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The effects of trait and state anxiety on attention to emotional images: An eye-tracking study

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Attentional biases for threatening stimuli have been implicated in the development of anxiety disorders. However, little is known about the relative influences of trait and state anxiety on attentional biases. This study examined the effects of trait and state anxiety on attention to emotional images. Low, mid, and high trait anxious participants completed two trial blocks of an eye-tracking task. Participants viewed image pairs consisting of one emotional (threatening or positive) and one neutral image while their eye movements were recorded. Between trial blocks, participants underwent an anxiety induction. Primary analyses examined the effects of trait and state anxiety on the proportion of viewing time on emotional versus neutral images. State anxiety was associated with increased attention to threatening images for participants, regardless of trait anxiety. Furthermore, when in a state of anxiety, relative to a baseline condition, durations of initial gaze and average fixation were longer on threat versus neutral images. These findings were specific to the threatening images; no anxiety-related differences in attention were found with the positive images. The implications of these results for future research, models of anxiety-related information processing, and clinical interventions for anxiety are discussed.

Keywords: Trait anxiety; State anxiety; Attentional bias; Eye tracking; Time course; Threat.

Past research has demonstrated that individuals with anxiety disorders, and high anxious individuals more generally, selectively attend to threatening versus neutral information (see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007, for a meta-analysis). This *attentional bias to threat* is argued to be a maladaptive response to threatening information that contributes to the development and maintenance of anxiety disorders (Beck & Clark, 1997; Mathews & Mackintosh, 1998; Williams, Watts, MacLeod, & Mathews, 1997). Although a clear relationship has been established between anxiety and an attentional bias to threat, the relative contributions of trait anxiety (i.e., the general tendency to experience anxiety) and state anxiety (i.e., a transient feeling of negative arousal) to the attentional bias remain largely unknown. Situations that are

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perceived as threatening typically give rise to state anxiety. One can readily appreciate that attentional biases, including early attention to threat stimuli and strategic deployment of attention towards or away from threat are adaptive in that they facilitate a successful fight or flight response. However, individuals with trait anxiety are more likely to perceive stimuli as threatening (e.g., MacLeod & Cohen, 1993; Mathews, Richards, & Eysenck, 1989) and are therefore more likely to experience state anxiety, even in mild to low threat situations. Furthermore, trait anxious individuals may require more information about a stimulus before drawing conclusions about its threat value. Attentional biases may thus be stronger for individuals with trait anxiety, and these biases may play a role in the development and persistence of anxiety problems. An examination of the way in which trait and state anxiety influence attention to threat is thus necessary in order to identify maladaptive patterns of attention to threat that contribute to the development of anxiety and its disorders and may be an important avenue for treatment efforts.

Trait and state anxiety and the threat-related attentional bias

Theoretically, various relationships have been proposed between trait and state anxiety and an attentional bias to threat. Beck (1976) proposed a cognitive theory of anxiety, emphasising the role of negative thinking styles in anxiety disorders. He suggested that vulnerability to anxiety results from the over-activation of threat-related cognitive structures, termed danger schemata, leading to the selective processing of congruent information and hypervigilance for threat. As such, Beck's cognitive theory of anxiety proposes that a threat-related attentional bias might reflect a stable, enduring cognitive mechanism underlying susceptibility to anxiety, and would seem compatible with the idea that a bias in attention towards threat is primarily related to *trait* anxiety. Alternatively, Bower's (1981) network model predicts that attentional biases to threat result from anxiety *states*. Bower posited an associative memory network in which emotional states are represented as nodes. When an individual experiences a particular emotional state, associated nodes containing mood-congruent memories and information are activated, leading to the selective processing of such information. Thus, according to Bower, a transient increase in state anxiety will cause an increase in attention to threatening stimuli.

Other researchers have proposed that trait and state anxiety interact to produce an attentional bias to threat. Williams et al. (1997) suggested that an increase in state anxiety enhances the appraisal of stimuli as threatening, whereas trait anxiety is implicated in the deployment of attention in response to stimuli appraised as threatening. They argued that individuals high in trait anxiety demonstrate vigilance for threatening stimuli, whereas individuals low in trait anxiety will avoid threat. Mathews and Mackintosh (1998) also proposed that increases in fear or state anxiety temporarily lower an individual's threshold for appraising stimuli as threatening, and that this effect is greater and more frequent in high trait anxious individuals.

Empirically, attentional biases to threat have been primarily investigated in individuals varying in levels of trait anxiety. In general, these studies have supported the idea that high trait anxious individuals display biased attention towards threatening stimuli and that this phenomenon is less likely to be observed in low trait anxious individuals (Bar-Haim et al., 2007). However, it is probable that the high trait anxious individuals in these studies would have been higher also in state anxiety than their low trait anxious counterparts. Indeed, studies that have assigned participants to anxiety groups on the basis of state anxiety scores have also observed anxiety-related attentional biases to threat (Bradley, Mogg, & Millar, 2000; Fox, Russo, Bowles, & Dutton, 2001; Mogg, Bradley, de Bono, & Painter, 1997). The relative roles of trait and state anxiety in attentional biases cannot be determined from studies examining either only trait or state anxiety because both trait and state anxiety have not been appropriately identified and systematically compared; rather, these studies tend to confound trait and state anxiety by evaluating groups of individuals who may differ simultaneously on both constructs.

Only a few studies have compared the effects of both trait and state anxiety on attention towards threatening stimuli, and these studies have yielded equivocal findings. For instance, Mathews and MacLeod (1985) employed an emotional Stroop task (Stroop, 1935) to measure attentional biases to threat in clinically anxious and control individuals. Results from this study indicated that clinically anxious individuals were slower than control individuals in naming the colour of threatening words relative to non-threatening words and that the degree of slowing (i.e., the attentional bias to threat) was significantly correlated with state anxiety scores, but not trait anxiety scores. On the other hand, a replication of this study found that clinically anxious individuals were slower than control individuals in naming the colour of threatening words relative to non-threatening words, yet the level of attentional bias to threat was significantly correlated with trait anxiety scores, but not state anxiety scores (Mogg, Mathews, & Weinman, 1989).

Other studies have found that the effect of anxiety on attention is an interactive function of both trait and state variables. Using a dot-probe paradigm (MacLeod, Mathews, & Tata, 1986), MacLeod and Mathews (1988) examined attentional biases in high and low trait anxious participants under naturally occurring conditions of low state anxiety (12 weeks before a major exam) and high state anxiety (1 week before the exam). In this study, the researchers found that at the high state anxiety testing session, high trait anxious individuals attended to exam-related threat words while low trait anxious individuals avoided such words. A study by Mogg, Bradley, and Hallowell (1994) replicated these results, also demonstrating vigilance and avoidance for threatening words in high and low trait anxious participants, respectively, under conditions of high exam stress.

Methodological considerations

The conflicting findings of past research examining the influences of trait and state anxiety on attentional biases to threat may be accounted for by methodological issues. Previous experiments have relied on the emotional Stroop task or the dot-probe paradigm to measure attention. In these paradigms, attention is not directly observed, but rather inferred from reaction times. This may be problematic because reaction times can be affected by general response slowing in addition to the shifting of attention, and the interpretation of the anxiety-related attentional bias based on reaction-time data has been shown to depend on whether response slowing is taken into account (Mogg, Holmes, Garner, & Bradley, 2008). Another weakness of these paradigms is that they generally only allow for measurement of attention at a single time point. However, attention is not a unitary construct; rather, it is comprised of several distinct components, such as initial orienting, engagement, and disengagement (Posner & Peterson, 1990). Studies that have measured attention over longer periods of time (e.g., 3000 ms) have found that anxiety-related patterns of attention to threatening stimuli vary considerably over the time course (e.g., Calvo & Avero, 2005; Rohner, 2002).

