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Trait Anxiety and Perceptual Load as Determinants of Emotion Processing in a Fear Conditioning Paradigm

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The impact of trait anxiety and perceptual load on selective attention was examined in a fear conditioning paradigm. A fear-conditioned angry face (CS+), an unconditioned angry face (CS−), or an unconditioned face with a neutral or happy expression were used in distractor interference and attentional probe tasks. In Experiments 1 and 2, participants classified centrally presented letters under two conditions of perceptual load. When perceptual load was high, distractors had no effect on selective attention, even with aversive conditioning. However, when perceptual load was low, strong response interference effects for CS+ face distractors were found for low trait-anxious participants. Across both experiments, this enhanced distractor interference reversed to strong *facilitation* effects for those reporting high trait anxiety. Thus, high trait-anxious participants were faster, rather than slower, when ignoring CS+ distractors. Using an attentional probe task in Experiment 3, it was found that fear conditioning resulted in strong attentional *avoidance* in a high trait-anxious group, which contrasted with enhanced vigilance in a low trait-anxious group. These results demonstrate that the impact of fear conditioning on attention is modulated by individual variation in trait anxiety when perceptual load is low. Fear conditioning elicits an *avoidance* of threat-relevant stimuli in high trait-anxious participants.

Keywords: emotion processing, fear conditioning, anxiety, attentional bias, perceptual load

There is substantive evidence that attentional processes prioritize threat-relevant stimuli that rapidly draw attention to their own location (Anderson, 2005; Eastwood, Smilek, & Merikle, 2003; Fox, Russo, Bowles, & Dutton, 2000), and this is particularly so in high trait-anxious individuals (e.g., Beaver, Mogg, & Bradley, 2005; Fox, Derakshan, & Shoker, 2008; Lundqvist & Ohman, 2005; Mogg & Bradley, 2005). However, the notion that emotionally arousing stimuli can be processed *before* the operation of selective attention remains controversial (Pessoa, 2005; Vuilleumier, Armony, Driver, & Dolan, 2001), even for those reporting high levels of trait-anxiety (Fox, Russo, & Georgiou, 2005).

Some studies suggest that preferential processing of emotional stimuli may be "automatic" requiring few attentive resources (e.g., Dolan & Vuilleumier, 2003). Enhanced amygdala activation in response to fear arousing facial expressions presented under conditions of inattention supports this hypothesis (Anderson, Christoff, Panitz, De Rosa, & Gabrieli, 2003; Bishop, Duncan, & Lawrence, 2004; Vuilleumier, Armony, Driver, & Dolan, 2001). Further evidence comes from patients with visual extinction who can detect emotional expressions more frequently than neutral expressions when presented in their neglected visual field (Fox, 2002; Lucas & Vuilleumier, 2008; Tamietto, Geminiani, Genero, & de Gelder, B, 2007; Vuilleumier & Schwartz, 2001a; Vuilleumier & Schwartz, 2001b). Because emotional content can be detected in the supposedly "extinguished" visual field, these findings indicate that emotional information is being processed in the absence of attention.

Other evidence, however, suggests that emotion processing requires attention (Pessoa, 2005). For instance, in a behavioral task in which participants had to indicate the orientation of a target under increasing levels of processing difficulty (Erthal et al., 2005), distracting photographs of mutilated bodies produced interference under easy and intermediate conditions, but not under a hard (high load) condition. While not conclusive, this absence of interference under high load indicates that the distractor images had not been processed, at least to the point at which they affected responses. Evidence from a difficult attentional blink paradigm (AB) also shows that emotionally expressive faces (fearful and happy) produce substantial blink effects, indicating that attention is required to process these arousing images (Fox, Russo, & Georgiou, 2005).

However, a few studies have reported that the impact of perceptual load or difficulty on emotion processing is strongly modulated by levels of both trait and state anxiety. Thus, in the Fox et al. (2005) study, faces with fearful expressions produced smaller attentional blink effects than happy expressions in a high trait-anxious group. Although a blink effect was still found, this was significantly less than for a low trait-anxious group. Likewise,

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using *functional MRI* (fMRI), it has also been shown that both trait and state anxiety modulate amygdala activity to fearful relative to neutral faces (Bishop, Duncan, & Lawrence, 2004; Etkin et al., 2004), but that this enhanced amygdala reactivity is eliminated under conditions of high perceptual load (Bishop, Jenkins, & Lawrence, 2006). It seems therefore that amygdala reactivity to fear signals occurring outside attention is suppressed as perceptual demand increases.

The *perceptual load theory* (Lavie, 1995, 2005; Lavie & Tsal, 1994) and the *biased competition model* of attention (Desimone & Duncan, 1995) provide good theoretical frameworks to explain these results. Thus, attentional guidance to distractors is proposed to be a product of an interaction between two competing mechanisms: preattentive processes relating to the salience or relevance of a stimulus (e.g., affective significance) and attention control processes relating to task performance. The assumption is that because of capacity limitations, any preattentive mechanisms relating to emotional processing of distractors will be suppressed, or at least severely reduced, if the perceptual demands of the central task exhaust attentional processing resources (Lavie, 1995; Desimone & Duncan, 1995). Pessoa and colleagues have argued persuasively that apparent evidence for emotion processing without attention is likely attributable to the possibility that the perceptual load of the target task was insufficient to ensure that attentional resources were exhausted (Pessoa, Kastner, & Ungerleider, 2002; Pessoa, McKenna, Gutierrez, & Ungerleider, 2002; Pessoa, Padmala, & Morland, 2005). In other words, what looks like emotion processing in the absence of attention is actually the capturing of spare attentive resources by affective stimuli.

Controversy still persists, however, over the extent to which highly aversive or self-relevant stimuli can engage preattentive processes and guide attentional selection in both unselected (Holmes, Kiss, & Eimer, 2006; Lucas & Vuilleumier, 2008; Vuilleumier & Schwartz, 2001a; Vuilleumier & Schwartz, 2001b) as well as anxious populations (Fox, 2002; Fox, Derakshan, & Shoker, 2008). Much of this debate revolves around uncertainties in quantifying both perceptual load and the degree of relevance of the affective stimuli. Fear conditioning procedures may be useful in this regard. For instance, some recent human fear learning studies with nonanxious participants have shown that conditioning not only produces an autonomic fear response (Boschen, Parker, & Neumann, 2007) but can also induce strong attentional biases for the conditioned stimulus (Padmala & Pessoa, 2008; Pischek-Simpson, Boschen, Neumann & Waters, 2009; Yates, Ashwin & Fox, 2010). In a previous study, for example, we found that fear conditioning led to the development of a bias toward threat-related stimuli, but only when perceptual load was low. Critically, evidence for distractor processing of emotional faces was completely eliminated under high perceptual load (Yates et al., 2010, see also Lim & Pessoa, 2008). These findings demonstrate that people who have acquired an autonomic fear response through aversive conditioning can show a measurable change in attentional processing of the threat they have learned to fear. Importantly, these results further suggest that perceptual load is a primary determinant of emotion processing (Lavie & Tsal, 1994).

However, previous research manipulating perceptual load has rarely examined individual differences in threat sensitivity (but see Bishop et al., 2006), and there is good reason to think that such variation is important. The previous studies using fear conditioning indicate an interactive relationship between fear learning and the development of attentional biases supporting an interactive model of cognition and emotion processing (e.g., Mathews & Mackintosh, 1998) in which the guidance of attention to threat is associated with variation in anxiety or fearfulness and depends on the strength of a preattentive representation in a threat evaluation system (TES). Thus, response-competition paradigms that investigate the impact of perceptual load on threat distractor processing should consider individual differences in trait-anxiety before drawing strong conclusions. The aim of the present study was to augment the affective salience of distracting stimuli by means of fear conditioning so that they become strongly represented as threat stimuli by the hypothesized *threat evaluation system* in both high and low anxious people. The novelty of the current study is that we varied both the affective salience of threat-related stimuli (angry faces) as well as the sensitivity of individuals to these stimuli while also manipulating perceptual load. This situation presents a particularly strong test of the *"emotion processing requires attention"* hypothesis. To preempt, we found that high perceptual load eliminated distractor processing even when threat-related expressions were highly salient (fear-conditioned) and even for high anxious participants. However, the impact of fear-conditioning was quite different for high and low trait-anxious participants under low perceptual load. Fear-conditioning led to an increase in distractor interference with low perceptual load as has been reported previously (Lim & Pessoa, 2008; Yates et al., 2010), but *only* for low trait-anxious participants. In marked contrast, high trait-anxious individuals showed a strong *facilitation* for fear conditioned angry faces. In a final experiment, we used the same fear conditioning procedure before a traditional attentional probe task. As predicted, fear conditioning led to enhanced vigilance for low anxious individuals but induced a strong avoidance of threat in high anxious participants. Taken together the results of these three experiments support the notion that strong threat elicits attentional avoidance in anxious individuals and that attentive resources are required to process emotionally relevant information even in an anxious population.

