Attentional bias to threat: an investigation of psychological predictors beyond trait anxiety

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Abstract

Attentional bias to threat (ABT) refers to the tendency to more rapidly orient attention to threatening stimuli, as compared to neutral or pleasant stimuli. Issues with the reliability of this phenomenon have been raised and little is currently known about individual differences that may contribute to ABT. This online study aimed to replicate ABT in trait anxiety and identify psychological predictors of ABT using both dot probe and flanker tasks comprising emotional images. Undergraduate students completed various psychological questionnaires, followed by the ABT tasks. Contrary to expectations, faster responses and enhanced accuracy for positive stimuli were found in a low trait anxiety sub-sample ($n = 33$) in the dot probe task, while overall slower performance among a high trait anxiety sub-sample ($n = 34$) was found in the flanker task. Higher ratings of state anxiety and stress and lower ratings of calmness were associated with greater flanker ABT scores in the overall sample ($N = 111$), while higher scores on facets of trait mindfulness and personality were associated with greater dot probe ABT scores. Trait anxiety was not associated with either ABT score. These findings highlight the difficulties replicating ABT in anxious individuals using behavioural tasks and indicate the importance of measuring state and trait psychological experiences when investigating ABT in experimental settings. Further replication of predictors is required.

Keywords Attentional bias · Attention · Anxiety · Personality · Emotions

Introduction

Attentional bias to threat (ABT) refers to the tendency to rapidly and preferentially attend to threatening stimuli relative to neutral or positive stimuli (Cisler & Koster, 2010). ABT has been extensively researched and found to be more pronounced in individuals with high levels of anxiety (see Bar-Haim et al., 2007). Furthermore, ABT has been proposed as a factor that maintains anxiety symptoms, whereby high anxiety individuals tend to be more easily distracted from threat-related or ambiguous information and maintain greater attentional focus on potentially threatening stimuli

to the exclusion of other information (Bar-Haim et al., 2007; Cisler & Koster, 2010; Eysenck et al., 2007). However, variability in the expression of ABT has been noted (MacLeod et al., 2019; McNally, 2019) and it is not clear which individual factors predict ABT. Enhanced understanding of this would help to quantify this attentional process and further examine its complex role in the aetiology of anxiety and clinical interventions for anxiety symptoms.

Attentional networks in anxiety

According to Petersen and Posner (2012), attention comprises three distinct networks. The alerting network allows tonic (sustained) and phasic (acute) vigilance in task performance (Petersen & Posner, 2012). The orienting network facilitates selective attention to sensory input and is directed by cortical regions such as the superior parietal cortex and temporal-parietal junction (Petersen & Posner, 2012). The executive control network enables voluntary functions such as overriding dominant responses and inhibiting distractors, and involves frontal areas such as the anterior cingulate

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cortex (Petersen & Posner, 2012). According to attentional control theory, individuals with high levels of anxiety (e.g., trait anxiety) have increased stimulus-driven, bottom-up attentional processing and disrupted goal-directed, top-down attentional processing in response to threat (Eysenck et al., 2007). It is possible that this may be underpinned by enhanced activity of the orienting network proposed by Petersen and Posner (2012), coupled with disruption to their proposed executive control network, in the presence of threatening information (Eysenck et al., 2007). Attentional control theory, and the research underpinning this work, largely pertains to *trait anxiety*; the general propensity to experience states characterised by worry, perceived threat, and fear (Eysenck et al., 2007).

Bottom-up or attentional orienting processes can be examined in dot probe tasks (Cisler & Koster, 2010). High relative to low anxiety participants typically demonstrate faster responses to dots appearing in the same location as threatening images (e.g., angry faces), as compared to neutral images (e.g., neutral faces), suggesting enhanced attentional orienting or facilitated attention to threat (Bar-Haim et al., 2007; Cisler & Koster, 2010). Faster responding to angry faces on the dot probe task has been observed in participants with high trait anxiety (Eldar et al., 2010) and a diagnosis of Generalised Anxiety Disorder (GAD; Bradley et al., 1999). Such findings of ABT have been suggested to reflect a form of *attentional hypervigilance* (Bar-Haim et al., 2007; Eldar et al., 2010). Angry faces may be more readily identified than other emotional expressions due to activation of an evolutionary threat-detection system (e.g., Fox et al., 2000; Öhman, 1993), whereby the individual conveying anger is attended to as the *source* of the threat (Davis et al., 2011). *Difficulty with disengagement* from threat has also been shown in dot probe tasks by slowed responses to targets that replace neutral images on trials where a non-target threatening image is also shown (Taylor et al., 2016).

Executive control processes can be examined in flanker tasks where responses are typically slower to target stimuli flanked by incongruent compared to congruent stimuli (Eriksen & Eriksen, 1974; Folstein & Van Petten, 2008). This has been referred to as an '*interference effect*' and is thought to reflect difficulty with *interference suppression* due to stimulus competition (Brydges et al., 2012; Qi et al., 2014) and involve top-down control of attention to resolve conflict (Petersen & Posner, 2012). Using a flanker task with happy or angry (threat-related) faces, Yu et al. (2018) found individuals with GAD, relative to healthy controls, showed overall slowed reaction times and poorer accuracy, suggesting general difficulties with attentional control. In other flanker-based tasks using emotional stimuli, slowed responding to targets flanked by threatening/negative distractors relative to neutral distractors has been found in both individuals with high levels of social anxiety symptoms

and a diagnosed anxiety disorder (Chen et al., 2016; Lichtenstein-Vidne et al., 2017). This has been interpreted as a form of *threat-specific interference* which occurs due to difficulty supressing distraction from irrelevant threat-related information (Chen et al., 2016; Lichtenstein-Vidne et al., 2017; Mattia et al., 1993). While ABT has been observed across anxiety disorders, it has also been repeatedly observed in trait anxiety (e.g., Bar-Haim et al., 2007). Further, it has been suggested that ABT may be a component of trait anxiety more generally (see Cisler & Koster, 2010).

