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Flexible Attention Deployment in Threatening Contexts: An Instructed Fear Conditioning Study

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Abstract

Factors leading humans to shift attention away from danger cues remain poorly understood. Two laboratory experiments reported here show that context interacts with learning experiences to shape attention avoidance of mild danger cues. The first experiment exposed 18 participants to contextual threat of electric shock. Attention allocation to mild danger cues was then assessed with the dot-probe task. Results showed that contextual threat caused subjects to avert attention from danger cues. In the second experiment, 36 participants were conditioned to the same contextual threat used in Experiment 1. These subjects then were randomly assigned to either an experimental group, trained to shift attention toward danger cues, or a placebo group exposed to the same stimuli without the training component. As in Experiment 1, contextual threat again caused attention allocation away from danger in the control group. However, this did not occur in the experimental group. These experiments show that acute contextual threat and learning experiences interact to shape the deployment of attention away from danger cues.

Keywords

Attention bias; acute stress; instructed fear conditioning; attention training

Organisms benefit when they can prioritize cues for cognitive processing, based on the relative level of threat conveyed by these cues. For example, when faced with an immediately present, extreme threat, healthy organisms attend to danger cues (LeDoux, 1995). In contrast, immediately present cues signaling less extreme threats only elicit vigilance in anxious but not in nonanxious individuals (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van Ijzendoorn, 2007; Hakamata et al., 2010; Mogg & Bradley, 1998).

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Immediately present threat cues also are processed differently depending upon the particular environments in which they appear. This presumably reflects the fact that such cues convey vastly different meanings and associations, depending on the broader context in which they appear. For instance, subtle signs of danger are processed quite differently when they are encountered in a dark alley or an active battle field, as opposed to in a lecture hall or a pleasant meadow. Indeed, context has been shown to modulate attention to different types of signs of danger; in threatening environments humans exhibit attention avoidance to mild danger cues, which are typically not avoided in less threatening environments (Amir et al., 1996; Garner, Mogg, & Bradley, 2006; Helfinstein, White, Bar-Haim, & Fox, 2008; Mansell, Clark, Ehlers, & Chen, 1999). Such avoidance occurs in veterans exposed to trauma reminders (Constans, McCloskey, Vasterling, Brailey, & Mathews, 2004), soldiers undergoing combat simulation (Wald, Lubin et al., 2011), and civilians exposed to rocket attacks (Bar-Haim et al., 2010). Thus, threatening contexts modulate attention to danger cues. If such modulation could be shown to occur in a phasic fashion that is shaped by experience, this context-dependent modulation of attention orienting could offer a unique window into studying the plasticity of threat–attention interaction and its role in facilitating adaptation to threat.

Without question, data collected during real-life stress possess considerable ecological validity. Nevertheless, such data cannot causally link a stressful environmental context to changes in attention, due to the absence of tight experimental control. The current studies used an experimental approach to examine the effects of contextual threat on attention avoidance of mild threat cues. Using an instructed fear conditioning paradigm, healthy young adults were conditioned to safe and danger contexts (conditional stimulus (CS– and CS+) that were signaled by two different-color lights (orange and green) projected from bulbs in a dark room, thus creating a surround-color context. Participants were explicitly told that they may or may not receive an electric shock in the CS+ context and that they will never receive a shock in the CS– context. Following a conditioning phase, participants performed the dot-probe attention bias task (MacLeod, Mathews, & Tata, 1986) while exposed to dangerous or safe contextual cues. In the dot-probe task, two word cues, one being a danger cue (e.g., DEAD) and the other being neutral (e.g., DATA) were shown briefly in each trial, and their removal was followed by a small probe in the location previously occupied by one of the words. Participants were required to respond as quickly as possible to the probe without compromising accuracy. Attention bias toward threat manifests when participants are faster to respond to probes that appear at the locations previously occupied by threat cues relative to neutral cues. The opposite pattern indicates threat avoidance.

So-called “bottom-up-capture” processes that regulate attention in the dot-probe task are deployed implicitly. As a result, these processes might most effectively be altered through implicit training, as in Attention Bias Modification (ABM) training. ABM uses the dot-probe task as a clinical tool; clinical trials reveal a moderately beneficial effect on anxiety (Eldar et al., 2011; Hakamata et al., 2010). During training, target location is systematically manipulated so that the proportion of targets appearing either behind neutral or threat-related stimuli varies in the experimental and control condition. Participants are not told of these contingencies and typically cannot report on the nature of learning that occurs with training. It is assumed that implicitly attending to task contingencies affects task performance. Through this process, successive exposure in the experimental condition to multiple training trials is thought to gradually and implicitly shape a bias toward cues appearing in the trained direction.

Prior studies using context fear conditioning as a model paradigm with rodents demonstrated that the amygdala is critical for the acquisition, storage, and expression of a conditioned fear

response (Phelps, 2006). In humans, prior studies of fear conditioning also are consistent with these animal models. Research using fMRI has reported increased BOLD signal in the amygdala in response to threat versus neutral stimuli (Buchel, Morris, Dolan, & Friston, 1998). Similarly, it has been demonstrated that even in an instructed fear paradigm, where people are specifically told the learning rule, the presentation of a threat stimulus relative to neutral stimulus resulted in activation of the amygdala (Phelps et al., 2001).