Experiment 1

Using an affective modification of the original Eriksen flanker paradigm (Eriksen & Eriksen, 1974) we investigated the extent to which trait anxiety modulates the processing of a fear-conditioned face distractor under two conditions of perceptual load. For each participant, one angry facial expression was conditioned with a burst of white noise (CS+), while another angry (CS−) and a neutral expression were not associated with aversive noise. After previous research (Lavie, 1995; Yates et al., 2010), perceptual load was manipulated by varying the demands of a central letter classification task, by presenting nontarget letters that were either similar (low perceptual load) or dissimilar (high perceptual load) to each other. The novelty of the present study is the use of a fear-conditioning procedure to boost threat-representations of distracting stimuli in both high and low anxious individuals under conditions of both low and high perceptual load. This provides a strong test of the "emotion processing requires attention" hypothesis. The fear-conditioning procedure we used has been extensively piloted and has been shown to reliably increase fear responding as measured by skin conductance responses (see Yates et al., 2010, for further details).

Method

Participants. Forty-six participants between 18 and 34 years old were recruited for the experiment. Twenty-three participants (20 female) reported high levels of trait anxiety (scores of 45 or above) and 23 (17 female) low levels of trait anxiety (scores of 35 or below) on the State–Trait Anxiety Inventory (Spielberger, Gorsuch, Lushene, & Vagg, 1983). All participants were preselected from a database of 240 people screened at the beginning of the academic year. All participants had normal or corrected-to-normal vision and were either paid £3 or awarded course credit. The University of Essex Ethics Committee approved the study protocol, and participants gave written informed consent.

Apparatus and stimuli. The experiment was presented on a Macintosh iMac4 computer with the screen set at a resolution of 1680 × 1050 pixels. Stimulus presentation and data collection were controlled by SuperLab Version 4 software (Cedrus Corporation, 1997). Response times were collected by means of a USB-based RB-834 response pad with a built in timer that allows data to be collected at 1 millisecond resolution (Cedrus Corporation). The aversive auditory stimulus of approximately 90 db was delivered binaurally through Sennheiser HD 495 digital headphones connected to a sound card in the iMac computer.

The distractor stimuli were three black and white photographs selected from the Ekman Pictures of Facial Affect (Ekman & Friesen, 1976). These photographs included two angry facial expressions (Ekman codes; WF3-01 and JJ3-12) and one neutral expression (EM2-04). The hair and nonfacial areas were removed in Adobe Photoshop (Adobe systems, Incorporated, San Jose, CA; www.abode.com), so that only the central face area was visible. Distracting face stimuli were presented with their center 3.8° above or below fixation and subtended a visual angle of 3.82° vertically and 2.87° horizontally (142 × 201 pixels). The distance between the distractor face and the nearest target or nontarget letter was approximately 1.2 cm (1.23° of visual angle). Targets were the lowercase letters ‘x’ or ‘z.’ Targets appeared at one of six positions in the center of the computer screen along with either the nontarget letter ‘o’ in the low load condition or with five nontarget letters ‘k,’ ‘s,’ ‘m,’ ‘v,’ and ‘n’ in the high load condition. The targets and the nontargets subtended a visual angle of 0.4° vertically and 0.4° horizontally and were separated by approximately 0.2° nearest edge to edge from any adjacent letters in the same row (see Figure 1).

Design and procedure. The experiment consisted of two phases: an initial fear-conditioning phase followed by the selective attention “flanker” task. Full instructions were presented on the computer screen at the beginning of each section. All stimuli were presented at a viewing distance of 56 cm from the screen, which was positioned at eye-level.

The fear-conditioning phase consisted of three event types; CS+, CS−, or N−. The conditioned stimulus (CS+) was counterbalanced across participants, with half of the participants conditioned to one angry face (e.g., WF3-01) and the other half conditioned to the other angry face (e.g., JJ3-12). For the CS+, the presentation of the appropriate angry face was immediately followed by the delivery of an auditory unconditioned stimulus (US),

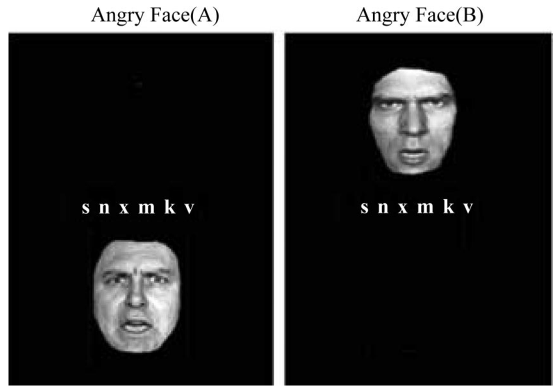

Figure 1. Example display on the flanker task showing angry distractor face A and angry distractor face B in the high perceptual load condition. Participants were instructed to ignore irrelevant distractor faces presented either above or below fixation and attend to the central letter classification task.

which was a 500-ms burst of white noise. Each trial began with a fixation-cross at the center of the screen presented for 500 ms. Upon offset of the fixation cross a face was presented in the same central location for 100 ms followed by either a blank screen for 500 ms or an aversive noise (CS+). Intertrial intervals varied between 15 s and 25 s, with a mean of 20 s, and were presented equiprobably to mitigate anticipatory and habituation effects. Participants were instructed to press one of two response buttons to indicate whether they liked or disliked the face in the photograph. During this fear-conditioning phase participants were presented with a total of 60 acquisition trials (20 CS+, 20 CS−, and 20 neutral faces) presented in a randomized order.

The selective attention “flanker” task followed immediately after the fear-conditioning phase. Once again, each trial began with a fixation-cross presented for 500 ms at the center of the screen. Upon offset of the fixation-cross the experimental trial was presented for 100 ms, consisting of a string of six letters presented at the center of the screen flanked by a distractor face either above or below the central letters. A blank screen followed each trial and participants were required to press one of two response buttons to indicate which target letter appeared in the central display ‘x’ or ‘z.’ Participants were instructed to concentrate on the task at hand and make their responses as quickly and accurately as possible, while ignoring the irrelevant face distractors. A blank screen was then presented for 500 msec, until the beginning of the next trial. The computer emitted a 500-Hz feedback tone as feedback when participants made an error.

One potential problem with this design is the expected extinction that is likely to occur during the flanker experiments, because the CS+ angry face is repeatedly presented without an aversive noise during each experimental block. To avoid any such extinction a fear-conditioning “top-up” consisting of 12 (4 CS+, 4 CS−, and 4 N−) trials was added before the start of each experimental block, using the same procedure as the initial conditioning phase. Differential SCR responding to CS+ and CS− threat-related stimuli is usually found within four conditioning trials (Purkis & Lipp, 2009), and the use of top-up trials have previously been used to good effect in studies showing that aversively conditioned stimuli are prioritized during an attention experiments (Smith, Most, Newsome, & Zald, 2006; Yates et al., 2010).

The ordering of the target and nontarget letters was fully counterbalanced across participants and the distractor face was equally likely to be the CS+, the CS−, or the neutral expression, either above or below the central letter display. The flanker experiment consisted of 36 practice trials followed by 8 blocks of 72 trials, which resulted in a total of 576 trials. All of the trials were completed in one session lasting approximately 45 min.

The dependent variables were reaction times (RTs) and accuracy scores (Error rate), which were investigated using 2 (Perceptual Load: high, low) × 3 (Distractor Salience: CS+, CS−, N−) × 2 (Trait Anxiety: high, low) general linear model (GLM) mixed design ANOVAs. Planned comparisons were examined by means of paired *t* tests adjusted at Bonferroni alpha level $p = .05$ where appropriate.

Results

Reaction times. RTs (ms) on error trials and RTs more than tree standard deviations from the mean were removed from data before analysis and accounted for <2% of the data. Analysis of the RTs revealed a main effect for load [$F(1, 44) = 342.6$, $p < .01$], with responses for the low load condition (Mean RT = 515 ms, *SD* = 72 ms) being faster than the high load condition (Mean RT = 655 ms, *SD* = 94 ms), confirming that the perceptual load modulation was successful in increasing task difficulty (see, Figure 2). There was no main effect of distractor salience [$F(2, 80) = 0.56$, $p > .05$] or trait anxiety [$F(1, 40) = 0.9$, $p > .05$]. However, there was a three-way interaction between perceptual load, distractor salience and trait anxiety [$F(2, 80) = 3.84$, $p < .05$].

Low anxious group. To examine this interaction we performed 2 (perceptual load) × 3 (distractor salience) ANOVAs for each anxiety group separately. For the low anxious group there was a main effect of load [$F(1, 22) = 185.1$, $p < .01$], with responses for the low load condition (Mean RT = 529 ms, *SD* = 64 ms) being faster than the high load condition (Mean RT = 661 ms, *SD* = 73 ms), confirming that load modulation successfully increased task difficulty for the low anxious group. There was also a main effect of distractor salience [$F(2, 44) = 6.5$, $p < .05$] and the perceptual load × distractor salience interaction was significant [$F(2, 44) = 7.6$, $p < .05$]. A one-way analysis on the low load condition revealed a main effect of distractor salience [$F(2, 44) = 21.96$, $p < .05$] with RTs being *slower* for the CS+ angry face trials compared with the CS− angry face trials [Mean RTs = 541 ms vs. 529 ms, $t(22) = 3.0$, $p < .05$] and the neutral face trials [Mean RTs = 541 ms vs. 515 ms, $t(22) = 5.9$, $p < .01$]. The CS− face trials were also slower than the neutral face trials [Mean RTs = 529 ms vs. 515 ms, $t(22) = 5.3$, $p < .01$]. A one-way analysis on the high load condition revealed no main effect of distractor salience [$F < 1$].

