

From a theoretical perspective, as well, it is important to understand the degree to which emotion-induced blindness reflects a disruption of perception rather than an impaired ability to report

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Briana L. Kennedy and Steven B. Most, Department of Psychology, University of Delaware.

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Correspondence concerning this article should be addressed to Steven B. Most, Department of Psychology, University of Delaware, Newark, DE 19716-2577. E-mail: most@psych.udel.edu

[1] Note, though, that recent evidence suggests that whereas emotional stimuli attract spatial attention, impairing perception of events elsewhere within a visual scene, emotion-induced blindness itself might reflect additional mechanisms that are specific to the location of an emotional distractor (Most & Wang, 2011). Such findings can inform our understanding of the conditions under which graphic roadside billboards might most likely pose hazards.

targets retrospectively. On one hand, emotional stimuli have been found to disrupt the maintenance of nonemotional information in visual working memory (Dolcos & McCarthy, 2006; Mather et al., 2006), which could support the notion that emotion-induced blindness simply reflects emotion's impact on retrospective report. On the other hand, recent evidence suggests that emotion-induced blindness stems from early perceptual competition between target and distractor representations. For example, in one study, participants viewed two simultaneous RSVP streams and searched for a target that could appear in either stream (Most & Wang, 2011). Importantly, the emotional or neutral distractor could also appear in either stream, in the same or opposite location as the target, and emotional disruption of targets only occurred when the target and emotional distractor appeared in the same stream. Had emotion-induced blindness in that experiment stemmed from impaired recollection, equal impairment should have been observed regardless of whether or not targets and distractors appeared in the same stream. Instead, the researchers suggested that emotion-induced blindness arises when targets and emotional distractors compete for dominance at overlapping points in space and time (note that although items were presented serially, they likely gave raise to neural responses that overlapped temporally; see Keysers & Perrett, 2002, for a relevant discussion). Such a mechanism would imply that emotion-induced blindness involves disruption of perceptual, rather than memorial, processes.

In the current experiments, we further explored whether emotion-induced blindness can be attributed to perceptual, rather than memorial, disruption. In the two-stream version of the experiment described above (Most & Wang, 2011), attention was distributed across two rapid streams, which could result in the contribution of different mechanisms than those involved in most emotion-induced blindness demonstrations, in which people attend to only one rapid stream. In order to test whether emotion-induced blindness in a single stream reflects disruption at a perceptual stage, we asked participants to respond as soon as they saw the target in the stream rather than withhold their response until the end of the stream, as has typically been done to date.

Experiment 1

Method

Participants. Twenty-two University of Delaware undergraduates (mean age 19.65 years; 9 women and 13 men) participated for course credit. All participants provided informed consent, and the experiment was approved by the University of Delaware Human Subjects Review Board.

Materials and procedure. Stimuli were colored, 320×240 pixel photographs. One hundred sixty-eight images served as the "critical distractors": 56 negative, 56 neutral, and 56 scrambled images. Negative and neutral images were mostly gathered from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2001) on the basis of ratings of valence and arousal, and these were supplemented by images taken from publicly available sources. All pictures had previously been rated on a 9-point scale by an independent group of 12 participants for valence (1 = negative, 9 = positive) and arousal (1 = low, 9 = high). Ratings confirmed that the 56 negative images (valence: $M = 1.73$, $SD = 0.54$; arousal: $M = 6.04$, $SD = 0.69$) and 56 neutral images (valence: $M = 4.99$, $SD = 0.45$; arousal: $M = 3.18$, $SD = 0.55$) differed significantly in both dimensions ($ps < 0.001$).

Negative emotional distractors included depictions of medical trauma, threatening animals, and violence, and the neutral distractors depicted people or animals that did not elicit emotional arousal (e.g., people with neutral expressions, nonthreatening animals). Scrambled images were the 56 negative images, each divided into an 8×6 grid and with the segments rearranged. The inclusion of these scrambled images served to control for differences in low-level properties between the negative and neutral sets, such as color and luminance. Another 128 images served as the targets (64 landscape and architectural images rotated 90 degrees both clockwise and counterclockwise). An additional 252 photographs were upright landscape and architectural images that served as filler images (i.e., which appeared in the streams but were neither targets nor distractors).

