

An Emotion-Induced Attentional Blink Elicited by Aversively Conditioned Stimuli

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The current study examines whether aversively conditioned stimuli can modulate attention to such a degree that they impair the perception of subsequently presented nonemotional targets. In the initial phase of this study, participants viewed 3 categories of photographs, 1 of which was paired with an aversive noise. Following conditioning, participants searched for a target embedded within a series of 17 rapidly presented images on each trial. Critically, a conditioned or unconditioned item from the initial phase appeared 200 ms or 800 ms before the target. At 200-ms lags but not 800-ms lags, the conditioned images impaired target detection relative to the other distractors. Thus, temporary visual deficits can be induced by otherwise neutral distractors whose aversive associations have only recently been learned.

Keywords: arousal, attentional blink, conditioning, emotion, emotion-induced blindness

Emotional stimuli attract attention (e.g., Anderson, 2005; Pessoa, Kastner, & Ungerleider, 2002), thereby increasing the likelihood that the emotional information will be used for goal-directed behaviors. The emotional salience of many of the stimuli used to assess the emotional modulation of attention may be interpreted as being evolutionarily important, in that they often involve images of threatening animals such as snakes and spiders (Öhman, Flykt, & Esteves, 2001) or threatening facial expressions (Öhman, Lundqvist, & Esteves, 2001). However, not all emotional responses are innate. For example, behavioral responses to conditioned stimuli, or pairings of a previously neutral stimulus with an aversive outcome, are a critical component of several theories of emotion (e.g., LeDoux, 2000). Learned associations between stimuli and consequences allow individuals to anticipate future outcomes so as to avoid aversive events and maximize rewards. Therefore, conditioned stimuli quickly become more important than items not associated with an emotional outcome. Surprisingly little research has examined whether this increase in importance translates into an attentional advantage for these items. This article addresses this issue by assessing not only whether conditioned images capture attention more than images not paired with an emotional outcome, but also whether they are prioritized to such a degree that they spontaneously impair the perception of less emotionally relevant information.

The few studies that have examined the influence of conditioned stimuli on attentional processes have tended to focus on the modulation of spatial attention. For example, Koster, Crombez, Van Damme, Verschuere, and De Houwer (2004, 2005) examined whether stimuli that had been paired with an aversive noise would influence spatial attention in an exogenous-cueing paradigm. In this task, a cue was presented for 200 ms before the appearance of a target; the cue was displayed in the same location as the target on 75% of the trials (valid cues) and in the opposite location on 25% of the trials (invalid cues). Koster and colleagues found that for valid cues, the conditioned stimuli captured attention 6 ms faster than did the neutral stimuli. Conditioned stimuli also held attention, as the reaction times on invalid trials were 12 ms longer for conditioned stimuli than for nonconditioned stimuli. Although these effects are quite small, they are replicable and demonstrate that learned associations between a stimulus and an aversive outcome can influence spatial attention (see also Beaver, Mogg, & Bradley, 2005; Stormark & Hugdahl, 1997; Van Damme et al., 2004). These findings were complemented by a recent neuroimaging study investigating attentional orienting to conditioned stimuli (Armony & Dolan, 2002) in which a target stimulus was located more quickly when it was presented in the same location as the conditioned stimuli; this effect also correlated with bilateral activations of the inferior occipital gyri, fusiform gyri, and amygdala. Thus, there is both behavioral and neuroimaging evidence to suggest that conditioned stimuli influence the orienting of attention.

A recent article by Richards and Blanchette (2004) demonstrated that not only can conditioned stimuli enhance normal orienting of spatial attention, but they can also interfere with nonspatial task performance. In this study, a group of words and a group of nonwords were both paired with aversive pictures. State anxious and nonanxious participants then completed an emotional Stroop task in which they stated the color of the printed words.

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High-anxious participants showed Stroop-like interference for conditioned nonwords; nonanxious participants did not show evidence of emotional modulation. These results highlight the possibility that conditioned stimuli can sometimes influence attention and disrupt task performance. However, in this paradigm, conditioning only affected responses to some stimuli (nonwords) in a subgroup of the participants (high anxious). It is possible that more robust measures might reveal such influences more generally, thus allowing a more precise determination of the degree to which conditioned stimuli modulate attention.