Evidence regarding the nature of anxiety-related attentional biases over time is mixed. Some studies have found that anxious individuals preferentially attend to threatening stimuli at both early (e.g., 100–500 ms) and late (e.g., 1000–1500 ms) time points (e.g., Bradley, Mogg, Falla, & Hamilton, 1998; Bradley, Mogg, White, Groom, & de Bono, 1999; Mogg et al., 1997). Others suggest that anxious individuals initially attend to threatening stimuli, but demonstrate avoidance at later stages of attention (Koster, Verschuere, Crombez, & Van Damme, 2005). This pattern of attention is referred to as *vigilance-avoidance* and is thought to result from automatic attentional orienting to threat followed by strategic avoidance in an effort to alleviate the anxiety produced by the threatening stimulus (Mogg, Bradley, Miles, & Dixon, 2004). A vigilant-avoidant pattern of attention to threat has been hypothesised to maintain anxiety states and interfere with habituation to anxiety-provoking stimuli (Mogg et al., 2004). Still other studies suggest that anxiety is characterised by delayed disengagement from threatening stimuli rather than a bias in initial orienting (Amir, Elias, Klumpp, & Przeworksi, 2003; Fox et al., 2001; Fox, Russo, & Dutton, 2002). Evidently, there is no consensus in the current literature about the nature of the attentional bias at any given time point or how it changes over time. Studies that continuously measure visual attention over longer durations (e.g., 3000 ms; Calvo & Avero, 2005) via eye tracking are thus valuable in elucidating the time course of anxiety-related attentional biases to threat and may help reconcile the conflicting findings of previous research.

Eye-tracking paradigms generally involve the continuous measurement of eye movements as participants are simultaneously presented with emotional and neutral stimuli. Eye-movement tracking provides a direct measure of the time course of visual attention and thus improves upon several of the limitations of the reaction-time paradigms. Only a few studies have assessed eye movements to investigate trait-anxiety-related attentional biases (Bradley et al., 2000; Calvo & Avero, 2005; Nelson, Quigley, Carriere, Smilek, & Purdon, 2012; Rohner, 2002). These studies have produced mixed findings, with some finding an attentional bias towards or away from negative stimuli in high trait anxious individuals (Calvo & Avero, 2005; Rohner, 2002) and others finding no main effect of trait anxiety on eye movements (Bradley et al., 2000; Nelson et al., 2012). A few recent studies have used eye tracking to examine attentional biases in socially anxious individuals and found evidence that such individuals have difficulty disengaging from threat (Buckner, Maner, & Schmidt, 2010; Schofield, Johnson, Inhoff, & Coles, 2012), however, it is unclear whether attentional biases related to social anxiety are similar to or different from attentional biases related to general trait anxiety. To date, no studies have investigated attentional biases as a function of both trait and state anxiety by monitoring eye movements.

Differences in state anxiety levels may help to explain the null findings of studies investigating attentional biases that have not detected trait-anxiety-related group differences in attention to threat (e.g., Bradley et al., 1997; Bradley et al., 2000; Mogg & Bradley, 2002; Nelson et al., 2012). For instance, high trait anxious individuals are more likely to also be in a state of anxiety, but this is not necessarily the case. If it is elevations in state anxiety that produce attentional biases to threat, a bias will often be observed in high trait anxious groups due to their concurrent high state anxiety, but will fail to be detected if high trait anxious groups are not similarly high in state anxiety. Likewise, if there is an interaction between trait and state anxiety, such that high levels of both variables are required to elicit an attentional bias, biases would only be found with high trait anxious individuals in a highly anxious state, and would fail to be observed with individuals high in only trait or state anxiety.

Understanding the relative contributions of trait and state anxiety to attentional biases also holds important implications for theories about the causal role of attentional biases in the development of anxiety. If an attentional bias to threat is primarily related to trait anxiety, the bias may reflect a cognitive mechanism causally contributing to anxiety problems (Mogg, Mathews, Bird, & Macgregor-Morris, 1990). Along this line, some researchers have postulated that an attentional bias to threat is an aetiological factor in anxiety, and that anxiety may be reduced by eliminating the bias (MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002). Recent research has corroborated this hypothesis, demonstrating that attention bias modification training may ameliorate symptoms of anxiety (see Hakamata et al., 2010, for a meta-analysis). However, if the attentional bias to threat is observed in individuals in a transient state of anxiety, the bias may be a product, as opposed to a cause, of anxiety (Mogg et al., 1990). Thus, treatment focusing on attention training may be tantamount to treating the symptoms, rather than the underlying cause, of the anxiety problem.

An additional concern of the present study is whether the anxiety-related attentional bias reflects the preferential processing of emotional stimuli in general (i.e., emotional selectivity), or of negative emotional stimuli specifically (i.e., negative selectivity). Studies that have addressed this issue by examining attentional biases for both threatening and positive stimuli have generally found that anxiety-related attentional biases are specific to threatening stimuli and have supported the negative selectivity hypothesis (see Ruiz-Caballero & Bermúdez, 1997, for a review; Bradley et al., 2000; Bradley et al., 1998). Less commonly, some studies have found that anxiety is associated with biased attention towards both threatening and positive stimuli, supporting the emotional selectivity hypothesis (Mogg & Marden, 1990; Riemann & McNally, 1995). Of particular relevance to the current research are studies that have found that emotional and negative selectivity effects are differentially related to trait and state anxiety (MacLeod & Rutherford, 1992; Rutherford, MacLeod, & Campbell, 2004). These researchers argued that heightened state anxiety increases attention to all emotional stimuli, regardless of trait anxiety, whereas biased attention to negative stimuli specifically is an interactive effect of trait and state anxiety, such that high levels of both variables are required to elicit the bias (Rutherford et al., 2004).

The present study

The present study was designed to directly compare the effects of trait and state anxiety on visual selective attention to emotional images. Given the inconclusive results of previous research, the aim of the present study was not to confirm any specific hypothesis, but rather to explore the phenomenology of attention as a function of trait and state anxiety over time. A secondary purpose of this study was to determine whether attentional biases generalise to all emotional stimuli, as predicted by the emotional selectivity hypothesis, or are specific to threatening stimuli, as predicted by the negative selectivity hypothesis. As a unique contribution to the emotional versus negative selectivity debate, the emotional and negative selectivity hypotheses were evaluated across the time course of attention and as a function of both trait and state anxiety.

One possible outcome would be a significant main effect of trait and/or state anxiety on attention towards threatening images (e.g., Beck, 1976; Bower, 1981, respectively). A second potential outcome is a significant interactive effect of trait and state anxiety on attention to threat (e.g., Mathews & Mackintosh, 1998; Williams et al., 1997). A third possible outcome is that attention is differentially influenced across the time course, yielding a significant interaction between time and trait anxiety, state anxiety, and/or the interaction between these two variables. An anxiety-related attentional bias observed for all emotional images (threatening and positive) would support the emotional selectivity hypothesis, while a bias observed only for the threatening images would support the negative selectivity hypothesis. If the validity of the emotional versus negative selectivity hypotheses depend on the interaction between trait and state anxiety, preferential processing of emotional and negative stimuli may both be associated with anxiety, but may be influenced differentially by trait and state variables (e.g., Rutherford et al., 2004).

METHOD

Participants

Participants were undergraduate students at the University of Waterloo, who participated for course credit. Participants were selected from a larger sample of undergraduate students who completed a number of screening questionnaires, including the State-Trait Anxiety Inventory – Trait scale (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), Beck Depression Inventory – II (BDI-II; Beck, Steer, & Brown, 1996), and Social Desirability Scale (SDS; Crowne & Marlowe, 1960; Strahan & Gerbasi, 1972). Recruitment favoured those who scored high ($\geq$47) and low ($\leq$36)[1] on the STAI in order to

[1] These STAI cut-off values represent the bottom and top third of the distribution of STAI scores in a large undergraduate sample (> 1000).

over-sample for low and high trait anxious participants. Participants who scored 19 or greater on the BDI-II and/or who endorsed suicidal ideation by a score other than 0 on item 9 were excluded from participation in order to control for the effects of depression on attention and to protect potentially vulnerable individuals from exposure to negative emotional states. Participants with high scores on the SDS (>12 on the 20-item version) were also excluded from participation as these individuals may under-report negative symptoms such as anxiety (Calvo & Miguel-Tobal, 1998; Derakshan & Eysenck, 2001). Participants who met all of the eligibility criteria were permitted to sign up for the study. Of these eligible participants, 128 participants completed the study.

Upon arrival at the study, participants completed a number of self-report questionnaires, including a re-administration of the STAI. Participants whose scores on the STAI in the lab session did not correspond with their scores on the STAI in the initial mass-testing session (i.e., participants who switched from the high trait anxious group to the low trait anxious group or vice versa) were excluded ($n = 2$). Another four participants were excluded due to difficulty in obtaining stable eye tracking (e.g., interference from glasses, eyelid occluding the pupil). Thus, the final sample consisted of 122 participants (75 female, 47 male, $M_{\text{age}} = 19.20$ years, $SD_{\text{age}} = 1.46$ years, age range: 17–27 years); 37 participants formed the high trait anxious group (≥ 47 on the in-lab STAI), 36 participants formed the mid trait anxious group (37–46 on the in-lab STAI), and 49 participants formed the low trait anxious group (≤ 36 on the in-lab STAI). The three trait anxiety groups did not differ in terms of age, $F(2, 114) = 2.20$, $p > .10$, or gender distribution, $\chi^2 = 3.06$, $p > .10$. All participants had normal or corrected-to-normal vision.