Previous research has combined fear conditioning with the dot-probe or similar attention tasks to quantify the degree to which conditioning alters attention capture and disengagement (Koster, Crombez, Van Damme, Verschuere, & De Houwer, 2004; Notebaert, Crombez, Van Damme, De Houwer, & Theeuwes, 2011; Van Damme, Crombez, & Notebaert, 2008). These studies used classical conditioning to imbue cues with greater threat potency than is typical of cues in most attention tasks, which often rely on mildly aversive threat words. Such conditioning studies show that aversively conditioned cues readily capture attention. However, contrary to these prior studies, where participants are conditioned using the same cues employed in a later attention-capture task, the current study uses instructed fear conditioning to create an aversive context. The dot-probe task is performed in this aversive context, using cues that otherwise are in no way part of the fear conditioning experiment.

In the instructed fear conditioning paradigm used here, participants become aware of the CS-UCS association before they directly experience CS-UCS pairings. The CS is treated as a threat based on the participant's awareness of the CS-UCS contingency, thereby eliciting a fear response with the first CS exposure. In instructed fear paradigms, the CS+ and the CS- are less ambiguous since participants know that the UCS could be delivered only in the presence of the CS+ and not in the presence of the CS-, resulting in a greater difference between the threat and the safe cues (Grillon, Baas, Lissek, Smith, & Milstein, 2004; Grillon et al., 2008; Grillon & Morgan, 1999). In addition, with this instructed fear paradigm, between-groups differences in levels of conditioning that could derive from learning and memory are minimized. This argument is supported by results from a recent meta-analysis showing that instructed fear more powerfully activates key brain regions than uninstructed fear conditioning (Mechias, Etkin, & Kalisch, 2010). This argument receives additional support from Grillon, Baas, Cornwell, and Johnson (2006) and Grillon, Levenson, and Pine (2007), who show greater physiological responding to instructed than uninstructed conditioning paradigms.

Based on field studies of dangerous contexts (Bar-Haim et al., 2010; Wald, Lubin et al., 2011; Wald, Shechner et al., 2011), we expected nonanxious adults participating in the current study to exhibit attentional avoidance of threat cues in the conditioned dangerous context; we also expected participants to be capable of overriding this attentional response following attention training. To test these hypotheses, two laboratory experiments were designed. In the first experiment, participants were conditioned to safe and danger contextual cues and were tested for differences in their attention pattern using the dot-probe task. We hypothesized that participants would exhibit attention patterns away from threat during dangerous contexts and attention patterns toward threat in the safe contexts. In the second experiment, participants were conditioned to the same contextual threat and were then randomly assigned to one of two training groups: an experimental group trained to shift their attention reflexively toward danger cues and a control group with placebo training. We expected to replicate the results from Experiment 1, with contextual threat again causing allocation of attention away from danger cues. However, in Experiment 2, we expected training to modulate this tendency, such that avoidance would manifest only in the control but not in the experimental group trained to shift attention toward danger cues.

Experiment 1

The first experiment exposed participants to an acute, contextual threat, in the form of an electric shock, during which time attention allocation to mild danger cues was assessed with the dot-probe task.

Method

Participants

The sample consisted of 18 undergraduate psychology students (9 females), ranging in age from 20 to 28 years ($M = 24.00$, $SD = 2.03$), who received course credit for participation. Participants with self-reported history of anxiety disorder were excluded from the experiment. The experiment was approved by the Institutional Ethics Committee and written informed consent was obtained from all participants prior to study commencement.

Materials

Threat-bias assessment: The dot-probe task—Threat-related attention patterns were evaluated using a word-based dot-probe task (Bar-Haim et al., 2010; Wald, Lubin et al., 2011; Wald, Shechner et al., 2011). Stimuli were 36 threat/neutral word pairs. The task consisted of 144 trials in which threat/neutral word pairs were presented in a random order. The sequence of events on a dot-probe trial is presented in Figure 1. Each trial began with a centrally presented fixation display “+++” (500 ms), immediately followed by a vertically aligned word pair written in 1-cm-high white block text (1,000 ms). One word appeared directly above, while the other appeared directly below, the location vacated by the preceding fixation signal. The word pair was then replaced by a target probe that appeared in either of the two locations vacated by the words. Probe type was either a pair of dots or a single dot, and this was determined randomly on each trial. Participants were required to identify which of the two probe types appeared by pressing the corresponding key as quickly as possible without compromising accuracy. The target remained on the screen until response or until 1,000 ms had elapsed. A blank screen intertribal interval (ITI) of 500 ms followed. If the participant responded faster than 1,000 ms, the time remaining to the 1,000 ms mark was added to the ITI. Thus, each trial was 3,000 ms long. Stimuli were displayed in full screen on a 15” laptop monitor approximately 60 cm in front of the participant. Trials with incorrect response, and trials in which response time was ± 2 standard deviations of the participant’s mean for a particular condition, were excluded from subsequent analyses. Threat bias was calculated as the difference between average response time to targets at neutral word locations and those at threat word locations. Thus, positive bias values represent attention bias toward threat whereas negative bias values reflect an attentional bias away from threat.