High anxious group. For the high anxious group there was a main effect of load [$F(1, 22) = 162$, $p < .01$], with responses for the low load condition (Mean RT = 503 ms, *SD* = 92 ms) being faster than the high load condition (Mean RT = 649 ms, *SD* = 110 ms), confirming that load increased task difficulty for the high anxious group. There was also a main effect of distractor salience [$F(2, 44) = 9.9$, $p < .01$] and the perceptual load × distractor salience interaction approached significance [$F(2, 44) = 2.55$, $p < .079$]. Given that this interaction was approaching significance, a separate one-way analysis was conducted for the low load and the high load conditions.

A one-way analysis on the low load condition revealed a main effect of distractor salience [$F(2, 44) = 24.19$, $p < .05$], with RTs being *faster* on CS+ angry face trials compared with CS− angry face trials [Mean RTs = 492 ms vs. 504 ms, $t(22) = 4.1$, $p < .01$] and neutral face trials [Mean RTs = 492 ms vs. 512 ms, $t(22) = 6.6$, $p < .01$]. The CS− face trial was also faster compared with the neutral face trials [Mean RTs = 504 ms vs. 512 ms, $t(22) = 2.9$, $p < .05$]. This pattern was unexpected and suggests a response *facilitation* effect associated with the affective salience of the face distractor. A one-way analysis on the high load condition revealed no main effect of distractor salience [$F(2, 44) = 1.16$, $p > .05$].

Between group comparisons. In relation to the three-way interaction between perceptual load, distractor salience, and trait anxiety, further independent *t* tests revealed only that the high anxious were faster to respond to the CS+ angry face compared with the low anxious [Mean RTs = 492 ms vs. 541 ms, $t(44) = 2.0$, $p < .05$], in the low load condition; no other comparisons reached significance (all *t* tests, $p > .05$).

Errors. An ANOVA on error rates revealed a main effect of load [$F(1, 44) = 151$, $p < .01$], with greater error rates for the high perceptual load condition (17%) versus low perceptual load condition (7%). There were no significant effects for distractor salience or anxiety or their interaction ($F < 1$ for all).

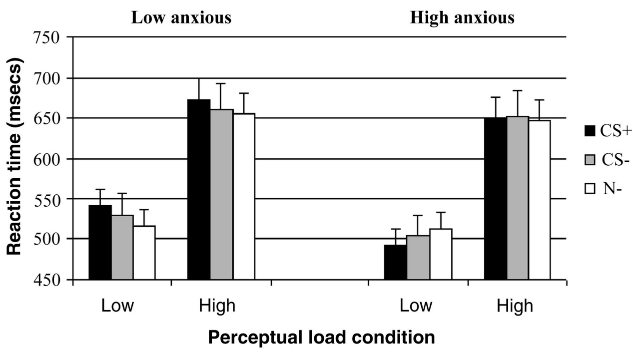

Figure 2. Mean correct reaction times (in milliseconds) in Experiment 1 as a function of perceptual load, type of flanker (CS+, CS−, or N−), and self-reported trait-anxiety (high, low). Error bars indicate the standard errors of the means. $^{*}p < .05$.

Discussion

The critical result to emerge from Experiment 1 was that any impact on task performance from CS+ angry face distractors was eliminated by perceptual load, which confirms our previous findings (Yates et al., 2010). Interestingly, this was the case regardless of anxiety level. An unexpected result to emerge from the low-load condition, however, was a contrasting pattern of responding for high and low trait-anxious individuals. The results for the low-anxious group replicated our previous findings for an unselected sample (Yates et al., 2010) in showing strong interference from CS+ distractors with low perceptual load that was eliminated under conditions of high load. However, our current high trait anxious group showed the opposite effect: *facilitation* from CS+

distractors under low load conditions that was eliminated with high perceptual load.

Finding facilitation from CS+ distractors in high anxious participants was unexpected, and there are a number of possible explanations. First, there is evidence that the presence of threat is associated with an enhanced preparedness to act (Flykt, 2006). Given the fact that high trait-anxiety is associated with increased threat sensitivity the presentation of the CS+ distractor may have elicited a fast preparation for action in these participants. This mechanism operates at the level of response preparation and does not necessarily involve attentional mechanisms. An alternative possibility is that the results may be attributable to a defensive response in which participants *avoid* extensive processing of threatening stimuli to regulate their fear response and limit further exposure to threat (Stormark & Hugdahl, 1996). This is an attentional-based account, which at first sight may seem inconsistent with the evidence that high levels of anxiety are associated with an enhanced vigilance for threat. A possible explanation, however, is that attentional processes may be affected in quite different ways by *fear* and *anxiety* states, respectively. To explain, several theoretical frameworks differentiate "fear" from "anxiety" such that "fear" is considered to be a specific reaction to an immediate threat, characterized by a defensive avoidance that facilitates rapid escape, while "anxiety" is seen as a more diffuse state of distress in response to less specific threat cues (e.g., worry about general ill health) and reflects what could be considered a "defensive approach" state, which is characterized by risk evaluation and vigilance (e.g., Lang, Davis, & Öhman, 2000; Gray & McNaughton, 2000). Some evidence for this hypothesis was presented in a study using an attentional probe task containing images of general threat as well as more specific blood-phobia-related images (Mogg, Bradley, Miles, & Dixon, 2004). Evidence for initial vigilance was found to threat signals, which was followed by attentional avoidance of the threat in highly anxious participants. However, attentional avoidance was only associated with self-reported specific fears (blood phobia) and was not associated with self-reported trait-anxiety, which reflects a more general form of anxiety/worry. These results strongly suggest that attentional avoidance of threat cues may be related to a motivational state of fear, rather than to a more general state of anxiety. Thus, we conducted a second experiment to replicate the findings of response facilitation to CS+ angry faces in fearful/anxious individuals but included a self-report measure of fearfulness as well as anxiety to assess whether any speeding of response with CS+ distractors relates to fearfulness rather than more general anxiety.

Experiment 2

To assess levels of fearfulness as well as more diffuse anxiety two questionnaires were completed, which are thought to provide separate indices of behavioral approach, behavioral avoidance and fear proper. Gray and NcNaughton (2000) have proposed that emotional experience depends on three separate systems. The *Behavioral Approach System (BAS*), which underlies the natural propensity to approach potential reward, the *Flight/Fight/Freeze (FFFS*) system, which underlies the defensive fear response designed to facilitate rapid escape from threat, and the *Behavioral Inhibition System (BIS*), which is seen as a conflict detection system that becomes activated if there is any conflict between the approach and avoidance behaviors elicited by activation of the BAS or the FFFS. According to Gray and McNaughton (2000) individual differences in fearfulness depend on the BIS located in the septohippocampal region of the brain and engages the amygdala to mobilize fear-related responses. Carver and White (1994) have developed the BIS-BAS scales to provide self-report measures of the BIS and the BAS systems and also include a subcomponent that assess the FFFS. It has been confirmed that people who report high levels on the BIS scale have a more reactive fear system in the brain in response to threat cues (Mathews, Yiend, & Lawrence, 2004). The BIS scale provides two subcomponents that relate to "anxiety" and "fear," respectively (see Heym, Ferguson & Lawrence, 2008; Poythress et al., 2008), and we hypothesize that the enhanced facilitation we found in high trait-anxious individuals when attempting to ignore threat cues (fear conditioned angry face) will be associated primarily with the "fear" component rather than the "anxiety" component.

Method

Participants. Thirty-eight experimentally naïve participants between 17 and 43 years old were selected from the community at the University of Essex who had already been screened for self reported trait-anxiety on the State–Trait Anxiety Inventory (Spielberger, 1983). Nineteen participants (11 female) reported high levels of trait anxiety (scores of 45 or above) and 19 (16 female) low levels of trait anxiety (scores of 35 or below). All participants had normal or corrected-to-normal vision and received payment for their time. The University of Essex Ethics Committee approved the study, and participants gave written informed consent.

Apparatus and stimuli. The apparatus, target, and nontarget letters for the high and low load conditions were exactly the same as in Experiment 1, except that a fourth photograph depicting a happy facial expression (code; GS-1–08) was added to the face stimuli used in Experiment 1. All other aspects relating to location, visual angle, and distance between the distractor face and the nearest target or nontarget letter were exactly the same as in Experiment 1.