The current research investigates attentional capture using a modified attentional-blink paradigm (Chun & Potter, 1995; Raymond, Shapiro, & Arnell, 1992) in which participants view rapid serial visual presentations (RSVPs) of photographs (Most, Chun, Widders, & Zald, 2005). This task produces robust effects and, in contrast to tasks relying on response-time measures, demonstrates that preferential attention to emotional stimuli can detrimentally affect the perception of nonemotional targets. In addition, this paradigm has been used successfully with pictures rather than words, thus negating concerns regarding word frequencies and interparticipant vocabulary variability. This task differs from the traditional attentional-blink paradigm in that rather than responses to Target 2 being disrupted by responses to Target 1, performance of a single task is impaired if the target stimuli are presented soon after the presentation of an emotional image. The emotional image is not task relevant but impairs responses in a fashion similar to how Target 1 impairs Target 2 in the traditional attentional-blink paradigm. The goal on each trial in the current paradigm is to detect a rotated target image among a set of rapidly presented distractors. On each trial, participants respond by indicating whether the target image is rotated 90° to the left or 90° to the right. Critical distractor images are embedded within the RSVP stream appearing either 200 ms (Lag 2) or 800 ms (Lag 8) before the target. Most and colleagues (2005) found that negative arousing pictures captured and held attention, impairing participants' ability to identify which direction the target was rotated at Lag 2; emotionally neutral critical distractors led to significantly smaller impairments. By Lag 8, participants responded accurately at least 90% of the time after both emotional and neutral distractors, demonstrating that participants had recovered from the emotional distraction by this time point. Similar effects have been observed in other paradigms that used words instead of pictures as targets and distractors (Arnell, Killman, & Fijavz, 2004; Barnard, Ramponi, Battye, & Mackintosh, 2005).

The current study used this emotional attentional-blink paradigm to assess whether recently conditioned, but otherwise neutral, stimuli might also be attentionally prioritized, thus impairing the perception of nonemotional targets. In an initial conditioning phase, participants viewed images from three categories: cars, birds, and buildings/cityscapes. During conditioning, either car or bird photographs were paired with an aversive burst of white noise, a stimulus that typically elicits an automatic startle response (Vrana, Spence, & Lang, 1988). Half of the participants learned this association for car photographs, and half learned it for bird photographs. Participants then completed the emotional attentional-blink task with the cars, birds, and building/cityscape images from the conditioning task appearing as critical distractors. We predicted that aversively conditioned stimuli would preferentially capture attention, causing participants to perform worse

when the target appeared soon after conditioned, rather than non-conditioned, distractors.

Method

Participants

Sixteen undergraduate students (5 men and 11 women) participated for credit in an introductory psychology course. All participants had normal or corrected-to-normal vision. Each participant gave informed written consent, as per Vanderbilt University Institutional Review Board guidelines.

Stimuli

The visual stimuli consisted of 10-cm × 7.5-cm color photographs and included target (rotated) pictures, critical distractor images, and noncritical distractor images. Noncritical distractor stimuli were drawn from a pool of 256 upright landscape/architectural photographs. Targets were drawn from an additional pool of 192 landscape/architectural photographs that had been rotated 90° either clockwise or counterclockwise (while maintaining the same dimensions as the nonrotated images); half were rotated right and half were rotated left. There were three categories of critical distractors: birds, cars, and additional upright buildings/cityscapes. Fifty-six images in each category served as critical distractors in the analyzed RSVP categories. These same images were also presented in an initial learning phase, where—depending on the participant—either birds or cars were paired with an aversive tone (buildings/cityscapes were never paired with the tone). Finally, additional items from the conditioned category appeared as critical distractors in 24 “reinforcement” RSVP trials that were not analyzed but that were presented for reasons described below. All visual stimuli were presented on a 17-in. (43.18-cm) 75-Hz CRT monitor attached to a 2.60-GHz Pentium 4 Dell microcomputer and were viewed from a distance of approximately 40 cm.

The auditory stimuli consisted of 85-dB SPL bursts of white noise presented via headphones. During the aversive conditioning phase of the experiment, this sound was 1,000 ms in duration. During the reinforcement trials of the emotional attentional-blink task, this sound lasted 100 ms.

Procedure

Participants completed two separate tasks during the experimental session: a conditioning phase in which a subset of images was paired with an aversive noise and an emotional attentional-blink task. In the conditioning phase, participants were shown 56 images from each of three categories: cars, birds, and buildings/cityscapes. For half of the participants, all car photographs were paired with an aversive burst of white noise and bird photographs were not paired with a noise; for the other half of the participants, all bird photographs were paired with the aversive noise and car photographs were not paired with a noise. The fact that participants were counterbalanced for which set of pictures was paired with the aversive noise is important, as it means that any differences found between these conditioned and nonconditioned stimuli cannot be attributed to inherent visual attributes. Photographs of buildings/cityscapes were never associated with a noise; these items were similar to the other items in the RSVP stream and served to control for mere familiarity. Each image was presented in the center of the screen for 2,000 ms; the order of image presentation was randomized for each participant. Participants were instructed to pay equal attention to all items but to note when an item was paired with a noise. The burst of white noise was delivered either 600 ms or 1,000 ms after the image appeared on the screen and lasted 1,000 ms; therefore, the conditioned image was visible for the entire duration of the noise. The interval between trials was 2,000 ms.