Context conditioning—The unconditioned stimulus (UCS) was an unpleasant but tolerable electrical stimulation to the wrist (0.5-s train of square pulses, 20 ms per pulse, delivered at 20 c/s). In a precalibration phase, each participant determined the level of UCS stimulation that is “unpleasant but still tolerable.” The conditioned stimuli (CSs) were two different-color lights (orange and green) projected from light bulbs in a dark room, thus creating a surround-color context. During acquisition, CSs were presented for epochs of 12, 36, or 108 seconds in a pseudorandom order. The acquisition phase consisted of 6 CS+ epochs (4 of which were paired with shocks), and 6 CS− blocks, which were never paired with a shock. Shocks were delivered in unpredictable time points within the time frame of the CS+ (Grillon et al., 2006). Number of shocks delivered within a CS+ block ranged from 0 to 3.

Participants were explicitly told that they may or may not receive an electric shock when the CS+ was on and that they will never receive a shock when the CS- is on (Figure 2a). Shock electrodes remained attached to the participants' wrist throughout all subsequent phases of the experiment.

Distress measurement—Distress was measured by both skin conductance response and self-report. Skin Conductance Response (SCR) indexed conditioning and was measured using the Prorelax (version 5.1) computer program (Mindlife, Israel). Two electrodes were placed on the index and middle fingers of the left hand. Velcro straps prevented electrode movement. Skin conductance response waveforms were analyzed offline. The level of SCR response was determined as the base-to-peak difference for the first waveform (in microsiemens, μ s) occurring in the time window of 0.5–10 seconds after stimulus onset.

In addition, participants reported the degree of distress they felt during the CS+ and CS- blocks on a scale ranging from 1 (*not stressful at all*) to 5 (*very stressful*).

Procedure

Using a within-subject design, the experiment consisted of two sessions. In the first session, baseline measure of attention bias was collected. The second session, 72 hours later, consisted of three phases: first, participants calibrated their subjective shock level; second, the acquisition phase, in which participants learned the safe (CS-) and danger (CS+) context signals; and third, the experiment phase, during which attention bias was measured again with changing background contexts (CS+ and CS-). Figure 2 depicts the sequence of events in the acquisition phase and the experiment phase as well as the conditioned context. The experiment phase consisted of six subblocks. In the first block (108 seconds, CS+) two shocks were delivered (12 and 90 seconds into the block), dot-probe performance during this block was not included in the analysis. The second and third blocks were CS- and CS+, during which no shocks were delivered. To counter potential extinction, a 12-seconds CS+ block followed during which an additional shock was delivered. Then two additional blocks of CS- and a CS+ followed during which no shocks were delivered. Thus, threat-related bias was recorded during two blocks of CS- and two blocks of CS+, during which no shocks were delivered. Electrical shocks were delivered to the left wrist while participants were using the right index and middle fingers to respond in the dot-probe task. To avoid any possible confound between the motor response and the electrical shock, the data from the first block were not analyzed. Also, similar to other dot-probe studies, the first block was considered as a practice block, allowing the examination of performance after at least some level of practice had occurred.

Results and Discussion

Instructed Fear Conditioning Enhances SCR and Self-Reported Distress

SCR amplitude during presentation of the CS+ was higher than SCR amplitude during the CS-, $F(1, 15) = 32.26, p < .001$, partial $\eta^2 = 0.71$ (Figure 3a). Participants also reported higher distress during the CS+ than during the CS-, $F(1, 17) = 236.66, p < .001$, partial $\eta^2 = 0.93$ (Figure 3b). Thus, conditioning generated more arousal in the threatening than the safe context.

Stress-Related Modulation of Attentional Threat Bias

A preliminary analysis revealed no block order effect, therefore results were averaged across the two blocks to increase power by reducing variability. In addition, accuracy rates for the tested conditions were high (above 90%) without speed-accuracy trade-offs. Repeated measures ANOVA with three within-subject conditions (baseline, CS-, CS+) revealed a

significant difference in threat-related attention between conditions, $F(2, 34) = 12.61$, $p < .001$, partial $\eta^2 = 0.43$. Mean reaction times are presented in Table 1. Post hoc contrasts on threat bias scores revealed no differences between the baseline and the CS– conditions, $p > .20$, which were both significantly higher than during the CS+ condition, $ps < 0.005$. Thus, contextual danger produced avoidance of mild threat cues (Figure 3c). Furthermore, attention bias scores for the baseline and CS– conditions did not differ from zero (i.e., no bias), $ps > 0.20$, but, in the CS+ condition participants' attention was directed away from threats, $t(17) = -3.98$, $p < .01$.

These results indicate that attention is directed away from mild danger cues when individuals are exposed to threatening contexts, experimental data that confirm and extend prior field studies (Bar-Haim et al., 2010; Wald, Shechner et al., 2011). The controlled experimental design used here constitute an important validation of these previously reported results of field studies in which the extreme contexts under which data were collected did not allow tight control of variation in threat levels, threat types, and physical setting.