Stimuli were presented against a gray background on a 19-inch CRT monitor with a refresh rate of 100 Hz, via the Psychophysics Toolbox for Matlab (Brainard, 1997; Pelli, 1997). Screen resolution was set to 800×600 pixels, making the 320×240 pixel photographs 5.4×4 inch stimuli. Participants sat at a comfortable distance from the computer screen, and head position was not fixed. The experiment was divided into four blocks, each containing 48 trials. Each trial consisted of a rapid serial presentation of 17 images in the center of the screen, with each image appearing for 100 ms before immediately being replaced by the next. Depending on the trial, the distractor appeared at the fourth or sixth serial position, and the target (a single, rotated image) appeared either two positions or eight positions later (Lag 2 and Lag 8, respectively). On each trial, participants were instructed to indicate the target's orientation via keypress as soon as they saw it. If the participant answered correctly, they heard a beep at the end of the trial, but no sound accompanied incorrect responses. The next trial began 1 s after the end of each stream (or 1 s after participants' responses when made after the stream ended).

Before starting the experiment, participants were shown examples of emotional and neutral images and engaged in a short 12-trial practice session, with RSVP rates starting at 200 ms and increasing to the experiment presentation rate of 100 ms. The practice session did not include distractors. Participants were debriefed at the end of the experiment.

Results and Discussion

Data from 1 female participant were excluded from analyses because of below-chance accuracy.

Percentage accuracy in reporting the target orientation served as the primary measure of interest (see Figure 1). An overall 3 (Distractor Type: negative, neutral, scrambled) $\times$ 2 (Lag 2 vs. Lag 8) within-subjects analysis of variance (ANOVA) revealed a significant main effect of Distractor Type, $F(2, 40) = 8.121$, $p = .002$, a main effect of Lag, $F(1, 20) = 7.59$, $p = .012$, and a Distractor Type $\times$ Lag interaction, $F(2, 40) = 12.52$, $p < .001$. At Lag 2, there was a significant effect of Distractor Type, $F(2, 40) = 15.85$, $p < .001$, with participants performing worse following negative distractors ($M = 75.1\%$, $SD = 8.1\%$) than following neutral distractors ($M = 84.8\%$, $SD = 12.5\%$), $t(20) = 3.40$, $p = .003$, or scrambled distractors ($M = 88.7\%$, $SD = 10.3\%$), $t(20) = 5.77$, $p < .001$. Performance did not significantly differ following neutral versus scrambled distractors at Lag 2, $t(20) = 1.76$, $p =$

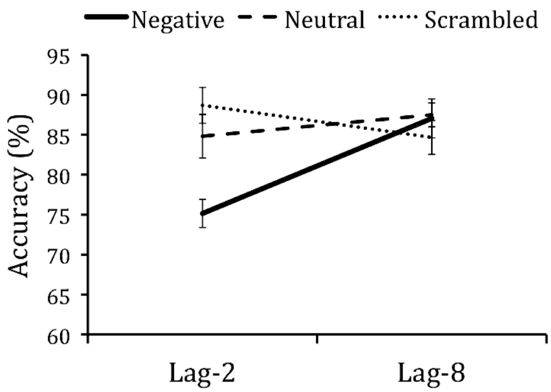

Figure 1. Average percentage of accuracies for target detection when presented two images (Lag-2) or eight images (Lag-8) after negative, neutral, or scrambled distractors. Error bars represent standard error.

.094. At Lag 8, there was no difference in accuracy between distractor types (negative: $M = 87.1\%$, $SD = 11.1\%$; neutral: $M = 87.5\%$, $SD = 6.8\%$; scrambled: $M = 84.7\%$, $SD = 9.7\%$), $F(2, 40) = 1.268$, $p = .292$, suggesting that the emotion-induced impairment had disappeared by the later lag.