After receiving verbal and written descriptions of the emotional attentional-blink paradigm, participants completed 16 practice trials. Each

trial consisted of 17 images presented in an RSVP stream for 200 ms each. This presentation speed was slower than the test speed (100 ms/image) but allowed participants to become comfortable with the paradigm. On each trial, 1 image was rotated 90° to the left or right (see Figure 1). Participants pressed the left or right arrow key to indicate the direction in which they thought the target image was rotated and were instructed to guess if they failed to detect the target. After responding, participants pressed the spacebar to initiate the next trial.

The emotional attentional-blink task involved 192 trials, divided into six blocks of 32 trials. Trials consisted of an RSVP stream of 17 images, each presented for 100 ms with no gaps in between. Participants were instructed to detect an image rotated 90° to the left or right and to respond by pressing the left or right arrow key. The target photograph was always a landscape or a building; participants were specifically told that the target items would not be birds or cars, but that these images might sometimes appear in the stream and should be ignored.

The key question in this study was whether aversively conditioned critical distractors would interfere with participants' ability to detect the rotated image more than nonconditioned distractors. Critical distractors appeared as the fourth, sixth, or eighth stimulus in the RSVP stream. The rotated image appeared as either the second item (Lag 2) or the eighth item (Lag 8) after the critical distractor. Thus, either 200 ms or 800 ms separated the appearance of the critical distractors from the appearance of the target (see Figure 1). Each trial began 1,000 ms after participants responded to the preceding trial.

One concern related to this design was that participants might quickly learn that a photograph from the conditioned category (birds or cars) was no longer paired with a noise and thus should not be thought of as aversive. To reduce the likelihood of such extinction, 24 reinforcement trials were added in which a new image from the conditioned category was paired with a 100-ms burst of white noise during the RSVP presentation. These trials were randomly interleaved throughout the study. The reinforcement trials were not included in the subsequent analyses but served only to reinforce

the association between the conditioned category of images and the aversive noise.

Results

Percentage accuracies were calculated for all trial types and lags for each participant; an accurate response consisted of correctly identifying the direction that a target image was rotated. These data were entered into a 3 (distractor type: familiar buildings/landscapes vs. nonaversively associated objects vs. conditioned objects) \times 2 (Lag 2 vs. Lag 8) repeated measures analysis of variance. There was both a main effect of lag, $F(1, 15) = 58.18$, $MSE = 0.004$, $p = .001$, and of distractor type, $F(2, 30) = 7.22$, $MSE = 0.004$, $p = .003$, as well as a Lag \times Distractor Type interaction, $F(2, 30) = 5.41$, $MSE = 0.002$, $p = .01$. Planned comparisons revealed that the main effect of lag was significant for all distractor categories (all $t_s > 4.10$, $p_s < .01$); participants were significantly less accurate at detecting the rotated image at Lag 2 than at Lag 8. The fact that both buildings/landscapes and distinct but nonaversively paired stimuli induced attentional blinks suggests that familiarity from the learning phase contributed to an attentional-blink effect, a finding consistent with earlier studies of spatial attention (Flowers, Polansky, & Kerl, 1981) and visual search (Diliberto, Altarriba, & Neill, 2000); of note, the greater distinctiveness within the stream of the nonconditioned birds or cars did not lead to a larger effect than familiarity alone. Importantly, in all cases participants were able to disengage attention by Lag 8, where mean accuracy was more than 90% for all distractor types. As can be seen in Figure 2, the main effect of distractor type appears to be driven by different accuracy levels at Lag 2. We therefore concentrate the remainder of our analyses on these data.