Experiment 2 was designed to extend Experiment 1 in a second group of participants. Considerable work demonstrates plasticity in human attention, and prolonged training has been shown to alter reflexive deployment of attention to mild threat cues, with associated changes in emotional responding (Eldar, Ricon, & Bar-Haim, 2008; Hakamata et al., 2010; MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002). Thus, in a second experiment, we tested whether such active modification of participants' attention patterns attenuates contextually elicited threat avoidance.

Experiment 2

Prior work using attention training regimens demonstrated plasticity in the deployment of attention. If such training regimens could influence the tendency to avoid mild danger cues presented in threatening contexts, this work might inform attempts to understand healthy and maladaptive responding to threat. Extreme levels of threat avoidance under threat predict emotional problems (Bar-Haim et al., 2010; Wald, Shechner et al., 2011). If training procedures could modify threat-related avoidance of danger cues, such learning or training of attention could provide further evidence for the causal link between contextual danger and attentional threat avoidance. Experiment 2 was designed to extend findings from Experiment 1 by demonstrating plasticity in context-elicited attentional avoidance, through Attention Bias Modification (ABM) training. We expected that a systematic training of participants to attend toward threat would counter their reflexive tendency to avoid threats under acute stress (CS+).

Method

Participants

The sample consisted of 36 undergraduate students, ranging in age from 21 to 26 years ($M = 22.86$, $SD = 1.38$), who participated in the experiment for course credit. No participant from Experiment 1 also participated in Experiment 2. Participants were randomly assigned to either an attention bias modification (ABM) group (14 females, 5 males), or a control group (14 females, 3 males). Participants who self-reported a history of anxiety disorder were excluded from the experiment. The experiment was approved by the Institutional Ethics Committee and written informed consent was obtained from all participants prior to experiment commencement.

Materials

Threat-bias assessment: The dot-probe task—The same dot-probe task and same analytic procedures used in Experiment 1 were used in the current experiment.

Attention bias modification (ABM)—In ABM protocols, target location on the dot-probe task is systematically manipulated to increase the proportion of targets appearing at the location where attention is to be trained (Bar-Haim, 2010; MacLeod, Koster, & Fox, 2009). The same dot-probe parameters utilized in Experiment 1 were used for the attention training phase of Experiment 2 (ABM and control) with the following modifications. In the ABM condition, target location was manipulated such that the probe appeared at the location previously occupied by the threat word in 100% of the trials. Thus, a learned bias toward threat was gradually induced with a repetition of 456 trials comprising the training phase. In the control group, participants were presented with the same stimuli as in the ABM condition except that targets appeared at the locations previously occupied by the threat and the neutral words with equal probability; that is, no attempt was made to modify the participants' attention patterns. To examine generalization of training, two different sets of stimuli were utilized for training (set B) and for threat bias baseline and final measurements (set A).

Context conditioning and distress measurement—Procedures were identical to Experiment 1.

Procedure

Procedures were identical to those of Experiment 1 with three exceptions: a) we counterbalanced color-context pairings for the CS+ and CS− conditions; b) we conducted the experiment over two consecutive days. In Day 1, baseline dot-probe performance, instructed context fear conditioning, and ABM were conducted. Dot-probe performance data under threat were collected in Day 2; and c) following conditioning, participants were randomly assigned to either ABM or placebo-control training (see Figure 4). Thus, following instructed context fear conditioning and before the collection of dot-probe data, half of the participants were randomly assigned to an attention-training condition (ABM group) and half were assigned to a placebo condition. We expected to detect context-associated threat-cue avoidance, as observed in Experiment 1, in the control group but not in the ABM group.

Results and Discussion

Instructed Fear Conditioning Enhances SCR and Self-Reported Stress

As in Experiment 1 conditioning generated more arousal in the dangerous than the safe context. SCR amplitude during presentation of the CS+ was higher than SCR amplitude during CS−, $F(1, 28) = 35.07$, $p < .01$, partial $\eta^2 = 0.56$ (Figure 5a), and participants self-reported higher distress during the CS+ condition than during the CS− condition, $F(1, 35) = 562.26$, $p < .001$, partial $\eta^2 = 0.94$ (Figure 5b).

Stress-Related Modulation of Attentional Threat Bias

As in Experiment 1, no block order effect was found and, therefore, results were averaged across the two blocks to increase power by reducing variability. In addition, accuracy rates for the tested conditions were high (above 90%) without speed–accuracy trade-offs. Repeated measures ANOVA with Group (ABM, control) as a between-subjects factor and Context Condition (Baseline, CS+, CS−) as a within-subject factor revealed a significant Group-by-Context interaction, $F(2, 68) = 4.09$, $p < .02$, partial $\eta^2 = 0.11$ (Figure 5c). Mean

reaction times are presented in Table 2. Post hoc contrasts indicated no group differences for the baseline and CS– conditions, $p_s > 0.27$, and a significant difference in the CS+ condition, $t(34) = 3.38$, $p = .006$. As expected, participants in the control group avoided mild threat cues during contextual danger. For participants in the ABM group, contextual danger did not influence attention to threat cues.