Measures

Beck Depression Inventory – II. The Beck Depression Inventory – II (BDI-II; Beck et al., 1996) is 21-item questionnaire that assesses the severity of depressive symptoms over the past two weeks. Items are rated on a 4-point scale, where higher scores indicate greater depressive symptomatology. The BDI-II demonstrates excellent reliability in undergraduate populations, with coefficient alpha estimates ranging from .91 to .93 (Beck et al., 1996; Dozois, Dobson, & Ahnberg, 1998). The coefficient alpha reliability estimate for the BDI-II in the current selection sample ($N = 3{,}917$) was .92.

Marlowe–Crowne Social Desirability Scale. The Marlowe-Crowne Social Desirability Scale (SDS; Crowne & Marlowe, 1960) is a measure of the tendency to respond in a socially favourable manner on self-report measures. Items are rated as either true or false, and higher scores indicate greater levels of social desirability. The 20-item short version of the scale was used in the present study (Strahan & Gerbasi, 1972) and demonstrates similar psychometric properties to the full version, with coefficient alpha reliability estimates ranging from .73 to .83 (Strahan & Gerbasi, 1972). The coefficient alpha reliability estimate for the SDS in the present selection sample ($N = 3912$) was .71.

State-Trait Anxiety Inventory. The State-Trait Anxiety Inventory – Trait scale (STAI; Spielberger et al., 1983) is a 20-item questionnaire that assesses the tendency to experience symptoms of anxiety. Items are rated on a 4-point scale (1 = *Almost never* and 4 = *Almost always*), with higher scores indicating greater trait anxiety. The STAI demonstrates good internal consistency and test–retest reliability (Barnes, Harp, & Jung, 2002). The coefficient alpha reliability estimate for the STAI administered in the in-lab study in the current sample was .91. Test–retest reliability of the STAI from the initial mass testing session to the in-lab study (across an interval ranging from one week to three months) in the current sample was .83.

State-Trait Inventory for Cognitive and Somatic Anxiety (State Version). The State-Trait Inventory for Cognitive and Somatic Anxiety (STICSA; Ree, MacLeod, French, & Locke,

2008) – State scale is a 21-item measure of cognitive and somatic symptoms of anxiety. Items are rated on a 4-point scale (1 = *Not at all* and 4 = *Very much so*), where higher scores indicate greater state anxiety. The state version of the STICSA demonstrates high internal reliability and good construct validity (Ree et al., 2008). Coefficient alpha reliability estimates for the STICSA, which was administered at several time points throughout the in-lab study, ranged from .83 to .92 in the present sample.

Affect Grid. The Affect Grid (Russell, Weiss, & Mendelsohn, 1989) is a 9 × 9 grid with two axes: pleasantness and arousal. At specified time points throughout the experiment, participants rated the pleasantness and arousal levels of their current mood by marking an "X" in the corresponding box on the grid. Pleasantness and arousal ratings ranged from 1 to 9 (1 = *Extremely unpleasant* or *Low in arousal* and 9 = *Extremely pleasant* or *High in arousal*). The pleasantness and arousal axes are scored independently, and shifts along these axes reflect changes in mood. Increases in anxiety are represented by decreases on the pleasantness axis and increases on the arousal axis. The Affect Grid demonstrates good reliability, with coefficient alpha estimates ranging from .81 to .91 (Russell et al., 1989).

Genuineness rating. Participants rated the genuineness of their mood and state anxiety ratings on a single-item scale generated for the purpose of this study. Participants were informed that they should rate how genuine their mood and state anxiety ratings were throughout the experiment, based on the extent to which they believed their ratings accurately reflected their mood experience. Genuineness ratings ranged from 1 to 9 (1 = *Not at all genuine* and 9 = *Completely genuine*).

Eye-tracking task and visual stimuli

This task was comprised of two blocks of 20 test trials, each of which involved the simultaneous presentation of two images selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008).[2] Each image pair consisted of an emotional image paired with a neutral image. Two different image sets were used for the two blocks of test trials, and the image sets were counterbalanced across experimental blocks to control for potential image set effects.

Half of the emotional images were threatening and half were positive in valence. All emotional–neutral image pairs were matched by the presence of people. The matching of emotional–neutral image pairs by the presence of people represents an improvement over studies that have matched emotional images containing people with neutral images containing inanimate objects, thus confounding human content and emotionality. Emotional–neutral image pairs were also roughly matched on colour, brightness, complexity, and content based on visual inspection by the first and second authors. In each trial, participants were required to fixate upon a centrally presented fixation cross in order to activate the next image pair. Once activated, each image pair was presented side-by-side at 90 pixels to the left and right of the centre of the screen (2.8° visual angle) for 3 seconds. A 500 ms break followed before the next fixation cross was presented. Emotional images appeared in equal proportion on the left and right sides of the screen. There was one practice trial and one buffer trial prior to the onset of the 20 test trials in each experimental block.

The IAPS provides normative ratings for all images on a 9-point scale for affective valence (1 = *Unpleasant* and 9 = *Pleasant*) and arousal (1 = *Low arousal* and 9 = *High arousal*). Average valence ratings were 2.40 ($SD = 0.35$) for the threat images, 5.18 ($SD = 0.67$) for the neutral

[2] IAPS image pairs used in the study: (Threatening–Neutral) 2683–7496, 2811–2512, 3500–2595, 3530–2397, 6212–8460, 6242–4100, 6312–2396, 6313–8050, 6315–2485, 6350–2372, 6510–6250.2, 6560–4605, 6570–6570.2, 9423–2560, 6243–2221, 6360–4631, 6830–2487, 6213–2749, 6244–2200, 6571–2580; (Positive–Neutral) 8380–8060, 8180–8160, 2340–2383, 2070–2250, 2080–9070, 530–2850, 2209–2480, 2165–2214, 2304–2271, 8461–2870, 2311–2312, 2550–2516, 2370–2570, 7325–2840, 8496–9700, 8120–8010, 2030–2830, 2091–2440, 8200–8465, 2391–2280.

images, and 7.49 ($SD = 0.39$) for the positive images. Average arousal ratings were 6.32 ($SD = 0.53$) for the threat images, 3.77 ($SD = 0.87$) for the neutral images, and 4.76 ($SD = 0.91$) for the positive images. A multivariate analysis of variance (MANOVA) comparing the Image Categories (threat vs. neutral vs. positive) on valence and arousal ratings yielded a significant effect of Image Category on both valence ratings, $F(2, 77) = 434.47$, $p < .001$, $\eta_p^2 = .92$, and arousal ratings, $F(2, 77) = 65.70$, $p < .001$, $\eta_p^2 = .63$. Follow-up pairwise comparisons with Bonferroni-corrected significance values for multiple comparisons revealed that all image categories significantly differed on valence and arousal ratings. Positive images had higher valence ratings than neutral images, which in turn had higher valence ratings than threat images, all ps $< .001$. Threat images had higher arousal ratings than positive images, which in turn had higher arousal ratings than neutral images, all ps $< .001$. Images were resized to 512×384 pixels and presented in colour against a light grey background.

Eye-tracking system

Eye movements were tracked using an SR Research Ltd. EyeLink 1000 desktop mounted eye-tracking system. This system consists of a single desk-mounted camera and IR Illuminator that tracks the pupil and corneal reflections for one eye at a rate of once per millisecond (1000 Hz). A chin and forehead rest were used during the eye-tracking task, fixing head location approximately 63.5 cm away from the computer screen. The system's default settings for acceleration and velocity thresholds were used for saccade detection.[3]

The stimuli were displayed using SR Experiment Builder Software. Areas of interest (AOIs) corresponding to the location of the emotional image and the neutral image on the screen were identified in order to determine the time spent viewing each image type. Two display screens were used in the experiment set-up. Participants viewed the stimulus displays at a resolution of 1280×1024 pixels on a Dell 1905FP 19″ LCD monitor. The experimenter received real-time feedback about eye gaze location on a second monitor, which allowed for the evaluation of system accuracy throughout the experiment and for recalibration if needed.

Procedure

Upon arrival at the study, participants provided informed consent and completed a series of self-report questionnaires on a computer in a randomised order, including the STAI, followed by paper versions of the STICSA and affect grid. Participants then completed the first block of the eye-tracking task. After the task, the affect grid and STICSA were re-administered to obtain mood and state anxiety ratings.