Planned comparisons revealed that the aversively conditioned stimuli at Lag 2 caused larger impairments than did the other distractor types. Accuracy in reporting the target image was significantly lower following conditioned critical distractors ($M = 76.6\%$, $SD = 7.5\%$) than following building/cityscape (neutral) distractors ($M = 85.3\%$, $SD = 6.9\%$); $t(15) = 3.68$, $p = .002$. Critically, accuracy was also significantly worse than when targets followed soon after familiar, nonconditioned distractors ($M = 85.3\%$, $SD = 7.4\%$); $t(15) = 3.81$, $p = .002$. This latter comparison is particularly important, as participants were counterbalanced for whether birds or cars had been paired with the white noise; therefore, this difference could not be attributed merely to differences in inherent visual characteristics. These results support our prediction that aversively conditioned stimuli not only capture attention to a greater degree than other previously viewed images, they also induce transient impairments in the perception of subsequently presented target images.

However, there is an alternative explanation for these data that is not addressed in the current experiment. It is possible that merely pairing an image with any sound, rather than with an aversive sound, will make that image more meaningful than images not paired with a sound. This increased salience might lead to an augmented attentional blink. It is also possible that the 24 extra reinforcement trials, in which a new image from the conditioned category (cars or birds) was paired with a 100-ms aversive sound during the RSVP stream of the attentional-blink task, may have made that category of images more familiar, or more salient. To test these alternative explanations, 16 new participants (8 men and

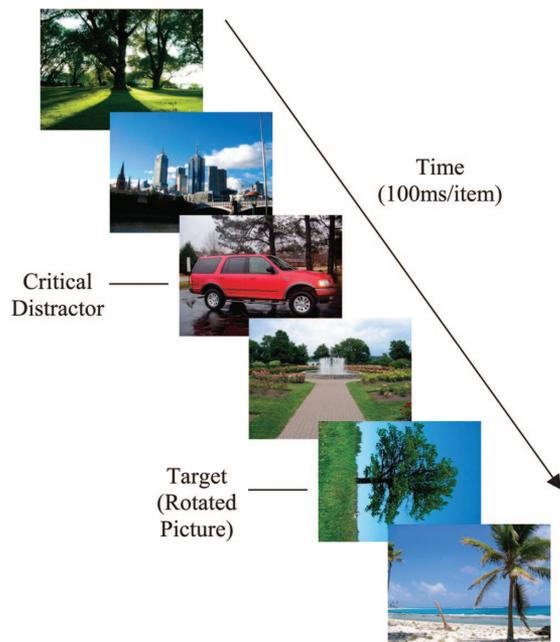


Figure 1. The trial procedure for the emotional attentional-blink paradigm (actual trial length = 17 images). Note that the critical distractor image could be a conditioned stimulus (bird or car), a nonconditioned stimulus (car or bird), or a building-landscape (neutral) image.

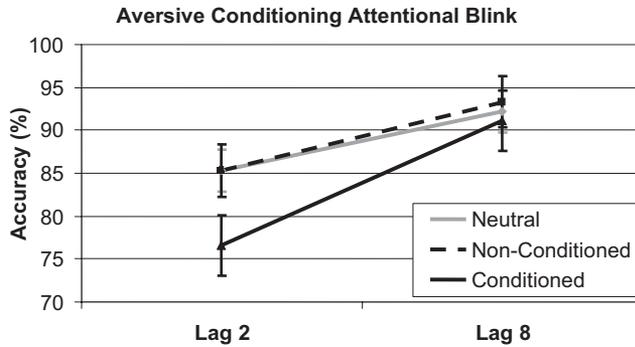


Figure 2. Accuracy scores for 16 participants conditioned with an aversive sound (an 85-dB burst of white noise). Error bars represent standard error of the mean.

8 women) participated in a follow-up control experiment identical to the main study in every way except that either birds or cars were paired with the sound of ocean waves instead of an aversive burst of white noise. The results of this control study demonstrate that aversively and nonaversively conditioned stimuli lead to different attentional effects. Whereas the Lag 2 neutral items ($M = 87.1%$, $SD = 6.4%$) and the previously viewed unconditioned images ($M = 82.8%$, $SD = 9.7%$) produced almost identical patterns of data across experiments, the nonaversively conditioned images ($M = 83.5%$, $SD = 6.0%$) were much more accurately detected than the aversively conditioned images in the main study. Specifically, in this second study, accuracy remained high following the nonaversively conditioned items and did not differ from that following nonconditioned stimuli, $t(15) = 0.30$, $p = .77$, or neutral buildings/landscapes, $t(15) = 1.51$, $p = .15$. There was also no difference between nonaversively conditioned ($M = 92.9%$), unconditioned ($M = 92.8%$), and neutral ($M = 92.4%$) conditions at Lag 8 (all t s < 1). Therefore, with the exception of the Lag 2 data for conditioned stimuli, the data are identical across the two experiments. These results suggest that the findings from the aversive-conditioning experiment were due to the emotional arousal or aversiveness of the conditioning and not to attentional effects resulting from the mere pairing of an image with a noise or to the increased familiarity caused by the reinforcement trials during the RSVP display.