For the control group, threat bias did not differ from zero in the baseline and CS– conditions, $p_s > 0.15$, but bias was significantly suppressed relative to zero in the CS+ condition, $t(16) = -2.62$, $p < .02$, replicating the results of Experiment 1. Contrasts in the ABM group indicate that threat bias did not differ from zero in the baseline, CS–, and CS+ conditions, all $p_s > 0.05$.

These results partially replicate findings from Experiment 1. Despite a significant bias suppression during CS+ in the Experiment 2 control group, suppression in Experiment 2 is approximately half the magnitude of that observed in Experiment 1. It is conceivable that the introduction of a 1-day lag between the instructed context fear conditioning and threat bias measurement in Experiment 2 reduced the effect relative to Experiment 1, in which these procedures were conducted in closer temporal proximity. Nevertheless, the present findings do show that a relatively short attention training applied before exposure to a potentially stressful context may be used to counter threat avoidance. Considering the reported association between threat avoidance and symptoms of depression and posttrauma, the latter result has both clinical and mechanism-related implications.

Summary and Concluding Discussion

Two findings emerged in the current research. First, both experiments demonstrated the capacity of contextual danger to induce threat avoidance. Previous work on attention avoidance during immediate-present threat relied on correlation methods (Bar-Haim et al., 2010; Wald, Lubin et al., 2011; Wald, Shechner et al., 2011). The current research used an instructed context fear conditioning paradigm to manipulate contextual threat and chart its effect on attention. By showing that contextual danger induces avoidance of mild threat cues, the study extends a growing literature on threat-related attention plasticity.

The second main finding demonstrated the capacity of subjects under immediately present contextually bound danger to overcome their tendency to avoid threat cues through implicit learning. Participants trained to attend to threat cues did not avoid them in threatening contexts. These data add to growing evidence on the malleability of attention biases (Hakamata et al., 2010). Specifically, unlike participants in Experiment 1 and the control participants in Experiment 2, participants randomized in Experiment 2 to receive attention training exhibited no signs of threat avoidance.

A good deal of work relying on the dot-probe task finds an attention bias toward threat cues in anxious individuals and no attention bias, either toward or away from threat cues, in nonanxious individuals (Bar-Haim et al., 2007; Shechner et al., 2011). Anxiety-related biases found in patients tend to resolve with successful treatment (Hakamata et al., 2010). This pattern contrasts with the pattern of contextually gated bias away from threat cues found in the current work. Taken together, however, prior findings in patients and the current data in healthy adult subjects suggest that threat-related attention biases are state-dependent. Specifically, in safe contexts, acutely symptomatic anxious patients attend to threat cues, whereas both healthy people and successfully treated patients, studied in this same context, ignore them. When the context becomes acutely threatening, healthy people tend to shift their attention and avoid mild threat cues.

The data reported here reveal two interacting forms of attention plasticity, elicited by two distinct situations. First, while minor threat cues do not typically capture healthy people's attention, contextual danger induces a phasic diverting of attention away from these very same cues. Thus, attention biases show context-related plasticity, acutely manifesting in a dangerous context but then equally quickly disappearing, when signs of such danger dissipate. Such phasic plasticity was evident in Experiment 1, where participants showed attention avoidance during the CS+ but not during the CS-. Second, this contextually gated form of attention is malleable as suggested by the results of Experiment 2. Here attention training eliminated attentional threat avoidance, suggesting that learning interacts with context-gated plasticity.

The adaptive advantages that accrue from attending to threats can be readily appreciated. This capacity likely facilitates more rapid coping responses in threatening contexts. Thus, how can we understand the interacting forms of attention plasticity found in the current work, elicited by danger cues, contextual threats, and attention retraining? The patterns of interactions observed in the current work are in accord with predictions from the biased competition model of attention allocation theory (Desimone & Duncan, 1995). This model suggests that cognitive resources are capacity-limited in humans, leading to stimulus prioritization in the brain, based on the outcome of a competition for capacity-limited resources. The outcome of such competition hinges on the brain's ability to suppress in a rapid and flexible manner attention-related responding. This suppression in one particular context causes neural responding to a cue to fall below the level typically manifested to this very same cue viewed in another context. This occurs when the new context signals the need to allocate cognitive resources to alternative cues currently of greater behavioral relevance. This explanation is partially supported by previous studies showing enhanced attention allocation to CS+ after fear conditioning (Koster, Crombez, Van Damme, Verschuere, & De Houwer, 2005; Koster et al., 2004). However, unlike in these prior studies, in the current study, the CS+ is not associated with an imminent cue but rather with a broader context, which likely signals a stronger threat than the dot-probe threat stimuli. As a result, one would expect this dangerous context to more powerfully capture attention than the relatively weak threat word used in the dot-probe task. However, this interpretation cannot fully account for the fact that a bias away from minor threats was observed in both studies.