Design and procedure. Before the experiment all participants completed the *Behavioral Inhibition System/Behavioral Activation System Scale* (BIS-BAS scales (Carver & White, 1994), so that levels of fearfulness in addition to more general anxiety states could be assessed. BIS-Anxiety and FFFS-Fear items were distinguished from within the BIS scale. BIS items 'Even if something bad is about to happen to me, I rarely experience fear or nervousness' and 'I have few fears compared with my friends' were treated as FFFS-Fear factors. The remaining five items were treated as BIS-Anxiety factors (see Heym et al., 2008; Poythress et al., 2008). There were three BAS scales relating to Reward Responsivity (RR), Drive (DR), and Fun seeking (FUN), which were of less interest in the current study. The experiment consisted of two parts: a fear conditioning (acquisition) phase and the main selective attention flanker task as in Experiment 1. Full instructions were presented on the computer screen at the beginning of each section.

The acquisition phase consisted of four event types: (1) a photograph of an angry face not paired with an aversive noise (CS−), (2) a photograph of an angry face paired with an aversive noise burst (CS+), (3) a photograph of a happy face not paired with aversive noise (H-), and (4) a photograph of a neutral face not paired with aversive noise (N−). All other aspects of the acquisition phase were exactly the same as Experiment 1. Each of the four faces was presented 20 times, resulting in a total of 80 trials for the fear-conditioning phase.

The flanker task immediately followed the acquisition phase, and the procedure was the same as Experiment 1. Before each test block in the flanker task there was a reinforced acquisition phase, consisting of 16 (4 CS+, 4 CS+, 4 H−, 4 N−) trials using the same design as the initial acquisition phase. The flanker task consisted of 36 practice trials followed by eight blocks of 96 trials, which resulted in a total of 768 trials. All of the trials were completed in one session lasting approximately 60 min.

The dependent variables were reaction times (RTs) and accuracy (Error rate), which were investigated using 2 (Perceptual Load: high, low) × 4 (Distractor Salience: CS+, CS−, H−, N−) × 2 (Trait Anxiety: high, low) general linear model (GLM) mixed design ANOVAs. A further correlational analysis was performed between response facilitation and interference effects (Distractor Effects) and the level of scores on the "fear" and "anxiety" subcomponents of the BIS scale. Paired *t* test comparisons adjusted at Bonferroni alpha level ρ .05 were conducted where appropriate.

Results

Reaction times. RTs (ms) on error trials and RTs more than three standard deviations from the mean were removed from data before analysis, and accounted for <2% of the trials. The mean correct RTs are shown in Figure 3. As in Experiment 1, analysis of the RTs revealed a main effect for Perceptual Load [$F(1, 36) = 171.1$, $p < .01$], with responses for the low load condition (Mean RT = 503 ms, *SD* = 77 ms) being faster than the high load condition (Mean RT = 638 ms, *SD* = 84 ms) with no main effects for Distractor salience [$F(3, 108) = 0.22$, $p > .05$] or Trait Anxiety [$F(1, 36) = 0.2$, $p > .05$]. However, there was a three-way interaction between perceptual load, distractor salience, and trait anxiety [$F(3, 108) = 9.3$, $p < .05$]. To examine the three-way interaction we performed 2 (load; high vs. low) × 4 (distractor; CS+ vs. CS− vs. H vs. N) ANOVAs for each anxiety group separately.

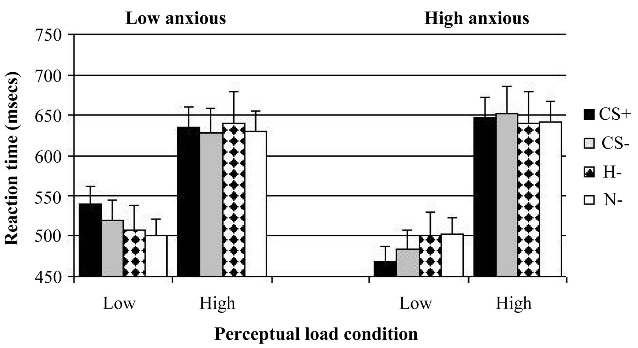

Figure 3. Mean correct reaction times (in milliseconds) in Experiment 2, as a function of perceptual load, type of flanker (CS+, CS−, H-, or N−), and self-reported trait-anxiety (high, low). Error bars indicate the standard errors of the means. * $p < .05$.

Low anxious group. For the low anxious group there was a main effect of load [$F(1, 18) = 48.9$, $p < .01$], with responses for the low load condition (Mean RT = 516 ms, *SD* = 67 ms) being faster than the high load condition (Mean RT = 632 ms, *SD* = 58 ms). There was a main effect of distractor salience [$F(3, 54) = 8.6$, $p < .01$], and the perceptual load × distractor salience interaction was significant [$F(3, 54) = 6.2$, $p < .01$]. To investigate the nature of this interaction we conducted separate one-way ANOVAs for the low load and the high load conditions. A one-way analysis on the low load condition revealed a main effect of distractor salience [$F(3, 54) = 15.68$, $p < .01$]. Paired *t* tests showed that RTs were *slower* for the CS+ angry faces compared with the CS− angry faces [Mean RTs = 539 ms vs. 519 ms, $t(18) = 3.5$, $p < .05$] the neutral face [Mean RTs = 539 ms vs. 501 ms, $t(18) = 7.5$, $p < .01$], and the happy face [Mean RTs = 539 ms vs. 507 ms, $t(18) = 5.9$, $p < .01$]. The CS− face also elicited more response interference than either the neutral face [Mean RTs = 519 ms vs. 501 ms, $t(18) = 4.9$, $p < .01$] or the happy face [Mean RTs = 519 ms vs. 507 ms, $t(18) = 2.9$, $p < .05$]. Interference from happy and neutral distracting faces did not differ [Mean RTs = 507 ms vs. 501 ms, $t(18) = 1.1$, $p > .05$]. A one-way analysis on the high load condition revealed no main effect of distractor salience [$F(3, 54) = 0.68$, $p > .01$].

High anxious group. For the high anxious group there was a main effect of perceptual load [$F(1, 18) = 157$, $p < .01$], with responses for the low load condition (Mean RT = 488 ms, *SD* = 85 ms) being faster than the high load condition (Mean RT = 643 ms, *SD* = 107 ms). There was a main effect of distractor salience [$F(3, 54) = 6.7$, $p < .01$], and the perceptual load x distractor salience interaction was also significant [$F(3, 54) = 3.9$, $p < .05$]. A one-way analysis on the low load condition revealed a main effect of distractor salience [$F(3, 54) = 24.28$, $p < .01$]. Paired *t* tests showed that RTs were *faster* with CS+ angry face distractors compared with CS− angry faces [Mean RTs = 468 ms vs. 483 ms, $t(18) = 3.3$, $p < .05$] neutral faces [Mean RTs = 468 ms vs. 500 ms, $t(18) = 4.8$, $p < .01$] and happy faces [Mean RTs = 468 ms vs. 503 ms, $t(18) = 4.7$, $p < .01$]. The CS− also produced response facilitation compared with the neutral face [Mean RTs = 483 ms vs. 500 ms, $t(18) = 3.2$, $p < .05$] and the happy face [Mean RTs = 483 ms vs. 503 ms, $t(18) = 4.1$, $p < .01$], with no difference occurring between the happy and the neutral face trials [Mean RTs = 503 ms vs. 500 ms, $t(18) = 0.53$, $p > .05$]. A separate one-way analysis on the high load condition revealed no main effect of distractor salience [$F(3, 54) = 0.44$, $p > .01$].

Between group comparisons. As in Experiment 1, a significant three-way interaction showed that low anxious participants showed response *interference*, while the high anxious participants showed response *facilitation* from fear conditioned angry facial expressions under conditions of low perceptual load. Independent *t* tests revealed that the high anxious group was significantly faster on CS+ angry face trials than the low anxious group [Mean RTs = 468 ms vs. 539 ms, $t(36) = 3.6$, $p < .01$], while the difference approached significance for the CS− angry face [Mean RTs = 484 ms vs. 519 ms, $t(36) = 1.9$, $p < .06$] in the low load condition. No other comparisons reached significance (all *t* tests, $p > .05$).

Error rate. An ANOVA on error rates revealed a main effect of load [$F(1, 36) = 119$, $p < .01$], with greater error rates for the high perceptual load condition (21%) verses low perceptual load condition (9%). There were no significant effects for distractor salience or anxiety or their interaction [$F < 1$ for all].

Correlations and comparisons between "fear" and "anxiety." The means and standard deviations for the BIS-Anxiety, FFFS, and BAS subcomponents are shown in Table 1. Trait Anxiety was positively correlated with BIS-Anxiety ($r(38) = .383$, $p < .05$) and FFFS ($r(38) = .640$ $p < .001$) and negatively correlated with BAS-RR [$r(37) = .585$. $p < .05$)] and BAS-D [$r(37) = .444$. $p < .05$; Pearson correlation two-tailed]. Independent *t* test confirmed that that high trait-anxious groups reported higher levels of "Fear" on the FFFS than the low trait-anxious group, $t(36) = 5.1$, $p < .001$, 2-tailed. The high trait-anxious group also showed higher levels of BIS-Anxiety than the low trait-anxious group, although this effect was somewhat smaller than for "Fear", $t(36) = 3.1$, $p < .004$, two-tailed.