Discussion

These findings demonstrate that emotionally neutral stimuli that have been paired with an aversive outcome capture attention and cause an attentional blink. This effect is not due to the mere pairing of a category of images with any sound, as nonaversive paired associations did not lead to an attentional blink. Thus, similar to inherently affective stimuli (Most et al., 2005), items merely associated with aversive stimuli may be prioritized by the attention system such that they preempt targets for which people actively search.

The incorporation of conditioning into the emotional attentional-blink paradigm also provides researchers with a useful tool to assess conditioned responses in brain-damaged patients. For example, most previous such assessments have relied on autonomic indicators such as galvanic skin responses to index the

impact of conditioned stimuli (e.g., Peper, Karcher, Wohlfarth, Reinshager, & LeDoux, 2001). However, in patients with damage to limbic areas such as the amygdala and hypothalamus, these autonomic responses are blunted, making it quite difficult to determine whether the conditioned stimuli are actually influencing the patient. The conditioned emotional blink task should allow researchers to determine whether such learned emotional associations influence attention and conscious perception in a goal-directed task, even in brain-damaged populations with autonomic impairments. This task could also be used more generally to determine whether autonomic and attentional responses to conditioned stimuli covary together or instead reflect dissociable processes.

At present, the neural substrates underlying the ability of conditioned emotional stimuli to preferentially engage attention are not clearly defined. However, given increasing evidence for a role of the amygdala in aspects of attentional modulation (Anderson & Phelps, 2001; Morris et al., 1998) and the substantial data implicating the amygdala in aversive conditioning (e.g., LeDoux, 2000), it seems reasonable to speculate that the amygdala plays a critical role in this process. There is also evidence linking amygdala activity to the emotional attentional-blink paradigm. Most, Chun, Johnson, and Kiehl (2006) have reported that changes in amygdala activity correlate with changes in emotion-induced attentional-blink susceptibility under different attentional conditions. Specifically, the degree to which adopting a specific attention set (e.g., looking only for a building) led to improved accuracy following an emotional distractor correlated with the degree to which doing so decreased hemodynamic responses in the left amygdala. This finding suggests a link between the amygdala and the emotional modulation of attention in this paradigm, but it is currently unclear whether this neural structure is directly involved in the prioritization of emotional stimuli or if changes in its activation are consequences of processes elsewhere in the brain. Future studies involving patients with amygdala lesions will be informative for resolving these issues.

The fact that learned emotional associations can modulate attention also has important implications for the study of anxiety and anxiety disorders. The role of fear conditioning has figured prominently in behavioral (and neurobehavioral) models of anxiety disorders (Lang, Davis, & Öhman, 2000). Studies of patients with anxiety disorders have often highlighted attentional biases to threatening stimuli. For instance, individuals with anxiety disorders allocate more attentional resources toward the detection of potentially threatening stimuli than do nonanxious individuals (Arend & Botella, 2002; Williams, Mathews, & MacLeod, 1996). This vigilance extends to early feature detectors that quickly analyze stimuli to determine if they exhibit characteristics consistent with stimuli that have proven to be threatening in the past (Öhman, 1993). However, the vast majority of the human studies of attentional biases in anxiety disorders have focused on responses to inherently fearful stimuli or to items that are related to an individual's particular anxiety. Relatively little research has examined whether these attentional biases extend to conditioned stimuli or whether such individuals show differential rates of acquisition or extinction of such conditioned attentional responses. The development of paradigms capable of examining such conditioning and extinction processes takes on particular importance in the face of models of anxiety disorders that emphasize hypercon-

ditionability or resistance to extinction as core factors in the vulnerability to the development of specific anxiety disorders (Orr et al., 2000; Pitman, Shin, & Rauch, 2001).

The current paradigm is notable in that it involved a whole class of stimuli rather than a repeated pairing of a single conditioned stimulus with a nonconditioned stimulus. Thus, the response was relatively generalized. In this study, we did not specifically test whether similar attentional effects extended to novel instances belonging to the conditioned category. Given the generalizable nature of most phobias, one might predict that conditioned attentional blinks will extend beyond the specific stimuli used in a given learning phase. Moreover, one might predict that patients with phobias will show greater generalization to other stimuli of the same class than will healthy individuals. Thus, we believe that the conditioned attentional-blink paradigm may prove useful for studying core features related to the development and expression of anxiety disorders.

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