Threatening contexts contain innumerable stimuli and diverse types of information, much of which is behaviorally relevant. In these situations it would be adaptive to suppress attention to minor, immediately present threat cues conveying less behaviorally relevant information than more dangerous cues, appearing in the broader context. As such, threat-related words viewed in dot-probe tasks represent one form of minor threat cue, and attention avoidance can be viewed as the effect of goal-based attention suppression. From this perspective, attention avoidance in the current studies can be viewed as analogous to attention-gated suppression of neural activity found in other studies (Rossi, Pessoa, Desimone, & Ungerleider, 2009).

Recent extensions of the biased competition model specifically implicate engagement of lateral prefrontal cortex (PFC) in suppression of responding. Typically, this effect occurs in inferior temporal cortex areas that show responding to particular stimulus features (Bishop, Duncan, Brett, & Lawrence, 2004). However, recent extensions also implicate the PFC in control of attention, through interactions with the amygdala and associated structures (Lau et al., 2011; Miller & Cohen, 2001). Thus, one would expect the attention training effects observed in the current work to arise through facilitation of lateral PFC responding to threat cues, appearing in threatening contexts. Consistent with this expectation, an attention-retraining regimen similar to the one employed in the current study has been shown to produce enhanced responding in lateral PFC (Browning, Holmes, Murphy, Goodwin, &

Harmer, 2010), and modulation in late, frontally gated event-related potentials (Eldar & Bar-Haim, 2010). Future work might extend the current work using similar imaging approaches.

The fact that the current findings emerge in healthy participants suggests that at least some forms of attention plasticity found here reflect healthy information processing. Other findings support this possibility. For example, attentional threat avoidance on the dot-probe task also has been documented in highly resilient, first-tier combat soldiers exposed to highly stressful contextual threats (Wald, Lubin et al., 2011). The presence of threat avoidance among individuals selected for their stress-hardiness suggests that attentional threat avoidance occurs among individuals who can maintain high levels of function even when they are exposed to extreme stress. Of note in the current study, no measurements of trait anxiety were taken. Hence, the categorization of participants as “healthy” merely reflects their reports on past or current psychopathology. Finally, this pattern of threat avoidance in the context of two competing stimuli, a threat and neutral stimulus, could be viewed as reflecting safety-seeking behavior. Such behavior could also serve to alleviate aversive arousal.

Nevertheless, not all forms of threat avoidance are adaptive. Participants in the available field studies who exhibited particularly extreme levels of attentional threat avoidance also showed the highest risk for mental health problems both concurrently and when followed longitudinally (Bar-Haim et al., 2010; Wald, Shechner et al., 2011). Thus, mild threat avoidance may be normative, whereas more extreme avoidance may indicate risk for stress-related problems. As such, training individuals to attend toward threats could protect them from mental health problems when they are exposed to stressful environments. Training participants toward threats might appear to be a counterintuitive procedure, given that most literature on attention biases in anxiety trains participants to avoid threat (Bar-Haim, 2010; Hakamata et al., 2010). However, most ABMT studies focus on chronically anxious patients treated under nonextreme environmental contexts, whereas ABM protocols targeting populations who are at enhanced risk for acute stress exposure (e.g., soldiers awaiting combat-deployment or civilians residing in volatile conflict areas) represent a more normative nonanxious portion of the population. Nevertheless, such suggestions remain speculative, since no work has examined the effects of attention training on clinical outcomes following real-world stress exposure. Data are needed examining such outcomes after traumatic stress in participants randomized to various threat-related attention training conditions. In summary, context interacts with learning to shape attentional threat avoidance. These findings explicate the manner in which experience and context interact to shape attention allocation toward or away from danger cues. In stressful contexts, healthy individuals tend to avoid minor threat cues, a form of naturally occurring plasticity that may have both adaptive and maladaptive health-related consequences. This naturally occurring response pattern can be altered through a form of implicit attention training that, in turn, may ultimately be shown to promote healthy stress-related adjustment.

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References

- Amir N, McNally RJ, Riemann BC, Burns J, Lorenz M, Mullen JT. Suppression of the emotional Stroop effect by increased anxiety in patients with social phobia. *Behaviour Research and Therapy*. 1996; 34:945–948.10.1016/S0005-7967(96)00054-X [PubMed: 8990547]
- Bar-Haim Y. Research review: Attention bias modification (ADM): A novel treatment for anxiety disorders. *Journal of Child Psychology and Psychiatry*. 2010; 51:859–870.10.1111/j.1469-7610.2010.02251.x [PubMed: 20456540]