Further analyses were conducted to assess the extent to which response facilitation or interference effects can be explained specifically by the subcomponents of BIS-Anxiety and FFFS. To do this we computed a *Distractor Effect*, which was the reaction time difference between the CS+ face and the Neutral face, and this variable was used as a measure of either response interference (positive scores) or response facilitation (negative scores). Initial correlations showed that the *Distractor Effect* correlated negatively with the STAI trait-anxiety score [$r(38) = -.83$, $p < .001$], BIS-Anxiety scores [$r(38) = -.38$, $p < .05$], and the FFFS score [$r(38) = -.59$, $p < .001$]. Because trait-anxiety subsumes items relating to both fear and anxiety, a hierarchical regression analysis was conducted with just the BIS-Anxiety and BIS-FFFS scores as predictors with the reaction time *Distractor Effect* as the dependent variable. The regression equation was significant [$R^2 = 0.41$, $F(2, 37) = 12.3$, $p < .001$], and the pattern of correlations showed that the FFFS score was more strongly related to the *Distractor Effect* (*Beta* = −.53, $p < .001$) than was the BIS-Anxiety score (*Beta* = −.26, $p < .06$). The negative relationship indicates that *faster* RTs on CS+ trials (i.e., facilitation) were related to the FFFS subcomponent to a greater extent than the BIS-Anxiety component.

Discussion

These findings replicate the results from Experiment 1 in showing that both fear-conditioned and nonconditioned angry faces affected performance on a selective attention task. As before, strong response *interference* effects for CS+ face distractors were found for a low trait-anxious group, which reversed to strong *facilitation* for a high trait-anxious group. Self-reported trait anxiety was found to have a positive relationship with BIS-Anxiety and FFFS. Importantly, the subcomponent FFFS-Fear was a better predictor of the variance in response *facilitation* effects, relative to the BIS-Anxiety effect. These results may reflect faster preparation for action in response to potential threat (Flykt, 2006). The results are also consistent with the hypothesis that fear conditioning activates a fear response, leading to increased anxiety and enhanced vigilance for threat cues in low trait-anxious individuals. However, for high trait-anxious individuals who already have a heightened sensitivity to threat, fear conditioning may elicit a more fundamental FFFS fear system that mobilizes avoidance responses. This activation of "fear" in high anxious populations may induce an attentional *avoidance* of threat cues, thus explaining the facilitation found on CS+ trials in this group.

This hypothesis is consistent with the theoretical framework proposing that anxiety is characterized by an initial orientation to threat followed by a subsequent avoidance of threat (Mogg & Bradley, 1998; Mogg, Bradley, Miles, & Dixon, 2004). Traditional measures of trait-anxiety incorporate both fearfulness and more general anxiety, and the assumption is that the fear component underlies attentional avoidance while more general anxiety underlies enhanced vigilance for threat cues. Mogg et al. (2004) provided some evidence for this proposal in their finding that avoidance on an attentional probe task was more strongly related to specific phobic fears rather than to more general levels of trait-anxiety. Stormack, Hugdahl, and Posner (1999) have also found suggestive evidence that conditioning a cue with white noise can induce an *avoidance* of the CS+ stimulus. Our hypothesis is that this fear-based mechanism may be activated more easily and rapidly in those with high trait-anxiety who are known to be particularly sensitive to threat-related material. To test this hypothesis we conducted a further experiment designed to investigate more directly whether fear conditioning elicits an avoidance response in high trait anxious people.

Table 1
Means and Standard Deviations for the Subcomponents of the BIS-Anxiety, FFFS, and BAS (Reward Responsivity [RR], Drive [D] and Fun Seeking [FS]) and the Distractor Effect for the Low (L.A.) and the High (H.A.) Trait-Anxious Groups

	L.A.		H.A.	
Variable	Mean	*SD*	Mean	*SD*
Distractor effect	37.95	21.60	−32.00	13.31
BIS-anxiety	15.53	2.22	17.53	1.71
BIS-fear	5.31	0.95	6.99	1.12
BAS-RR	16.58	1.31	14.32	1.80
BAS-D	11.74	1.70	9.79	1.58
BAS-FS	10.58	1.35	10.32	1.42
Trait-anxiety	34.16	3.85	50.21	3.03

Experiment 3

Cognitive models of anxiety have proposed that anxiety is associated with a tendency to selectively allocate attention toward threat-related material (Mogg & Bradley, 1998; Williams, Watts, MacLeod & Mathews, 1997), and such biases seem to play a causal role in the development of anxiety disorders (MacLeod, Koster, & Fox, 2009, for review). The attentional probe task is a common measure of biased attention and was designed to overcome methodological problems with other tasks such as the emotional Stroop task (MacLeod, Mathews, & Tata, 1996). The attentional probe task presents pairs of items (faces, words, or images) side by side for typically about 500 ms followed by a probe (e.g., : or ..) to be categorized as rapidly as possible. This task consistently demonstrates that both clinically anxious groups as well as nonclinical participants reporting high levels of trait-anxiety are faster to detect probes occurring in the location recently occupied by a fear-relevant (e.g., angry facial expression) as opposed to a neutral stimulus (see Bar-Haim et al., 2007, for review).

Research on assessing biased attention toward threat cues has, however, found more mixed results with regard to specific phobias and social anxiety. Thus, when emotional faces have been paired with objects people with social anxiety have been found to orient their attention *away* from the faces (Mansell, Clark, Ehlers, & Chen, 1999), while other studies have reported enhanced vigilance for angry as opposed to neutral facial expressions in social anxiety (e.g., Mogg, Philippot & Bradley, 2004). A framework that can reconcile these conflicting findings is the notion of a two-stage *vigilance-avoidance* model as proposed by Mogg, Bradley, de Bono, and Painter (1997). The hypothesis is that anxiety is characterized by an initial rapid allocation of attention toward threat-relevant material followed by an avoidance of threat material. This attentional *avoidance* of threat may serve the useful role of minimizing discomfort as in the case of a socially anxious person deliberately avoiding eye contact, for instance. While plausible, the empirical evidence for the pattern of initial vigilance followed by subsequent intentional avoidance is somewhat mixed, with studies generally finding vigilance for threat with presentation times of around 500 ms, but a mixed pattern of results when duration times are longer (e.g., Mogg et al., 1997; Mogg et al., 2004).

Results are somewhat more consistent with groups such as those with specific phobias. Thus, using eye-movements as the dependent measure, several studies have reported that spider phobic individuals initially attend to threat (spider pictures) and then quickly avoid it (e.g., Rinck & Becker, 2006). Similarly, it has been found that socially anxious people are quicker to look toward emotional relative to neutral faces, but they then look at the emotional faces for less time, which is consistent with a vigilant-avoidant pattern of bias (Garner, Mogg, & Bradley, 2006). These results appear to be at odds with studies demonstrating that high trait and state-anxious people tend to dwell for longer periods on threat-relevant material taking longer to disengage their attention from threat relative to low anxious groups (Fox, Russo, Bowles, & Dutton, 2001; Koster, Crombez, van Damme, Verschuere, & De Houwer, 2005). Several factors, such as assessing different stages of attention (e.g., covert vs. overt shifts of attention), may explain these apparently different patterns (Garner et al., 2006). However, it is also possible that avoidance is more associated with fear states, while maintenance of attention on threat is more characteristic of generalized anxiety states. The finding of the current Experiment 2 that a self-report measure of fear, and not anxiety, was related to the avoidance of CS+ stimuli supports this suggestion.

The hypothesis to be tested in this experiment is that fear conditioning may elicit enhanced vigilance for threat in a low trait-anxious group, but that the fear state induced by conditioning may result in *avoidance* of threat in a high trait-anxious group. The attentional probe paradigm circumvents the possibility that response preparation might be driving the results of the previous two experiments. This is because the critical trials in the attentional probe task contain the threat-related stimulus (CS+) as well as a neutral stimulus. Thus any speeding of response preparation would occur regardless of where the probe appears in relation to the critical stimulus. If the allocation of attention is driving the results, however, then differences should be found when the probe occurs in the location of threat (CS+) and in a less threatening location (N).

Previous studies of fear conditioning with the attentional probe task have shown that conditioning leads to an increased bias to allocate attention toward threat-relevant material. Thus, in one study pictures of snakes and spiders were paired with a burst of white noise (CS+) or an innocuous noise (CS−). Across two experiments, it was found that this fear conditioning procedure led to the development of an attentional bias for the CS+ stimuli on a subsequent attentional probe task (Beaver, Mogg, & Bradley, 2005). Subsequent work using electric shock (Pischek-Simpson et al., 2009) as the unconditioned stimulus has shown that fear conditioning induces an attentional bias for the conditioned stimulus. Using a flanker task, we have previously found that fear conditioning with aversive noise can lead to enhanced interference effects from CS+ angry facial expressions (Yates et al., 2010) consistent with the notion that biased attention is modulated by fear learning. However, the pattern of results found in the present Experiments 1 and 2 indicate that these results may be restricted to low anxious individuals. In marked contrast, the speeding of response on CS+ trials observed in high trait-anxious individuals suggests that an attentional avoidance of threat might be elicited in high anxious people by fear conditioning. The present experiment provides a direct test of this hypothesis.