A standard mood induction procedure was used to induce participants into a state of anxiety (see Eich, Ng, Macaulay, Percy, & Grebneva, 2007; Jefferies, Smilek, Eich, & Enns, 2008). Participants were instructed to develop an anxious mood by listening to music that has been validated to promote an anxious mood and thinking of a personally relevant anxious thought for five minutes.[4] After five minutes, participants rated their current mood and state anxiety level on another affect grid and STICSA.

Participants then completed the second block of the eye-tracking task. At the end of the experiment, participants completed a genuineness rating, indicating how genuine their mood and state anxiety ratings were throughout the experiment.

[3] The default settings use thresholds for acceleration and velocity of 8000° per second and 30° per second, respectively, to identify a saccade. A fixation was defined as gaze behaviour that did not qualify as a saccade, given the noted acceleration and velocity thresholds.

[4] Full details of the mood-induction procedure and musical selections can be found at: http://www.psych.ubc.ca/~ennslab/Vision_Lab/Mood_Induction_Procedures.html.

Data analysis

The primary analysis examined whether trait or state anxiety differentially influenced attention to the emotional (threatening and positive) images over time (i.e., *proportion of viewing time*). Each 3-second trial was divided into six 500 ms intervals. The mean proportions of viewing time to the threatening images and to the positive images were calculated for each 500 ms interval (viewing time on emotional image/total viewing time on the emotional image + neutral image). Higher proportions indicate greater attention towards the emotional images. A 3 (Trait Anxiety: low vs. mid vs. high) × 2 (State Anxiety: baseline vs. elevated) × 2 (Image Type: threat vs. positive) × 6 (Time: 0–500 ms vs. 501–1000 ms vs. 1001–1500 ms vs. 1501–2000 ms vs. 2001–2500 ms vs. 2501–3000 ms) mixed analysis of variance (ANOVA) was conducted to examine whether trait anxiety groups, state anxiety conditions, and/or image types influenced the proportion of viewing time to images over time. All within subjects effects that violated the assumption of sphericity were adjusted using the Greenhouse–Geisser correction (adjusted degrees of freedom are noted as adj. *df*). To evaluate the time course of attention, one-sample *t*-tests were conducted to determine whether there was a bias towards or away from the emotional images at any of the 500 ms time intervals. In other words, the mean proportion of viewing time to the emotional images was contrasted with a value of .50, representing equal viewing time on the emotional and neutral images. This was done for the threat and positive images separately after the initial ANOVAs.

Secondary analyses examined whether trait or state anxiety differentially influenced attention to the emotional (threatening and positive) images across several additional eye-movement measures: (1) first fixation probability; (2) first fixation gaze duration; and (3) average fixation duration. *First fixation probability* was defined as the likelihood of initially fixating on the emotional image relative to the neutral image for each image pair and was assessed as a measure of initial orienting. The first fixation was identified for each trial as the earliest fixation on an image that lasted longer than 100 ms. The mean probability of first fixation on the emotional image relative to the neutral image was calculated (i.e., first fixations on emotional image/first fixations on emotional + neutral image). Probabilities significantly above .50 indicate that the first fixation was more likely on the emotional image than the neutral image. *First fixation gaze duration* was defined as the length of time spent looking at the initially fixated image before shifting visual attention off the image, and was assessed as a measure of maintenance of attention. *Average fixation duration* was defined as the total amount of time spent viewing a particular image type (e.g., threat) divided by the number of fixations made on that image type, averaged across each trial and was also assessed as a measure of maintenance of attention. Average fixation duration bias indices were computed by subtracting the average fixation durations for the neutral images from the average fixation durations for the emotional images (e.g., average fixation duration bias index for threatening images = average fixation duration for threatening images – average fixation duration for neutral images paired with threatening images). Mixed ANOVAs with trait anxiety as a between-subjects factor and state anxiety as a within-subjects factor were conducted on these supplementary eye-movement indices to determine the influences of trait and state anxiety on various components of attention (e.g., initial orienting, maintenance of attention), in addition to overall proportion of viewing time.

As noted earlier, two different sets of image pairs were used for the eye-tracking trial blocks (i.e., before and after the state anxiety manipulation) and the image sets were counterbalanced across experimental blocks to control for potential image set effects. To test for image set effects, the data were analysed including image set order as a between-subjects factor in all analyses. Unexpectedly, results showed that image set order interacted significantly with all of the observed effects. The image set effect will be discussed in further detail in the results section. However, it is important to note that counterbalancing of the image sets controlled for the image set effect, and any effects observed cannot be accounted for by differences in attention to the two image sets. As such, we decided that the most meaningful and parsimonious representation of results would be to report all analyses averaged over the two image set orders. Since an approximately equal number of participants viewed the image sets in each order, any image set effects are averaged out, and the effects due to the variables of interest are reported for the full sample of participants.

RESULTS

Group characteristics

Mean questionnaire scores for the low, mid, and high trait anxious groups are presented in Table 1. A MANOVA with trait anxiety as the independent factor was conducted on all of the measures (STAI, BDI-II, SDS). Low, mid, and high trait anxious groups differed significantly from one another on all measures, all ps $< .05$, with the exception of the mid and high trait anxious groups on the SDS, $p > .10$. Scores on the SDS, however, did not correlate significantly with any of the outcome variables and were therefore not used as covariates in subsequent analyses.

Manipulation check

An affect grid and the STICSA were used to obtain mood and state anxiety ratings throughout the experiment and evaluate the effectiveness of the mood induction. Participants rated the pleasantness and arousal of their mood and completed the STICSA prior to the mood induction after completing the first block of the eye-tracking task (T1) and following the mood induction prior to the second block of the eye-tracking task (T2).[5] Mean mood and state anxiety ratings are displayed in Table 2.

Increases in state anxiety on the affect grid are reflected by decreases in pleasantness and increases in arousal. Three 3 (Trait Anxiety: low vs. mid vs. high) $\times$ 2 (Time: T1 vs. T2) mixed ANOVAs were conducted on the affect grid pleasantness ratings, affect grid arousal ratings, and STICSA scores separately. For the pleasantness ratings, analyses revealed a significant a main effect of Time $F(1, 118) = 156.45$, $p < .001$, $\eta_p^2 = .57$, such that ratings were significantly lower after the mood induction (T1: $M = 3.83$, $SD = 1.45$) than before the induction (T2: $M = 5.65$, $SD = 1.28$). There was also a significant main effect of Trait Anxiety, $F(2, 118) = 7.10$, $p = .001$, $\eta_p^2 = .11$, and no significant Trait Anxiety by Time interaction, $p > .10$. Post hoc contrasts revealed that pleasantness ratings did not differ significantly between high ($M = 4.35$, $SE = 0.17$) and mid ($M = 4.57$, $SE = 0.18$) trait anxious participants, $p > .10$, but were significantly higher for low ($M = 5.18$, $SE = 0.15$) relative to high and mid trait anxious participants, $p = .01$. For the arousal ratings, analyses revealed a significant main effect of Time, $F(1, 118) = 5.04$, $p = .027$, $\eta_p^2 = .04$, such that ratings were significantly higher after the mood induction (T2: $M = 5.94$, $SD = 1.83$) than

Table 1. *Mean questionnaire scores for low, mid and high trait anxiety groups*

	Low trait anxiety (n = 49)	*Mid trait anxiety (n = 36)*	*High trait anxiety (n = 37)*	
Questionnaire	*M (SD)*	*M (SD)*	*M (SD)*	*F*
STAI	31.12 (3.95)	41.33 (2.68)	51.70 (4.20)	324.30***
BDI-II	3.06 (2.94)	8.19 (5.16)	11.05 (4.45)	41.55***
SDS	8.67 (2.09)	7.29 (2.62)	7.59 (2.41)	4.15*

Notes: SD = standard deviation; STAI = State Trait Anxiety Inventory; BDI-II = Beck Depression Inventory – II; SDS = Marlowe–Crowne Social Desirability Scale. *$p < .05$; ***$p < .001$.

[5] One participant did not complete the affect grid or STICSA at T1 and was removed from analyses.