Thus, emotion-induced blindness was observed when participants were instructed to respond immediately after seeing the target. Notably, on average across correct trials, participants responded to the target 678 ms after the offset of the target ($SD = 192$ ms). This suggests that in some trials, participants likely responded after the end of the stream (but also note that because participants had a 50% chance of answering correctly when failing to detect the target, the average response time in the current experiment is likely inflated by trials in which participants simply guessed after the fact). Although this average response time is comparable to participants' response times in studies involving speeded responses to targets that appear soon after an emotional stimulus (e.g., MacLeod, Mathews, & Tata, 1986), it remains debatable whether the results of Experiment 1 were influenced by participants' sometimes waiting until the end of the stream to make their response.

In order to directly test whether a delay in responding altered the impact of emotional distractors on target perception, we conducted a second experiment in which participants were instructed to make half of their responses immediately after awareness of the target and the other half of responses after the entire stream ended. We also extended the length of the streams in order to make it easier to respond before the stream ended.

Experiment 2

Method

Participants. Twenty-nine University of Delaware undergraduates (mean age 18.7 years; 16 women, 13 men) participated for course credit. All participants provided informed consent, and the experiment was approved by the University of Delaware Human Subjects Review Board.

Materials and procedure. The materials and procedure were the same as Experiment 1 with a few, notable exceptions. In two of the four blocks of 84 trials, participants were asked to make their responses as soon as they saw the target, and in the other two blocks they were asked to wait until the end of the stream before responding (the 12 practice trials always required an immediate response). The response delay was counterbalanced across subjects, such that for 14 participants, Blocks 1 and 3 required an immediate response and for 15 participants, Blocks 1 and 3 required a delayed response. Participants were instructed which type of response delay they should use at the beginning of each block. To ensure that the immediate-response condition allowed ample opportunity to respond before the end of the stream, the target was always followed by 10 filler images. Participants heard a beep immediately after making each correct response (as opposed to after the entire stream had ended, as in Experiment 1) to further encourage fast responses (when called for).

Results and Discussion

Response times indicated that participants had followed the instructions, with shorter response times after target presentation in the immediate-response condition ($M = 697$ ms, $SD = 105$ ms) than in the delayed-response condition ($M = 1672$ ms, $SD = 73$ ms), $t(28) = 46.130$, $p < .001$. In the immediate-response condition, response times were comparable to those in Experiment 1, $t(48) = 0.474$, $p = .638$, suggesting that participants had indeed initiated their responses immediately upon detecting their targets in Experiment 1.

An omnibus 3 (Distractor Type: negative, neutral, scrambled) × 2 (Lag 2 vs. Lag 8) × 2 (Response Delay: immediate vs. delayed) within-subjects ANOVA revealed a significant main effect of Distractor Type, $F(2, 56) = 43.811$, $p < .001$, Lag, $F(1, 28) = 39.442$, $p < .001$, and Response Delay, $F(1, 28) = 16.551$, $p < .001$, but no significant Distractor Type × Lag × Response Delay interaction, $F(2, 56) = 1.190$, $p = .312$ (see Figure 2). In the immediate-response condition, as in Experiment 1, participants were impaired at Lag 2 following negative distractors ($M = 75.6\%$, $SD = 10.8\%$) relative to following neutral distractors ($M = 86.7\%$, $SD = 6.7\%$), $t(28) = 5.926$, $p < .001$, and scrambled distractors ($M = 87.8\%$, $SD = 7.4\%$), $t(28) = 5.534$, $p < .001$, with no difference in performance between neutral and scrambled