Method

Participants. Twenty-eight participants were selected from the student population at the University of Essex who had already been screened for level of self-reported trait-anxiety on the State–Trait Anxiety Inventory (Spielberger, 1983). All were between 18 and 27 years of age. Fourteen participants (5 male) reported high levels of trait anxiety (scores of 45 or above) and 14 (6 male) low levels of trait anxiety (scores of 35 or below). All participants had normal or corrected-to-normal vision and received payment for their time. The University of Essex Ethics Committee approved the study and participants gave written informed consent.

Apparatus and stimuli. Experimental stimuli were presented and reaction time and error data were collected with a Macintosh iMac4 computer, by means of SuperLab Version 4 software (Cedrus Corporation, 1997). The screen resolution was set at 1680 × 1050 pixels. Reaction times were collected by means of a USB-based RB-834 response pad with a built in timer that allowed data to be collected at 1 millisecond resolution (Cedrus Corporation). The aversive auditory stimulus of approximately 90 db was delivered binaurally through Sennheiser HD 495 digital headphones connected to a sound card in the iMac computer.

Skin conductance responses (SCRs) were recorded from sensors attached to the index and middle fingers of the nondominant hand with a ProComp Infiniti software eight-channel encoder with Biograph Infiniti software (version 2.0.1, Thought Technology Ltd, Plattsburgh, NY, 2003), and data were collected on a Dell Latitude notebook. Signals were sampled at a rate of 256 samples per second.

The target faces were the three black and white photographs selected from the Ekman Pictures of Facial Affect set (Ekman & Friesen, 1976) as used in the previous two experiments. Thus, there were two angry faces (A) and (B) (codes; WF3-01, and JJ3-12, respectively) and one neutral face (code; EM2-04). All stimuli had the hair and nonfacial areas removed in Adobe Photoshop (Adobe systems, Incorporated, San Jose, CA; www.abode-.com), so that only the central face area was visible. The location of each target face subtended a visual angle of 10.23° vertically and 8.17° horizontally (450 × 350 pixels) and were positioned at the center of the screen. Each face was presented against a black background.

Design and procedure. Upon entering the lab, a brief explanation of the experiment was given and each participant signed an informed consent form. The attentional probe task was then explained and each participant was administrated up to 30 practice trials using face stimuli (all neutral expressions) that were not used in the main experiment to ensure that they achieved above 90% accuracy on the task. After this the sensors were attached to the index and middle finger of the nondominant hand to measure skin conductance responses (SCRs). There were two phases during which SCRs were collected: habituation and acquisition. To guard against possible anticipatory effects, the intertrial intervals were varied between 15 s and 25 s with a mean of 20 seconds. Across both phases, the experimental face stimuli (Angry Face A, Angry Face B, Neutral Face) were presented in a pseudorandomised order with the restriction that only two successive presentations of each face was allowed. The screen was positioned at eye-level, and all stimuli were presented at a viewing distance of 60 cm.

Before conditioning, participants were allowed to habituate to the equipment and experimental environment while SCRs were being recorded. They were asked to relax and keep as still as possible while the face stimuli were presented in a random order. Each face was presented on the computer screen for 2 s and each was presented three times, giving a total of 9 trials.

During the acquisition phase participants were informed that they would again be shown a series of faces and that occasionally they would hear a loud noise, which might be uncomfortable. They were once again asked to try and remain as still as possible. Each of the three face stimuli was presented eight times for 4 s each (generally considered to be a *first interval response*) in a random order, giving a total of 24 trials. Half of the participants (seven high trait anxious, seven low trait anxious) were delivered the aversive 90 db noise during the first 500 ms of the presentation of angry face (A) while the remaining half received the aversive noise during the first 500 ms of the presentation of angry face (B). Each trial began with a fixation cross presented for 500 ms, upon offset of the fixation cross a face was presented with one of the angry expressions (Angry Face A or B) always being accompanied by the aversive noise (CS+), the other angry expression and the neutral expressions were never accompanied by the aversive noise (CS− and N−, respectively).

The attentional probe task was presented immediately after the acquisition phase. The SCR sensors were removed and participants were reminded about the procedure in this task. Smaller versions of the CS+, CS−, and N− stimuli were presented on successive trials side by side. Each image extended a visual angle of about 4° vertically and 3° horizontally, and each trial consisted of a CS+ and a N− photograph or a CS− and a N− stimulus. The angry (CS+, CS−) and neutral (N−) faces were separated by about 4° of visual angle (2° either side of fixation), and no aversive noises were presented throughout the experiment. Each trial began with a central fixation cross for 500 ms followed by the stimulus pair (CS+ and N, or CS− and N) for 500 ms. This display was immediately followed by a probe target which was a pair of dots either vertically (:) or horizontally (..) aligned. Probes remained visible until response and participants were required to categorize the probe (: or ..) as quickly and accurately as possible by pressing one of two keys on the response pad. The particular response keys were counterbalanced across participants. After response there was a blank screen for 1000 ms before the onset of the fixation cross for the next trial. Each participant was presented with 80 experimental trials with the CS+ and the CS− stimuli occurring equally often on the left and the right hand side of fixation (20 times each). On half of the trials the probe appeared in the *same* location as the angry face (CS+ or CS−) and on the other half the probe appeared in the other location (*different*), which was the location of the N− item. After the attentional probe task each participant was debriefed and paid.

SCR data during the habituation phase were investigated with a 2 (Anxiety: high, low) × 3 (Stimulus Type: CS+, CS−, N−) ANOVA, while a 2 (Anxiety: high, low) × 3 (Stimulus Type; CS+, CS−, N−) × 8 (Trials) ANOVA was conducted for the SCR data during the acquisition phase. The minimal response criterion was 0.05 microsiemens (μS). Before statistical analysis, the SCR data underwent a correction range to reduce variation not related to psychological processes and a subsequent square-root transformation to normalize the distribution (Lykken, 1972). The dependent variable was the SCRs measured as the maximal amplitude in conductance initiated in a 1–4 s latency window following the onset of each face (Prokasy & Kumpfer, 1973). The attentional probe reaction time and error data were analyzed by means of a 2 (Critical Stimulus Type: CS+, CS−) × 2 (Probe Location: same or different from Critical Stimulus) ANOVA as within-subject factors.

Results

Skin conductance response. An Anxiety Group × Stimulus Type ANOVA was conducted on the mean SCRs as shown in Figure 4. There was a significant main effect for Anxiety Group, $F(1, 26) = 6.4$, $p < .018$, such that mean SCR was higher for high ($M = 8.3$ μS), relative to low ($M = 5.7$ μS) trait anxious partic-

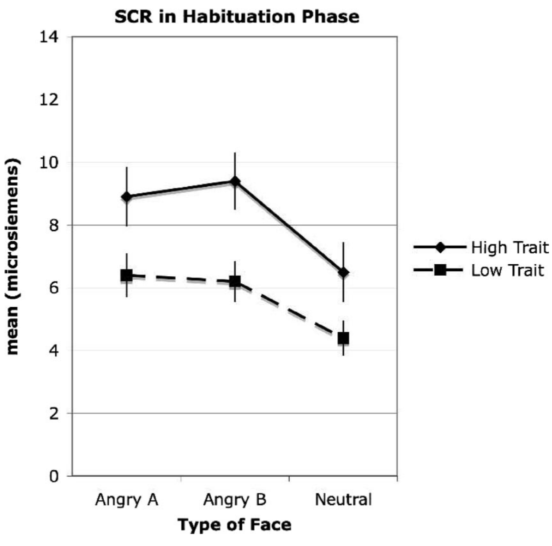

Figure 4. Mean skin conductance response (SCR) in the initial habituation phase of Experiment 3 for Angry Face A and Angry Face B and the Neutral expression. SCR are measured in terms of MicroSiemens, and error bars indicate the standard error of the means.

ipants. The main effect of Stimulus Type was also significant, $F(2, 52) = 20.5$, $p < .001$, while the Anxiety Group × Stimulus interaction did not reach significance, $F(2, 52) < 1$. Critically, paired sample t tests revealed that the two angry faces did not differ from each other in terms of SCRs, $t(27) < 1$, while both Angry Face A, $t(27) = 4.4$, $p < .001$ and Angry Face B, $t(27) = 5.3$, $p < .001$ elicited larger SCRs than the Neutral expression (see Figure 4).