Table 2. *Mean pleasantness, arousal, and state anxiety ratings before and after mood induction*

	T1 (before mood induction) M (SD)	*T2 (after mood induction) M (SD)*
Low trait anxiety		
Pleasantness	6.04 (1.25)	4.31 (1.56)
Arousal	5.81 (1.36)	6.25 (1.83)
State anxiety	26.92 (5.22)	33.17 (7.19)
Mid trait anxiety		
Pleasantness	5.61 (1.23)	3.53 (1.28)
Arousal	5.36 (1.40)	5.42 (1.76)
State anxiety	28.44 (5.64)	35.94 (9.24)
High trait anxiety		
Pleasantness	5.19 (1.22)	3.51 (1.30)
Arousal	5.59 (1.59)	6.05 (1.84)
State anxiety	34.86 (8.14)	43.81 (11.34)

Notes: *SD* = standard deviation; Pleasantness = rating on the pleasantness dimension on the affect grid; Arousal = rating on the arousal dimension on the affect grid; State Anxiety = score on the State-Trait Inventory for Cognitive and Somatic Anxiety (State Version).

before the mood induction (T1: $M = 5.61$, $SD = 1.45$). The main effect of Trait Anxiety and the Trait Anxiety × Time interaction were not statistically significant, $ps > .10$.

For the STICSA scores, there was a significant main effect of Time, $F(1, 118) = 150.89$, $p < .001$, $\eta_p^2 = .56$, such that State Anxiety scores were significantly higher after the mood induction (T2: $M = 37.25$, $SD = 10.27$) than before the mood induction (T1: $M = 29.80$, $SD = 7.19$). There was also a significant main effect of Trait Anxiety, $F(2, 118) = 18.15$, $p < .001$, $\eta_p^2 = .24$, and no significant Trait Anxiety by Time interaction, $p > .10$. Post hoc contrasts revealed that State Anxiety ratings did not differ significantly between low ($M = 30.04$, $SE = 1.04$) and mid ($M = 32.19$, $SE = 1.20$) trait anxious participants, $p > .10$, but were significantly higher for high ($M = 39.34$, $SE = 1.19$) relative to low and mid trait anxious participants, $p < .001$.

Based on these analyses, it can be concluded that the mood induction had its intended effect. Participants reported higher arousal and lower pleasure on the affect grid, as well as higher state anxiety as assessed by the STICSA, after the mood induction than they did prior to the mood induction. Participants also reported that their mood and state anxiety ratings throughout the experiment were genuine ($M = 7.33$, $SD = 0.92$) and accurately reflected their mood experiences. Genuineness ratings did not differ significantly across trait anxious groups, $p > .10$.

Proportion of viewing time

The mean proportions of viewing time on the emotional (threatening and positive) images for low, mid, and high trait anxious groups are presented in Table 3.

Analyses revealed a main effect of Time, $F(3.24, 385.15, \text{adj. } df) = 22.11$, $p < .001$, $\eta_p^2 = .16$, a State Anxiety × Image Type interaction, $F(1, 119) = 8.41$, $p = .004$, $\eta_p^2 = .07$, and an Image Type × Time interaction, $F(2.67, 317.44, \text{adj. } df) = 6.06$, $p = .001$, $\eta_p^2 = .05$. No other effects were statistically significant, $p > .10$, including the main effect of trait anxiety group, and thus, further analyses were conducted collapsed across trait anxiety. To facilitate interpretation of the State Anxiety × Image Type interaction, separate paired samples *t*-tests comparing attention to emotional images in the baseline and elevated state anxiety conditions were conducted for the threatening and positive images. Follow-up analyses were not conducted for the Image Type × Time interaction because it did not involve either of the variables of interest (trait and state anxiety).

A paired samples *t*-test was conducted to determine whether state anxiety conditions were associated with differential attention to threatening images. Attention to threatening images was greater overall in the elevated state anxiety condition ($M = 0.54$; $SD = 0.12$) than the baseline state anxiety condition ($M = 0.51$; $SD = 0.10$), $t(121) = 2.57$, $p = .011$.

One-sample *t*-tests were conducted to determine whether there was a bias towards or away from threat at any of the time intervals. A more conservative *p*-value of $p < .004$ was used based on the Bonferroni correction for multiple comparisons. As depicted in Figure 1, there was an attentional bias towards the threatening images in

Table 3. *Mean proportions of viewing time to threatening and positive images for low, high, and mid trait anxious groups*

	Baseline state anxiety condition			*Elevated state anxiety condition*		
	Low trait anxiety	*Mid trait anxiety*	*High trait Anxiety*	*Low trait anxiety*	*Mid trait anxiety*	*High trait anxiety*
Time interval	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*
Threatening images						
T1	0.52 (0.13)	0.51 (0.12)	0.50 (0.09)	0.53 (0.13)	0.55 (0.11)	0.52 (0.10)
T2	0.57 (0.17)	0.57 (0.15)	0.60 (0.14)	0.59 (0.17)	0.61 (0.15)	0.59 (0.15)
T3	0.56 (0.20)	0.57 (0.13)	0.56 (0.16)	0.58 (0.19)	0.58 (0.20)	0.55 (0.16)
T4	0.53 (0.20)	0.51 (0.13)	0.48 (0.16)	0.55 (0.19)	0.51 (0.22)	0.53 (0.14)
T5	0.48 (0.19)	0.50 (0.14)	0.41 (0.14)	0.50 (0.22)	0.50 (0.20)	0.49 (0.16)
T6	0.48 (0.21)	0.48 (0.15)	0.41 (0.18)	0.50 (0.24)	0.52 (0.18)	0.49 (0.22)
Positive images						
T1	0.55 (0.11)	0.56 (0.09)	0.58 (0.12)	0.57 (0.10)	0.53 (0.11)	0.53 (0.11)
T2	0.58 (0.11)	0.56 (0.10)	0.57 (0.09)	0.59 (0.10)	0.54 (0.10)	0.57 (0.10)
T3	0.56 (0.15)	0.55 (0.15)	0.53 (0.14)	0.53 (0.16)	0.57 (0.18)	0.53 (0.13)
T4	0.52 (0.15)	0.55 (0.13)	0.51 (0.15)	0.51 (0.16)	0.57 (0.17)	0.50 (0.12)
T5	0.53 (0.14)	0.54 (0.14)	0.50 (0.13)	0.50 (0.16)	0.52 (0.16)	0.54 (0.15)
T6	0.57 (0.13)	0.55 (0.17)	0.52 (0.17)	0.52 (0.17)	0.52 (0.15)	0.56 (0.16)

Note: *SD* = standard deviation.

the baseline state anxiety condition at T2 (501–1000 ms), $t(121) = 5.73$, $p < .001$, and T3 (1001–1500 ms), $t(121) = 3.84$, $p < .001$. There was also a trend towards an attentional bias away from the threatening images at T5 (2001–2500 ms), $t(121) = -2.50$, $p = .014$, and T6 (2501–3000 ms), $t(121) = -2.38$, $p = .019$, although these effects did not reach significance at the family-wise error rate. In the elevated state anxiety condition, an attentional bias towards the threatening images was present at T1 (0–500 ms), $t(121) = 3.07$, $p = .003$, T2 (501–1,000 ms), $t(121) = 6.86$, $p < .001$, and T3 (1,001–1,500 ms), $t(121) = 4.18$, $p < .001$. At all other time points, the mean proportion of viewing time to the threatening images did not differ significantly from a proportion of .50, $p > .004$. Collapsing across time, an overall attentional bias towards the threatening images relative to the neutral images was observed in the elevated state anxiety condition, $t(121) = 3.59$, $p < .001$, but not in the baseline state anxiety condition, $p > .10$.

A paired samples *t*-test was conducted to determine whether state anxiety conditions were associated with differential attention to positive images. Attention to positive images did not differ between the baseline state anxiety condition ($M = 0.55$, $SD = 0.07$) and the elevated state anxiety condition ($M = 0.54$, $SD = 0.08$), $p > .10$.

One-sample *t*-tests were conducted to contrast the mean proportion of viewing time to the positive images at each time interval against a value of .50. A more conservative *p*-value of $p < .008$ was used based on the Bonferroni correction for multiple comparisons. As depicted in Figure 2, participants demonstrated significantly greater attention towards the positive image relative to the neutral image at T1 (0–500 ms), $t(121) = 8.32$, $p < .001$, T2 (501–1000 ms), $t(121) = 9.81$, $p < .001$, T3 (1001–1500 ms), $t(121) = 4.72$, $p < .001$, and T6 (2501–3000 ms), $t(121) = 3.38$, $p = .001$. There was also a trend towards an attentional bias to the positive image at T4 (1501–2000 ms), $t(121) = 2.65$, $p = .009$, and T5 (2001–2500 ms), $t(121) = 1.97$, $p = .051$, although these effects did not reach significance at the family-wise error rate. Collapsing across time, an overall attentional bias towards the positive images relative to the neutral images was observed, $t(121) = 7.48$, $p < .001$.