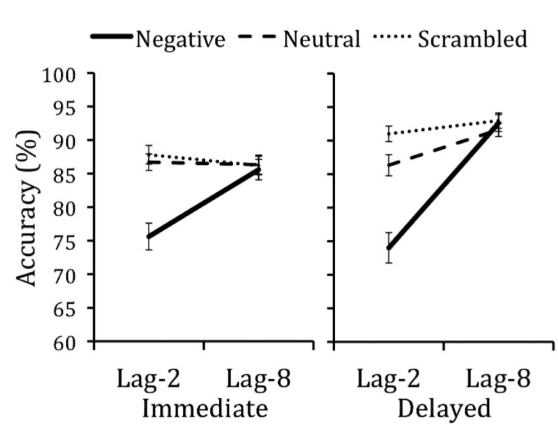

Figure 2. Average percentage of accuracies for immediate and delayed responses to targets presented two images (Lag-2) or eight images (Lag-8) after negative, neutral, or scrambled distractors. See text for details.

trials, $t(28) = 0.717$, $p = .479$. No differences among distractor types were present at Lag 8 (negative: $M = 85.6\%$, $SD = 8.2\%$; neutral: $M = 86.3\%$, $SD = 7.7\%$; scrambled: $M = 86.2\%$, $SD = 7.4\%$), $F(2, 56) = 0.132$, $p = .877$.

Furthermore, the Distractor Type × Response Delay interaction was not significant, $F(2, 56) = 0.880$, $p = .420$, indicating that distractor type made a similar impact when responding to targets after the entire stream ended as when responding immediately. Indeed, at Lag 2 in the delayed-response condition - as in the immediate response condition - performance was impaired following negative distractors ($M = 74.0\%$, $SD = 12.2\%$) relative to following neutral distractors ($M = 86.3\%$, $SD = 8.5\%$), $t(28) = 4.732$, $p < .001$, and scrambled distractors ($M = 91.0\%$, $SD = 6.2\%$), $t(28) = 6.926$, $p < .001$. In this case, performance following neutral distractors was worse than that following scrambled distractors, $t(28) = 3.109$, $p = .004$. However, by Lag 8, Distractor Type had no impact on performance (negative: $M = 92.6\%$, $SD = 6.7\%$; neutral: $M = 91.6\%$, $SD = 5.5\%$; scrambled: $M = 93\%$, $SD = 6.1\%$), $F(2, 56) = 0.426$, $p = .655$. Overall, Experiment 2 replicated the findings of Experiment 1 and demonstrated that emotion-induced blindness occurred when participants responded both immediately after seeing the target and after a delay.

General Discussion

Awareness of targets is often impaired when they appear soon after an emotionally arousing stimulus, an effect known as *emotion-induced blindness* (e.g., Most et al., 2005). Although the design of previous experiments makes it difficult to discern whether the mechanisms driving emotion-induced blindness involve disruptions to perception or to memory, due to the fact that participants were asked to withhold their target responses until the end of each stream, our current data reveal that emotion-induced blindness occurs when participants are asked to respond immediately to a target. This supports the notion that emotional distractors disrupt processes involved in conscious perception over and beyond disruptions to encoding and maintenance in working memory.

Of course, it is important to note that the line separating perception and memory is a fuzzy one. Conscious perception unfolds via a complex coordination of processes, some of which occur early in the stream of visual information processing and some of which occur quite late. For example, the attentional blink (AB)—which appears to be phenomenologically related to emotion-induced blindness—has been posited to reflect relatively "central," late-stage bottlenecks in information processing (Chun & Potter, 1995; Di Lollo, Kawahara, Ghorashi, & Enns, 2005; Raymond, Shapiro, & Arnell, 1992). According to an influential two-stage model of the AB, all stimuli in the streams are registered during a first, rapid "detection" phase but then must receive additional, more elaborate processing during a slower, serial "consolidation" phase to be available for conscious report (Chun & Potter, 1995). If the second target appears very soon after the first target, consolidation of it is delayed until after the first target is consolidated, and its representation can decay or be overwritten without ever reaching reportable awareness. Note that such theoretical accounts suggest that memory processes play an integral role in the very construction of conscious perception. The current data do not rule out the possibility that emotional stimuli disrupt such "micromemorial" mechanisms (although see Most & Wang, 2011, for evidence against such an account); but they do suggest that emotion-induced blindness does not simply reflect disruption of working memory once a target has been consciously perceived.

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