The mean SCRs during the acquisition phase are shown in Figure 5 for high and low trait-anxious groups. An Anxiety Group × Stimulus Type × Trial ANOVA revealed main effects for Anxiety Group, $F(1, 26) = 5.9$, $p < .03$), Stimulus Type, $F(2, 52) = 211.1$, $p < .001$, and Trial, $F(7, 182) = 36.6$, $p < .001$. As expected there was a Stimulus Type × Trial interaction, $F(14, 364) = 28.4$, $p < .001$, which was not qualified by Anxiety Group, $F(14, 364) < 1$. As can be seen in Figure 5 the SCRs to the CS+ stimulus did not differ from those to the CS− stimulus on Trial 1, but on all other trials the SCRs were higher for the CS+ relative

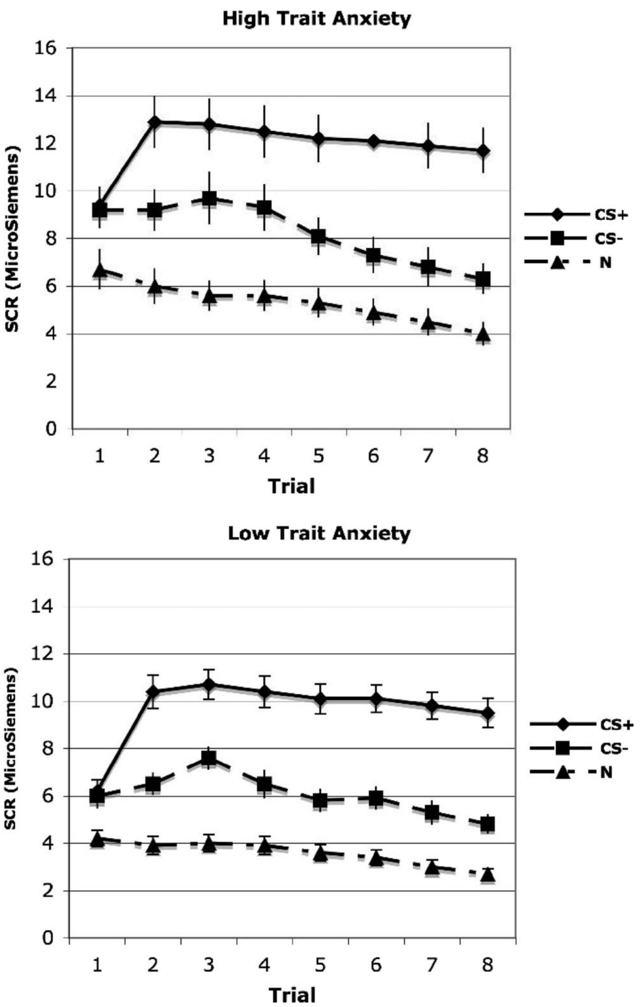

Figure 5. Mean skin conductance responses (SCRs) during the acquisition phase of Experiment 3 for high trait (upper panel) and low trait-anxious (lower panel) individuals. SCRs are measured in terms of Micro-Siemens, and error bars indicate the standard error of the means.

to both CS− and N− trials (all ps $< .001$). SCRs for the CS− trials were higher than N− trials on all 8 trials (all ps $< .001$).

Attentional probe task. Mean correct reaction times (within 3 standard deviations of the mean) for categorizing probe stimuli when they occurred in either the *same* or *different* location from the critical angry face stimulus (either CS+ or CS−) are presented in Figure 6. As can be seen, low trait-anxious participants were faster on same relative to different trials for both the CS+ and CS− trials. In contrast, the high trait-anxious were slower on same trials on CS+ trials but faster on CS− trials. To facilitate understanding these results, attentional biases scores were computed by subtracting the mean RT on *same* trials from mean RT on *different* trials. Thus, positive scores indicate vigilance for the angry face (CS+ or CS−) while negative scores indicate avoidance of the angry face. The means of these attentional bias scores for high and low trait-anxious groups are shown in Figure 7.

The mean attentional bias scores were subjected to a 2 (Anxiety Group: high, low) × 2 (Stimulus Type: CS+, CS−) ANOVA. There was no main effect of Stimulus Type, $F(1, 26) < 1$, while there was a main effect for Anxiety Group, $F(1, 26) = 7.2$, $p < .013$. More critically, the Anxiety Group × Stimulus Type interaction approached significance, $F(1, 26) = 4.1$, $p < .053$. Because of our prior predictions, further planned comparisons were conducted for each anxiety group separately. For the high trait-anxious group the bias on CS+ trials differed from the bias scores on CS− trials, $t(-2.6)$, $p < .011$. The avoidance observed on CS+ trials was significantly different from 0 (representing no bias), $t(13) = -2.1$, $p < .03$, while the vigilance observed on CS− trials just failed to reach significance, $t(13) = 1.7$, $p < .06$. For the low trait-anxious group the bias scores on CS+ and CS− trials did not differ from each other, $t(14) < 1$. However, the vigilance observed for this group on CS+ trials did differ from 0, $t(14) = 2.1$, $p < .03$, while the vigilance observed on CS− trials was not significant, $t(14) < 1$. Further analysis revealed that the bias observed on CS+ trials did differ between the high trait-anxious ($M = -13.3$, *avoidance*) and the low trait-anxious ($M = 15.1$, *vigilance*) groups, $t(14) = -2.95$, $p < .007$, while the vigilance observed in both groups on CS− trials did not differ between the anxiety groups, $t(14) < 1$.

Discussion

This study was designed to investigate attentional biases to angry facial expressions in groups of high and low trait-anxious individuals to address the question of whether fear conditioning can induce attentional biases for threat-related faces (Beaver et al., 2005; Pischek-Simpson et al., 2009; Yates et al., 2010). On the basis of these previous studies, it was predicted that both groups would show increased SCRs to a facial expression that had been paired with an aversive noise (CS+). Based on the results of the current Experiments 1 and 2, it was predicted that fear conditioning would produce a different pattern of results on the attentional probe task for high and low anxious individuals. Specifically, it was predicted that the low trait anxious individuals would demonstrate an enhanced attentional bias for CS+ stimuli as has been found in previous studies with unselected samples (Beaver et al., 2005; Pischek-Simpson et al., 2009). However, based on our results with the flanker task after fear conditioning in the previous experiments, it was predicted that fear conditioning would lead to

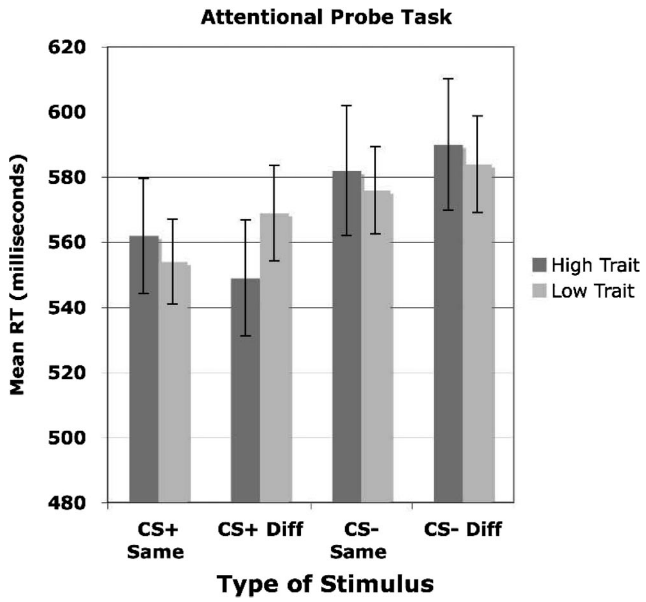

Figure 6. Mean correct reaction times (RTs) on the attentional probe task in Experiment 3 as a function of trait-anxiety group, and whether probes and critical stimuli (CS+ or CS−) appeared in the same or different location.

an attentional avoidance of CS+ stimuli on the attentional probe task.

The results were in line with predictions. First, the fear conditioning procedure in which an angry facial expression was paired with an aversive noise did result in enhanced SCRs across eight trials and this did not differ between the high and low trait-anxious groups. However, as expected, fear conditioning did lead to different patterns of bias on the attentional probe task such that low trait-anxious individuals showed an enhanced vigilance for threat (CS+) while the high trait-anxious group showed a marked avoidance of the CS+ stimuli. These results support our hypothesis that fear conditioning elicits a fear-based state in high trait-anxious individuals, which invokes a tendency to avoid threat-relevant material.

General Discussion

This study addressed a number of important theoretical issues in the understanding of emotion processing. First, we investigated whether fear-relevant stimuli require attentive processes or whether they can be analyzed in the absence of attention. By means of fear conditioning—pairing an angry facial expression with aversive noise—we increased the threat value of an already threat-related stimulus (angry facial expression). Using a similar procedure, we have already reported that even such highly salient threat-related stimuli do not induce increased response interference from unattended distractors in a flanker task when perceptual load is high (Yates et al., 2010). However, here we included a group of high trait-anxious individuals to provide a stronger test of the 'emotion processing requires attention' hypothesis. Even when trait-anxiety was high, fear-conditioned CS+ stimuli did not produce response interference under high load conditions. These results in both Experiments 1 and 2 support the hypothesis that, in the absence of sufficient attentional resources, even highly aversive stimuli are not processed (Pessoa et al., 2002, 2005).