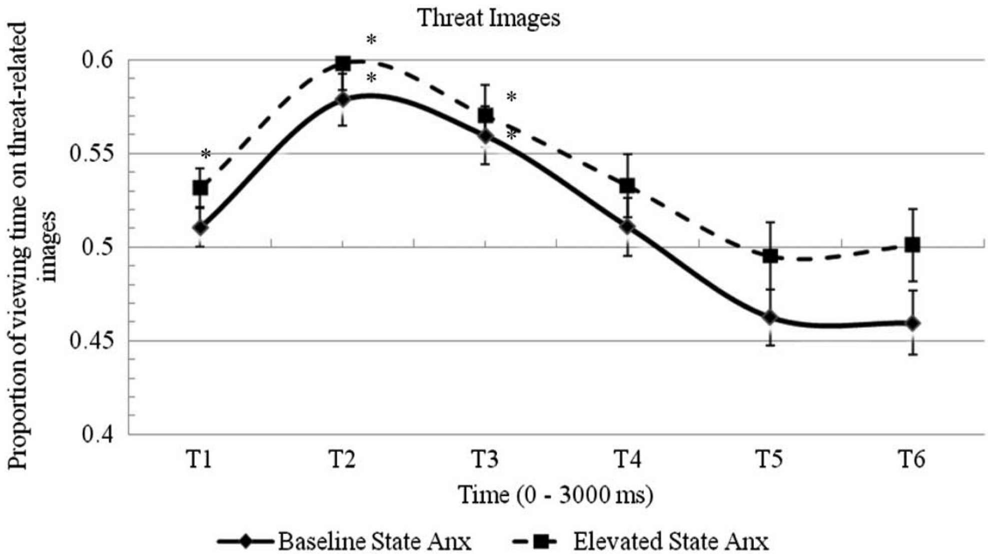

Figure 1. *Time course of the proportion of viewing time on threat images for baseline and elevated state anxiety conditions. Error bars represent* ± 2 *standard errors.* * *Indicates values greater than .50 at family-wise significance value of* $p < .05$.

First fixation probability

A 3 (Trait Anxiety: low vs. mid vs. high) $\times 2$ (State Anxiety: baseline vs. elevated) $\times 2$ (Image Type: threat vs. positive) mixed ANOVA was conducted to determine whether trait anxiety, state anxiety, and/or image type influenced the probability of first fixation on the emotional image. Analyses revealed a main effect of Image

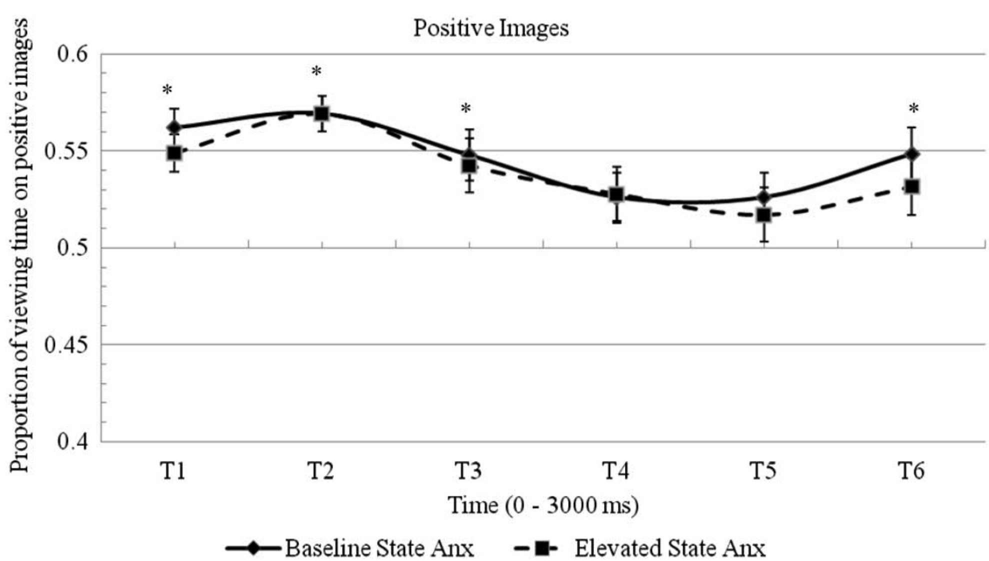

Figure 2. *Time course of the proportion of viewing time on positive images for baseline and elevated state anxiety conditions. Baseline and elevated state anxiety conditions do not differ significantly,* $p > .10$. *Error bars represent* ± 2 *standard errors.* * *Indicates values (averaged across baseline and elevated state anxiety conditions) greater than .50 at family-wise significance value of* $p < .05$.

Type, $F(1, 119) = 13.38$, $p < .001$, $\eta_p^2 = .10$, such that there was a greater probability of first fixation on the positive images ($M = 0.55$, $SD = 0.08$) than the threatening images ($M = 0.52$, $SD = 0.08$). There were no other significant effects, $p > .10$, including the main effects of trait and state anxiety, so further analyses were collapsed across these factors.

One-sample *t*-tests were conducted to determine whether the probability of first fixation on the threatening and positive images differed significantly from chance levels (.50). As depicted in Figure 3, participants demonstrated a bias in first fixation towards both the threatening images, $t(121) = 2.07$, $p = .04$, and the positive images, $t(121) = 7.67$, $p < .001$, compared to the neutral image pairs.

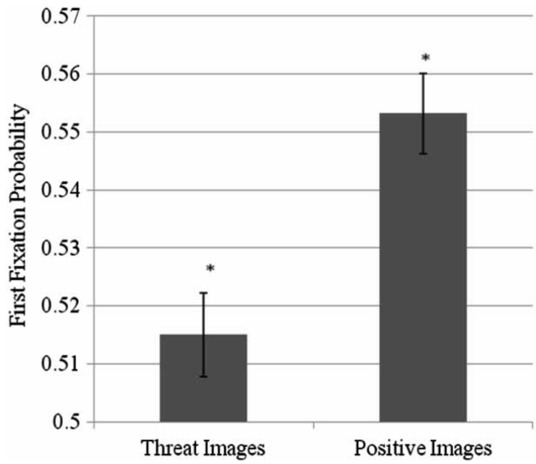

Figure 3. *First fixation probability on threat and positive images. Error bars represent ±2 standard errors. * Indicates values greater than .50 at significance value of p < .05.*

First fixation gaze duration

A 3 (Trait Anxiety: low vs. mid vs. high) × 2 (State Anxiety: baseline vs. elevated) × 2 (Image Type: threat vs. positive) × 2 (Bias Index: emotional vs. neutral) mixed ANOVA was conducted on the first fixation gaze durations. Results revealed a main effect of State Anxiety, $F(1, 119) = 5.34$, $p = .023$, $\eta_p^2 = .04$, such that first fixation gaze durations were longer overall in the elevated state anxiety condition than the baseline state anxiety condition, and a main effect of Bias Index, $F(1, 119) = 131.63$, $p < .001$, $\eta_p^2 = .53$, such that first fixation gaze durations were longer overall for emotional images (i.e., threatening and positive) than neutral images. The Image Type × Bias Index and State Anxiety × Image Type × Bias Index interactions were marginally significant, $F(1, 119) = 3.76$, $p = .055$, $\eta_p^2 = .03$, and $F(1, 119) = 3.15$, $p = .079$, $\eta_p^2 = .01$. No other effects were statistically significant, $p > .10$, including the main effect of trait anxiety, and so further analyses were collapsed across trait anxiety group.

To facilitate interpretation of the interactions, first fixation gaze duration bias scores were computed by subtracting the first fixation gaze duration for neutral images from the first fixation gaze duration for emotional images. A 2 (State Anxiety: baseline vs. elevated) × 2 (Image Type: threat vs. positive) repeated-measures ANOVA was conducted on the first fixation gaze duration bias scores. The analysis revealed a main effect of Image Type, $F(1, 121) = 4.15$, $p = .044$, $\eta_p^2 = .03$, and a marginally significant main effect of State Anxiety, $F(1, 121) = 2.82$, $p = .096$, $\eta_p^2 = .02$, which were qualified by a marginally significant State Anxiety × Image Type interaction, $F(1, 121) = 3.75$, $p = .055$, $\eta_p^2 = .03$.