- Bar-Haim Y, Holoshitz Y, Eldar S, Frenkel TI, Muller D, Charney DS, Wald I. Life-threatening danger and suppression of attention bias to threat. *The American Journal of Psychiatry*. 2010; 167:694–698.10.1176/appi.ajp.2009.09070956 [PubMed: 20395400]
- Bar-Haim Y, Lamy D, Pergamin L, Bakermans-Kranenburg MJ, van Ijzendoorn MH. Threat-related attentional bias in anxious and non anxious individuals: A meta-analytic study. *Psychological Bulletin*. 2007; 133:1–24.10.1037/0033-2909.133.1.1 [PubMed: 17201568]
- Bishop S, Duncan J, Brett M, Lawrence AD. Prefrontal cortical function and anxiety: Controlling attention to threat-related stimuli. *Nature Neuroscience*. 2004; 7:184–188.10.1038/nm1173
- Browning M, Holmes EA, Murphy SE, Goodwin GM, Harmer CJ. Lateral prefrontal cortex mediates the cognitive modification of attentional bias. *Biological Psychiatry*. 2010; 67:919–925.10.1016/j.biopsych.2009.10.031 [PubMed: 20034617]
- Buchel C, Morris J, Dolan RJ, Friston KJ. Brain systems mediating aversive conditioning: An event-related fMRI study. *Neuron*. 1998; 20:947–957.10.1016/S0896-6273(00)80476-6 [PubMed: 9620699]
- Constans JJ, McCloskey MS, Vasterling JJ, Brailey K, Mathews A. Suppression of attentional bias in PTSD. *Journal of Abnormal Psychology*. 2004; 113:315–323.10.1037/0021-843X.113.2.315 [PubMed: 15122951]
- Desimone R, Duncan J. Neural mechanisms of selective visual attention. *Annual Review of Neuroscience*. 1995; 18:193–222.10.1146/annurev.ne.18.030195.001205
- Eldar S, Apter A, Lotan D, Perez-Edgar K, Naim R, Fox NA, Bar-Haim Y. Attention bias modification treatment for pediatric anxiety disorders: A randomized control trial. *American Journal of Psychiatry*. 2011 Advance online publication. 10.1176/appi.ajp.2011.11060886
- Eldar S, Bar-Haim Y. Neural plasticity in response to attention training in anxiety. *Psychological Medicine: A Journal of Research in Psychiatry and the Allied Sciences*. 2010; 40:667–677.
- Eldar S, Ricon T, Bar-Haim Y. Plasticity in attention: Implications for stress response in children. *Behaviour Research and Therapy*. 2008; 46:450–461.10.1016/j.brat.2008.01.012 [PubMed: 18313034]
- Garner M, Mogg K, Bradley BP. Orienting and maintenance of gaze to facial expressions in social anxiety. *Journal of Abnormal Psychology*. 2006; 115:760–770.10.1037/0021-843X.115.4.760 [PubMed: 17100533]
- Grillon C, Baas JM, Cornwell B, Johnson L. Context conditioning and behavioral avoidance in a virtual reality environment: Effect of predictability. *Biological Psychiatry*. 2006; 60:752–759.10.1016/j.biopsych.2006.03.072 [PubMed: 16950216]
- Grillon C, Baas JP, Lissek S, Smith K, Milstein J. Anxious responses to predictable and unpredictable aversive events. *Behavioral Neuroscience*. 2004; 118:916–924.10.1037/0735-7044.118.5.916 [PubMed: 15506874]
- Grillon C, Levenson J, Pine DS. A single dose of the selective serotonin reuptake inhibitor citalopram exacerbates anxiety in humans: A fear-potentiated startle study. *Neuropsychopharmacology*. 2007; 32:225–231.10.1038/sj.npp.1301204 [PubMed: 16971899]
- Grillon C, Lissek S, Rabin S, McDowell D, Dvir S, Pine DS. Increased anxiety during anticipation of unpredictable but not predictable aversive stimuli as a psychophysiological marker of panic disorder. *American Journal of Psychiatry*. 2008; 165:898–904.10.1176/appi.ajp.2007.07101581 [PubMed: 18347001]
- Grillon C, Morgan CA 3rd. Fear-potentiated startle conditioning to explicit and contextual cues in Gulf War veterans with posttraumatic stress disorder. *Journal of Abnormal Psychology*. 1999; 108:134–142.10.1037/0021-843X.108.1.134 [PubMed: 10066999]
- Hakamata Y, Lissek S, Bar-Haim Y, Britton JC, Fox NA, Leibenluft E, Pine DS. Attention bias modification treatment: A meta-analysis toward the establishment of novel treatment for anxiety. *Biological Psychiatry*. 2010; 68:982–990.10.1016/j.biopsych.2010.07.021 [PubMed: 20887977]
- Helfinstein SM, White LK, Bar-Haim Y, Fox NA. Affective primes suppress attention bias to threat in socially anxious individuals. *Behaviour Research and Therapy*. 2008; 46:799–810.10.1016/j.brat.2008.03.011 [PubMed: 18472088]
- Koster EH, Crombez G, Van Damme S, Verschuere B, De Houwer J. Does imminent threat capture and hold attention? *Emotion*. 2004; 4:312–317.10.1037/1528-3542.4.3.312 [PubMed: 15456400]