A second focus of the current study was the role that fear learning and conditioning might play in the development of attentional biases toward threat. Previous research has shown that fear conditioning leads to an increase in the tendency to allocate attention toward threat-relevant material under low perceptual load conditions in an attentional probe task (Beaver et al., 2005; Pischek-Simpson et al., 2009). Biased allocation of attention toward threat using this task is characteristic of a wide variety of anxiety conditions (see Bar-Haim et al., 2007, for review) and supports the notion that fear learning may play a fundamental role in the development of such potentially toxic biases for threat. Research is now converging to suggest that such biases are not only important for the maintenance of anxiety states but may also play an important causal role in the development of anxiety (see MacLeod et al., 2009; Browning et al., 2010 for review). To illustrate, a recent study has found that threat-related biases in attention—particularly when they are automatic—can predict stress reactivity as measured by salivary cortisol release in stressful situations up to 8 months after the assessment of bias (Fox, Cahill, & Zougkou, 2010). Further evidence comes from studies showing that the experimental induction of negative and positive biases under laboratory conditions can lead to fundamental changes in emotional vulnerability (Browning et al., 2010, for review). Demonstrations that classic fear conditioning procedures can also induce biases in an unselected sample provide further support for the hypothesis that associative learning may underlie the development of potentially toxic biases.

The results reported in Experiments 1 and 2 provide some support for this hypothesis but also found an unexpected effect of fear conditioning in a high trait-anxious sample. For low trait-anxious individuals we replicated our previous finding in an unselected sample

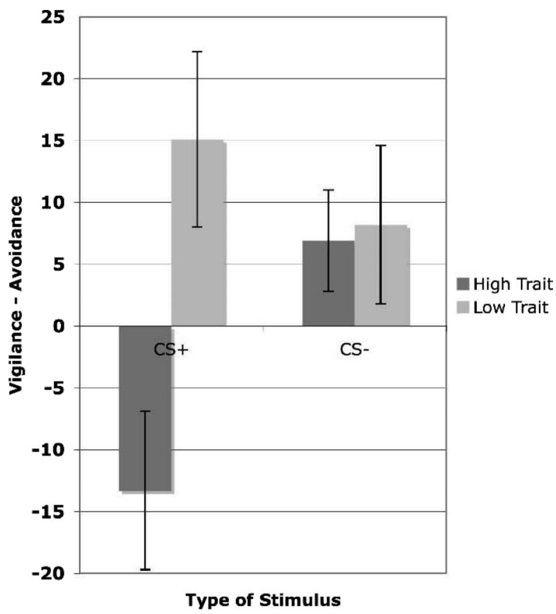

Figure 7. Mean attentional bias scores (mean RT on *different* trials—mean RT on *same* trials) for both high and low trait-anxious groups for both CS+ and CS− trials. Positive scores indicate vigilance for the critical face (CS+ or CS−) relative to a neutral face, while negative scores indicate avoidance of the critical face.

that fear conditioning with aversive noise as the UCS and an angry face as the CS leads to increased distractor interference effects in a flanker task (Yates et al., 2010). However, an unexpected *facilitation* with CS+ distractors in the flanker task was found for high trait-anxious individuals. Experiment 2 replicated this unexpected finding and also revealed that the magnitude of facilitation was correlated with self-reported fear rather than anxiety. This raises the possibility that fear conditioning elicited a fear reaction to withdraw from aversive stimuli in high trait-anxious individuals (cf., Gray & McNaughton, 2000). Fear states (e.g., social phobia, spider phobia) have frequently been associated with the attentional avoidance of fear-relevant stimuli in previous studies (e.g., Mansell et al., 1999), so the induction of a specific fear, as opposed to a more generalized anxiety state, may explain the enhanced facilitation found when CS+ items were presented as distractors. In other words, the induction of fear in high trait-anxious participants might lead to an attentional avoidance of threat-relevant stimuli. An alternative possibility is that the results are attributable to enhanced response preparation effects in the presence of threat (Flykt, 2006) that are likely to be stronger in high trait-anxious individuals.

We attempted to disentangle these competing hypotheses directly in Experiment 3 by presenting a classic attentional probe task immediately after our fear-conditioning procedure. Enhanced anxiety-related response preparation should lead to a general speeding of response in the presence of the CS+ stimulus regardless of where the probe appears. However, if the attentional explanation is correct then the location of the probe should affect the response time. In support of this view, fear conditioning did induce attentional avoidance of CS+ faces in high trait-anxious people but enhanced vigilance for CS+ stimuli in a low trait-anxious group. These results support cognitive models of anxiety that assume that attentional bias can follow a vigilance-avoidance pattern with regard to threat-relevant stimuli (Beaver et al., 2005; Mogg et al., 1997). Results have indicated that specific phobias (e.g., spider or social phobia) are characterized by an initial and rapid allocation of attention toward threat, but that this is followed by an attentional avoidance of the same stimuli (e.g., Garner et al., 2006; Rinck & Becker, 2006). Avoidance of threat has been more difficult to find in high trait-anxious groups (e.g., Mogg et al., 2004), and several studies report that high trait-anxious people tend to dwell on threat, taking longer to disengage their attention from threat-relevant stimuli (Fox et al., 2001, 2002; Koster et al., 2005; Yiend & Mathews, 2001). The current findings suggest that it is important for future research to separate fear from anxiety as both of these underlying dimensions may have quite different effects in attention tasks, motivating avoidance or vigilance, respectively. When fear is induced in already anxious individuals a pattern of defensive avoidance may be the result. Enhanced amygdala activation is likely to underlie these effects. Thus, previous research has found that the degree of activation of the (right) amygdala to masked fearful facial expressions correlates highly with the speed of response to fearful expressions in a visual search task (Ohrmann et al., 2007). In other words, enhanced threat sensitivity as in high trait-anxiety is associated with increased amygdala activation to threat and enhanced scanning of the visual environment for threat.

In conclusion, the current study confirms that perceptual load is a major determinant of whether unattended fear-conditioned face distractors are processed. This is an important extension of the perceptual load hypothesis (Lavie, 1995, 2005; Pessoa, 2005). Thus, the capacity for spatially separate aversive stimuli (CS+) to disrupt performance on a reaction time task only occurred under conditions of low perceptual load, when attentive resources were available. When perceptual load was high these effects were eliminated. Even when trait anxiety was high and stimuli had a high threat value, interference only occurred when perceptual load was low. Second, when perceptual load was low the current study adds to the growing evidence that fear learning and associative mechanisms are likely to play a role in the development of attentional biases toward threat. This is an important demonstration because threat-related biases in attention are implicated in both the *development* and *maintenance* of anxiety disorders. Thus, for low trait-anxious individuals fear conditioning led to the establishment of an attentional bias toward the CS+ stimulus. These results indicate that future interventions designed to reduce the incidence of anxiety disorders could usefully focus on methods to reduce the impact of fear learning in low anxious people.

Perhaps the most interesting finding in the current study was the impact of fear conditioning on attentional bias in an already high trait-anxious group. For these anxious individuals, the induction of a fear state had a very different effect on the attentional probe task compared with a low anxious group. Instead of showing greater vigilance for threat as in the low trait-anxious group, high anxious individuals demonstrated a marked *avoidance* of fear conditioned stimuli. This finding is consistent with models of fear suggesting that fear is associated with the avoidance of aversive stimulation, which is one way in which anxiety states can be regulated but can also lead to a maintenance of conditions such as social phobia (e.g., Clark, 1999; Gray & MacNaughton, 2000). Thus, Clark and his colleagues have argued that when confronted with a threatening situation (e.g., a social gathering) social phobia is associated with a tendency to focus attention inward and self-monitor one's own reactions rather than attending to the external environment. In addition to safety-seeking strategies such as avoiding eye contact, this reduced monitoring of external cues can play an important role in the maintenance of social anxiety (Clark, 1999; Clark & Wells, 1995). Using the attentional probe task, subsequent work has found that in a socially stressful situation, socially phobic individuals are faster to orient their attention toward threat cues (emotional faces) as measured by eye movements, but that the threat cue was then looked at for less time than was the case for those with low levels of social anxiety (Garner et al., 2006). These findings are consistent with the hypothesis that eliciting a fear state in an anxious population may lead to attentional avoidance of threat signals.

Studies of attentional bias in anxiety have revealed a complex pattern of vigilance and avoidance. The current results add to this growing evidence and suggest that it is important to separate generalized anxiety states from more specific fearful states. Generalized anxiety and worry may be related to vigilance for threat followed by an increased maintenance of attention on threat cues (e.g., Fox et al., 2001). In contrast, fear-based states may be related to an initial vigilance for threat, followed by an intentional and strategic avoidance of threat to regulate rising levels of fear (e.g., Rinck & Becker, 2006). The complexities of dynamic vigilance and avoidance mechanisms should be interrogated in future research by varying the duration of the critical stimuli in addition to including physiological measures of fear arousal such as SCRs and electroencephalographic activity. The present findings seem best reconciled by the notion that different processes, relating to both vigilance and avoidance of threat cues, operate at the same time when there is competition for attentional resources between threat and benign cues and processes relating to fear-based defensive mechanisms that afford an opportunity to avoid further exposure to threat.

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