To further break down the State Anxiety × Image Type interaction, paired samples *t*-tests were conducted to compare the first fixation gaze duration bias scores across state anxiety conditions for threat and positive images separately. As depicted in Figure 4, the first fixation gaze duration bias scores were significantly greater in the elevated state anxiety condition than the baseline state anxiety condition for the threatening images, $t(121) = -2.18$, $p = .031$. The first fixation gaze duration bias scores did not differ across state anxiety conditions for the positive images, $p > .10$.

Average fixation duration

A 3 (Trait Anxiety: low vs. mid vs. high) × 2 (State Anxiety: baseline vs. elevated) × 2 (Image Type:

threat vs. positive) mixed ANOVA was conducted on the average fixation duration bias indices to determine whether trait anxiety groups, state anxiety conditions, and/or image types were differentially related to the average fixation duration. Results showed a main effect of State Anxiety, $F(1, 119) = 4.97$, $p = .028$, $\eta_p^2 = .04$, such that the average fixation duration bias indices were greater overall in the elevated state anxiety condition ($M = -1.57$, $SE = 1.94$) than in the baseline state anxiety condition ($M = -7.77$, $SE = 2.15$), and a main effect of Image Type, $F(1, 119) = 23.00$, $p < .001$, $\eta_p^2 = .16$, such that average fixation duration bias indices were greater overall for threatening images ($M = 5.19$, $SE = 2.77$) than positive images ($M = -14.54$, $SE = 2.31$).

One-sample *t*-tests were conducted to determine whether the average fixation duration bias indices for threatening and positive images differed significantly from zero (i.e., to determine whether average fixation durations for the emotional images differed significantly from average fixation durations for the neutral images) in the baseline and elevated state anxiety conditions. The average fixation duration bias index for threatening images did not differ significantly from zero in the baseline state anxiety condition, $p > .10$, but was significantly greater than zero in the elevated state anxiety condition, $t(121) = 2.61$, $p = .01$, such that participants had longer fixations on the threatening images than the neutral images for the threatening–neutral image pairs under elevated state anxiety. The average fixation duration bias index for positive images was significantly smaller than zero in both the baseline and elevated state anxiety conditions, $t(121) = -4.70$, $p < .001$ and $t(121) = -4.07$, $p < .001$, respectively, such that participants had longer fixations on the neutral images than the positive images for the positive–neutral image pairs.

Image set effect

As mentioned in the data analysis section of the methods, inclusion of image set order as a between-subjects factor in the analyses revealed that image set order interacted significantly with

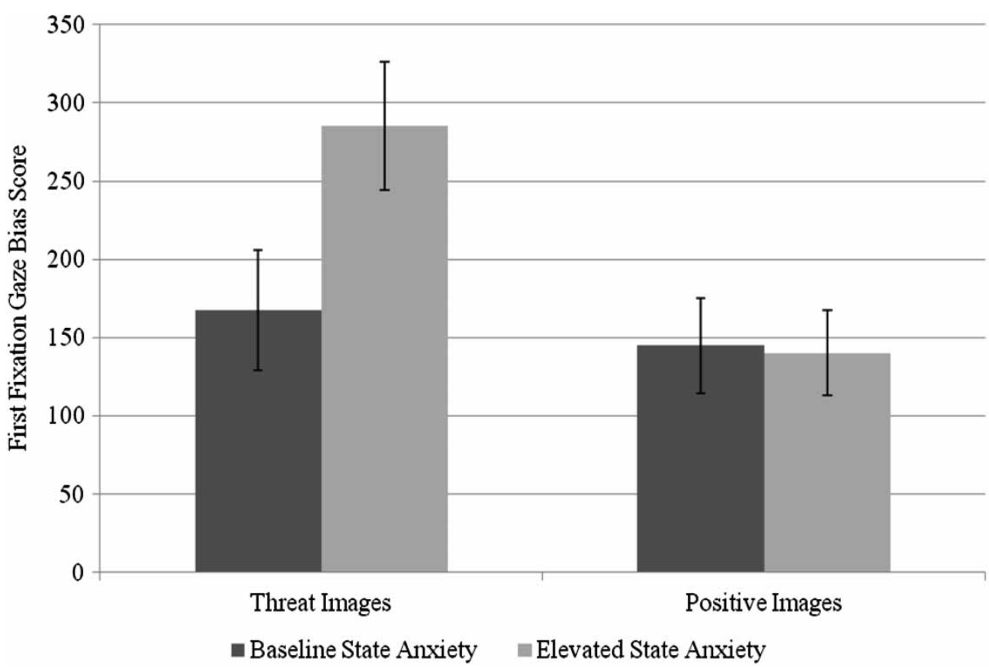

Figure 4. *First fixation gaze bias score on threat and positive images. Error bars represent ±2 standard errors.*

all of the observed effects. Inspection of the results revealed that the pattern of results produced by image set two was quite discrepant from the pattern of results produced by image set one, such that the effects of state anxiety (e.g., increase in the proportion of viewing time to threatening images) were only apparent with image set one. To determine the cause of the discrepancy, we examined the pattern of attention averaged over participants to each image pair separately. This examination revealed that image set two contained several image pairs that produced inconsistent attentional patterns. Our observation suggested that several of these inconsistent image pairs contained neutral images that included attractive men or women, sexual connotations (e.g., a man and a woman kissing), or visually complex scenes that would conceivably require more time to process. Although these images were rated as neutral in valence in the IAPS rating system, we infer that they tended to attract more attention from participants due to their content. Thus, image set two suffered from several unfortunate stimulus pairings, such that some of the "neutral" images in this set tended to attract participants' attention, regardless of state anxiety conditions. However, the image set effect is eliminated as a cause of the observed state anxiety effects by our counterbalancing the order of presentation of the two image sets.

Furthermore, through visual inspection of the individual trial data, we identified five problematic image pairs from image set two and removed them from the dataset.[6] Analyses on these data showed that the pattern of results obtained with image set one and image set two were more congruent than with the original data. Averaging across both presentation orders of the two image sets, attention to threatening images was significantly greater in the elevated state anxiety condition ($M = 0.55$, $SD = 0.12$) than the baseline state anxiety condition ($M = 0.52$, $SD = 0.11$), $t(121) = 3.17$, $p = .002$. Thus, removing the five problematic image pairs from image set two increased the strength and statistical significance of the overall state anxiety effect on attention to threatening images and yielded more congruent patterns of results between the two image sets. However, these results should be interpreted with caution given the post hoc nature of the analyses and the reduced number of trials in image set two after the problematic image pairs were removed.

DISCUSSION

The current study examined the associations between trait anxiety, state anxiety, and attentional deployment to threatening and positive images over time in order to better understand the relative contributions of trait and state anxiety to anxiety-related attentional biases to emotional information. The results suggest that state anxiety is associated with increased attention to threatening stimuli and are consistent with previous studies that have found a state-anxiety-related attentional bias to threat (Bradley et al., 2000; Fox et al., 2001; Mathews & MacLeod, 1985; Mogg et al., 1997). Analyses of the secondary eye-movement measures (i.e., first fixation gaze duration and average fixation duration) showed state anxiety effects as well; under elevated state anxiety, attention was maintained longer on threat images once they were fixated. There was an overall attentional bias to positive images and a bias in first fixation towards emotional versus neutral images, but these biases were not specific to individuals with high levels of trait or state anxiety. Given that elevations in state anxiety were associated with an increase in attention to only the threatening images, these findings are consistent with the bulk of studies that have found support for the negative selectivity hypothesis (e.g., Bradley et al., 1998; Bradley et al., 2000; Ruiz-Cabellero & Bermúdez, 1997). The idea that state anxiety is related to biases to emotional stimuli generally whereas the interaction between trait and state anxiety is related to biases to

[6] Image pairs removed: (Threatening–Neutral) 6360–4631, 6560–4605, 6570–6570.2, 6571–2580, 9423–2560.

negative stimuli specifically was not supported here (e.g., Rutherford et al., 2004).

Taken together, the findings suggest that state anxiety enhances attention for threatening stimuli, but not positive stimuli, and are consistent with an associative network model (Bower, 1981). According to this model, when an individual experiences an increase in state anxiety, associated anxiety-related thoughts and memories are activated and there is a shift towards the selective processing of mood-congruent information. In the context of an associative network model, we would expect state anxiety to be associated with increased attention to threatening images, which are congruent with the anxious state. These results also fit within theories regarding the adaptive function of emotion (LeDoux, 1996; Oatley & Johnson-Laird, 1987). The basic emotion of fear likely provided an evolutionary advantage to an organism by allowing it to rapidly detect and allocate attentional resources to danger in its environment (LeDoux, 1996). The amygdala is central to this fear system, and its activity is associated with the detection and processing of fear-relevant information (Lang, Davis, & Öhman, 2000; Öhman & Mineka, 2001). It is postulated that anxiety is related to the activation of the fear system (Davis, 1997). On an intuitive level, elevations in state anxiety, such as in response to situational factors (e.g., an attack), would seem to be particularly related to the activation of the amygdala-centred fear system, in turn leading to the enhanced detection and processing of threatening stimuli.