- Koster EH, Crombez G, Van Damme S, Verschuere B, De Houwer J. Signals for threat modulate attentional capture and holding: Fear-conditioning and extinction during the exogenous cueing task. *Cognition & Emotion*. 2005; 19:771–780.10.1080/02699930441000418
- Lau JY, Britton JC, Nelson EE, Angold A, Ernst M, Goldwin M, Pine DS. Distinct neural signatures of threat learning in adolescents and adults. *Proceedings of the National Academy of Sciences of the United States of America*. 2011; 108:4500–4505.10.1073/pnas.1005494108 [PubMed: 21368210]
- LeDoux JE. Emotion: Clues from the brain. *Annual Review of Psychology*. 1995; 46:209–235.
- MacLeod C, Koster EH, Fox E. Whither cognitive bias modification research? Commentary on the special section articles. *Journal of Abnormal Psychology*. 2009; 118:89–99.10.1037/a0014878 [PubMed: 19222317]
- MacLeod C, Mathews A, Tata P. Attentional bias in emotional disorders. *Journal of Abnormal Psychology*. 1986; 95:15–20.10.1037/0021-843X.95.1.15 [PubMed: 3700842]
- MacLeod C, Rutherford E, Campbell L, Ebworthy G, Holker L. Selective attention and emotional vulnerability: Assessing the causal basis of their association through the experimental manipulation of attentional bias. *Journal of Abnormal Psychology*. 2002; 111:107–123.10.1037/0021-843X.111.1.107 [PubMed: 11866165]
- Mansell W, Clark DM, Ehlers A, Chen Y-P. Social anxiety and attention away from emotional faces. *Cognition and Emotion*. 1999; 13:673–690.10.1080/026999399379032
- Mechias ML, Etkin A, Kalisch R. A meta-analysis of instructed fear studies: Implications for conscious appraisal of threat. *Neuroimage*. 2010; 49:1760–1768.10.1016/j.neuroimage.2009.09.040 [PubMed: 19786103]
- Miller EK, Cohen JD. An integrative theory of prefrontal cortex function. *Annual Review of Neuroscience*. 2001; 24:167–202.10.1146/annurev.neuro.24.1.167
- Mogg K, Bradley BP. A cognitive-motivational analysis of anxiety. *Behaviour Research and Therapy*. 1998; 36:809–848.10.1016/S0005-7967(98)00063-1 [PubMed: 9701859]
- Notebaert L, Crombez G, Van Damme S, De Houwer J, Theeuwes J. Signals of threat do not capture, but prioritize, attention: A conditioning approach. *Emotion*. 2011; 11:81–89.10.1037/a0021286 [PubMed: 21401228]
- Phelps EA. Emotion and cognition: Insights from studies of the human amygdala. *Annual Review of Psychology*. 2006; 57:27–53.10.1146/annurev.psych.56.091103.070234
- Phelps EA, O'Connor KJ, Gatenby JC, Gore JC, Grillon C, Davis M. Activation of the left amygdala to a cognitive representation of fear. *Nature Neuroscience*. 2001; 4:437–441.10.1038/86110
- Rossi AF, Pessoa L, Desimone R, Ungerleider LG. The prefrontal cortex and the executive control of attention. *Experimental Brain Research*. 2009; 192:489–497.10.1007/s00221-008-1642-z
- Shechner T, Britton JC, Perez-Edgar K, Bar-Haim Y, Ernst M, Fox NA, Pine DS. Attention biases, anxiety and development: Towards or away from threats or rewards? *Depression and Anxiety*. 2011 Advance online publication. 10.1002/da.20914
- Van Damme S, Crombez G, Notebaert L. Attentional bias to threat: A perceptual accuracy approach. *Emotion*. 2008; 8:820–827.10.1037/a0014149 [PubMed: 19102593]
- Wald I, Lubin G, Holoshitz Y, Muller D, Fruchter E, Pine DS, Bar-Haim Y. Battlefield-like stress following simulated combat and suppression of attention bias to threat. *Psychology Medicine*. 2011; 41:699–707.10.1017/S0033291710002308
- Wald I, Shechner T, Bitton S, Holoshitz Y, Charney DS, Muller D, Bar-Haim Y. Attention bias away from threat during life threatening danger predicts PTSD symptoms at one-year follow-up. *Depression and Anxiety*. 2011; 28:406–411.10.1002/da.20808 [PubMed: 21381159]

Figure 1.
The dot-probe paradigm.

Figure 2. (a) Instructed fear conditioning; (b) The experimental phase; (c) Dangerous and safe contextual cues.

Figure 3. (a) SCR onset levels; (b) Self-reported anxiety levels across the experimental blocks; (c) Attention bias scores across blocks. Means and standard errors.

Figure 4.
Experiment 2 design.

Figure 5.

(a) SCR onset levels and Figure; (b) Self-reported anxiety levels across the experimental blocks; (c) Attention bias scores across blocks. Means and standard errors.

Table 1

Mean Attention Bias Scores (and Standard Deviations) for Neutral and Threat-Related Words Across Conditions in Study 1

Condition	Neutral words	Threat-related words
Baseline	437 (48)	435 (47)
CS+	426 (51)	444 (52)
CS-	433 (49)	431 (50)

Table 2

Mean Attention Bias Scores (and Standard Deviations) for Neutral and Threat-Related Words Across Conditions in Study 2

	Condition	Neutral words	Threat-related words
Control	Baseline	449 (46)	450 (49)
	CS+	398 (39)	404 (40)
	CS–	398 (44)	398 (46)
ABM	Base line	443 (38)	444 (40)
	CS+	411 (35)	407 (36)
	CS–	408 (34)	412 (39)

Note. ABM = Attention Bias Modification.