Neuroscience research has corroborated the notion that state anxiety in particular is associated with the amygdala response to threatening stimuli. Bishop and colleagues (Bishop, 2009; Bishop, Duncan, & Lawrence, 2004; Bishop, Jenkins, & Lawrence, 2007) have found evidence that heightened state anxiety is associated with increased activity in brain regions involved in the detection and evaluation of threat (e.g., amygdala), whereas trait anxiety is related to decreased functioning in regions involved in the control of attention in the presence of competing stimuli (e.g., prefrontal cortex). These neuroimaging results also converge with a recent study that found that trait and state anxiety were differentially related to the functioning of the executive control, alerting, and orienting attentional systems (Pacheco-Unguetti, Acosta, Callejas, & Lupianez, 2010). Trait anxiety was associated with deficits in the executive control network, while state anxiety was related to an over-functioning of the alerting and orienting networks. Thus, findings from neuroimaging and cognitive work have important implications for research on anxiety-related attentional biases and propose that increased state anxiety enhances detection and orientation of attention to threat, whereas increased trait anxiety causes difficulty with disengagement from threat once it has been attended.

Why, then, was there no effect of trait anxiety on attention to the threatening images? Since trait anxiety is thought to be associated with the reduced recruitment of brain regions involved in controlling attention in the presence of competing stimuli (Bishop, 2009; Bishop et al., 2007), paradigms that require participants to disengage from threatening stimuli and/or attend to other stimuli in the presence of threatening distracters may be most appropriate for observing a trait-anxiety-related attentional bias. Indeed, some studies have found that high trait anxious individuals have slower disengagement from, rather than facilitated detection of, threatening material compared to low trait anxious individuals (e.g., Koster, Crombez, Verschuere, & De Houwer, 2004; Koster, Crombez, Vershuere, Van Damme, & Wiersema, 2006). Similarly, a recent study that combined a dot-probe task that required attentional disengagement with eye-movement tracking found that social anxiety was associated with difficulty disengaging attention from threatening facial expressions (Schofield et al., 2012). The present study used a passive viewing task to measure natural patterns of attention to threatening and neutral images; participants were not instructed to control or direct their attention to specific images. As such, this paradigm did not require participants to recruit brain regions associated with attentional control and may not be suitable for detecting an effect of trait anxiety on attention. Our findings are consistent with some previous studies using passive eye-tracking paradigms that have also failed to detect a trait-anxiety-related attentional bias (Bradley et al., 2000; Nelson et al., 2012).

Furthermore, the situation itself was not objectively threatening, and the threat value of the images was likely quite readily appraised. It may be the case that attentional biases may be more evident when the threat value of a stimulus is more difficult to appraise, such as when the stimulus is unpredictable or ambiguous. In such cases, individuals with high trait anxiety may deploy more attention to the stimulus than would those low in trait anxiety as they process information about the stimulus and evaluate threat. In future research it would be interesting to employ paradigms that assess both passive and controlled attention in order to disentangle the effects of trait and state anxiety on the various components of attention towards threatening stimuli, as well as vary parameters of the stimulus relevant to assessing how threatening it is.

There are a number of limitations to the present study that warrant consideration. Some participants may have been in crossed anxiety states (i.e., high state of anxiety in the baseline state anxiety condition or low state of anxiety in the elevated state anxiety condition) due to personal or contextual factors. Mood and state anxiety ratings confirmed that participants showed an overall increase in state anxiety from the baseline to elevated state anxiety condition. However, the possibility that some participants may have been in crossed anxiety states remains, and it would be of interest for future research to contrast the elevated state anxiety condition with a low state anxiety condition generated by a calming mood induction. Moreover, although the state anxiety induction appeared to have its intended effect as evidenced by increases in self-reported state anxiety, the use of behavioural or physiological indices of state anxiety (e.g., startle response, skin conductance, heart rate) in future research would corroborate these self-report measures.

Since all participants completed the eye-tracking task in the baseline state anxiety condition first and in the elevated state anxiety condition second, it cannot be ruled out that order effects influenced the results observed here. The consistency of the effect of state anxiety on attention across a number of eye-movement measures, as well as the specificity of the effect of state anxiety on attention to threatening images and not to positive images, makes it unlikely that order effects could fully account for these results. Still, this study should be repeated using a between-subjects state anxiety manipulation in order to investigate this possibility.

Finally, as described in the methods and results, an image set effect was observed such that attentional patterns differed for image set one versus image set two. Counterbalancing of the image set order ensured that any observed results are not due to the potential confound of the order in which the image sets were viewed. Thus, the image set effect does not limit the theoretical conclusions that can be drawn from this study about the effect of state anxiety on attention to threat. However, the error introduced by the inconsistent image pairs may have reduced the power of this study to detect a trait anxiety effect. The IAPS images consist of scenes, which may be more ecologically valid than words or facial expressions as used widely in other studies of attentional bias. However, the complexity of the scenes in the IAPS images makes it difficult to adequately match the emotional and neutral images presented simultaneously in a trial. All of the images in the study were matched by the presence of people, eliminating a potential confound of previous studies, but matching on the basis of colour, brightness, complexity, and content was done roughly by visual inspection. Visual attention is affected by various attributes of images (e.g., Epstein & Ward, 2010; Parkhurst, Law, & Niebur, 2002), and thus, the increase in ecological validity allotted by the use of the IAPS images comes at the potential cost of additional error resulting from inadequate matching of emotional and neutral images.

These limitations notwithstanding, the present study holds important implications for future research and models of anxiety-related information processing. These results provide evidence that trait and state anxiety have separable effects on the attentional response to threatening stimuli and emphasise the need for future research to consider both trait and state anxiety in the study of anxiety-related attentional biases. While these results do not discount the influence of trait anxiety on attention to threat, they emphasise the role of state anxiety on attention to threat, a role which has often been overlooked in previous work in this area. Recent work has suggested that under extreme stress or life-threatening danger, individuals direct attention *away* from threat (Bar-Haim et al., 2010; Wald et al., 2011). Future studies that examine attentional biases under conditions of naturally occurring extreme stress or anxiety may provide insight as to how varying degrees of state anxiety differentially affect patterns of attention to threat. Trait anxiety did not affect patterns of attention to threat, although it remains for future research to determine whether trait anxiety effects may be more consistently observed using paradigms that require participants to control attention. Such work would have significant implications for theories of anxiety-related attentional biases, as current models do not account for separable influences of trait and state anxiety on the functioning of different attentional systems.

Future research might extend the applicability of these results to theories and treatment of clinical anxiety by examining the effects of trait and state anxiety in clinically anxious samples. The present study used an analogue sample of low, mid, and high trait anxious undergraduate students. Although analogue samples are common in the literature on anxiety-related attentional biases, trait anxiety effects on attention to threat may be more readily observed in comparisons of clinically anxious and non-anxious individuals. Furthermore, attention may be differentially affected by a state anxiety induction in clinically anxious individuals compared to an analogue sample of high trait anxious individuals. Thus, examinations of trait and state anxiety effects on attention to emotional images using clinical samples would be a valuable contribution to the literature.

Such investigations may shed light upon the issue of whether attention modification programmes, such as those that train attention away from threatening stimuli or improve attentional control more generally, could be effectively used in the treatment of anxiety. The current results suggest that individuals in a state of anxiety demonstrate attentional biases to threatening relative to neutral stimuli, regardless of trait anxiety levels. Accordingly, an attentional bias to threat may be a by-product of elevated state anxiety rather than a cause of anxiety, and attention training programmes designed to eliminate the bias may not be addressing the root of the anxiety problem. Further, it may be unwise to use attention training to attempt to eliminate an adaptive attentional bias to threat that is characteristic of individuals in a state of anxiety. On the other hand, we previously discussed that impaired attentional control may be related to trait anxiety, and could possibly represent one mechanism by which anxiety problems develop and persist. Thus, attention modification approaches that train individuals to disengage attention from threatening stimuli, or that improve general ability to control attention in the presence of threat, could indeed prove to be effective and efficient treatments for anxiety. It remains for future research to further investigate how trait and state anxiety influence the functioning of various attentional systems, and how this knowledge can be used to improve the prevention and treatment of anxiety and its disorders.

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