Individual differences in attentional bias to threat

The magnitude of the effect for ABT in anxious populations has been inconsistent in meta-analyses, with some studies finding no effect (see Bar-Haim et al., 2007; Kruijt et al., 2019). Furthermore, issues of low reliability with tasks designed to capture ABT has been identified in previous experimental studies (Evans & Britton, 2018; Kappenman et al., 2014; Price et al., 2015). This has led to speculation that there is considerable variability in the individual expression of ABT, and that ABT may not be a stable or consistent characteristic of anxiety (MacLeod et al., 2019; McNally, 2019). Issues relating to the reliability and psychometric properties of tasks designed to measure ABT are inherently related to the expression of ABT as a phenomenon. However, the present study sought to focus specifically on psychological factors that may explain variance in ABT as a phenomenon, as measured by behavioural tasks, as opposed to testing or evaluating the reliability of the tasks used. While the impact of trait anxiety or anxiety symptoms on ABT, and the relationship between trait anxiety or anxiety symptoms and ABT, has been extensively researched, to date, limited research has explored further individual differences that may contribute to ABT findings, and whether trait anxiety explains variance after controlling for these factors. In the following section, we outline key areas of individual difference within the domains of attention, mood, psychological symptomatology, and personality that may play a role in the expression of ABT.

Previous findings suggest pre-existing attentional abilities may influence ABT. For example, Angelidis et al. (2018) found those with higher electroencephalographic (EEG) theta/beta ratio (suggesting low attentional control) directed attention towards mild threat images and avoided high threat images. Furthermore, ability to shift attention (a facet of attentional control) moderates the relationship between social anxiety and disengagement from threat-stimuli (emotional faces), with greater social anxiety symptoms associated with slower disengagement from threat at lower levels of shifting ability (Taylor et al., 2016). Similar patterns have been identified in individuals with high levels of trait anxiety (Derryberry & Reed, 2002). Predictors of attentional bias to social threat have

also been examined in middle school children (e.g., Helzer et al., 2009), with fearful temperament associated with ABT in those with lower levels of attentional control. Therefore, there is evidence to suggest that greater levels of attentional control and social anxiety may be associated with lower and greater ABT, respectively, with this depending on the stimuli used.

There may also be individual differences in ABT due to comorbidity of anxiety with other mental health difficulties and personality traits that are related to differential attentional responses to threatening or negative information. For example, there is evidence of attentional biases to threat/negative information in anxiety disorder but not a depressive disorder, using both dot probe and flanker-based tasks (Lichtenstein-Vidne et al., 2017; Mogg & Bradley, 2005). Further, Jiang et al. (2017) found participants exposed to a stress-evoking task, relative to controls, did not show ABT on a dot probe task, suggesting acute stress buffered the expression of ABT. However, individuals with high levels of worry show ABT (Georgiades et al., 2021; Williams et al., 2014). Further, greater levels of mood dysregulation have been associated with greater attentional bias towards threatening faces (Hommer et al., 2014), while other work has found that greater difficulties with emotional regulation have been associated with greater variability in ABT (Bardeen et al., 2017). Beyond clinical symptoms or disorders, different personality traits may influence ABT on behavioural tasks. For example, a Behavioural Activation System (BAS) has been proposed to underly reward sensitivities, while a Behavioural Inhibition System has been proposed to underly sensitivity to punishment (Gray, 1987). Reward and punishment-related stimuli readily capture attention when of personal relevance (Watson et al., 2019). Anxious individuals are prone to avoidance of punishment or threat (Perkins et al., 2010), and thus may be more driven by a Behavioural Inhibition System. Furthermore, while openness to experience is related to greater stress resilience (Williams et al., 2009), neuroticism shares a relationship in the opposite direction (Oshio et al., 2018), with individuals high in neuroticism prone to responding reactively to emotional information (Thake & Zelenski, 2013). Therefore, while depression may not share a relationship with ABT, other forms of psychological distress such as emotional dysregulation and worry may share positive relationships. Moreover, greater neuroticism and punishment sensitivity may be associated with greater ABT, while such a relationship may not be expected in those with greater reward sensitivity and openness to experience.

The role of mindfulness in attentional bias to threat

Mindfulness involves the practice of non-judgemental, present-moment awareness (Tang et al., 2015). Mindfulness meditation practice has been proposed to improve aspects of self-regulation through practice of emotional regulation, self-awareness, and attentional control (Hölzel et al., 2011; Tang et al., 2015). Therefore, there is potential overlap between attentional processes that mindfulness has been proposed to train, and processes thought to be impacted by anxiety. Thus, ABT may be affected by one's mindfulness experience or ability. For example, high levels of the 'non-reacting' facet of trait mindfulness (pre-existing mindful ability in everyday life) has been associated with faster disengagement from distracting emotional stimuli (Makowski et al., 2019). Other individual factors are likely to interact with such relationships. MacDonald and Olsen (2019) found levels of 'focusing' attentional control ability mediated a negative relationship between trait mindfulness and anxiety. Further, Norris et al. (2018) found faster reaction times on incongruent flanker trials following a 10-minute mindfulness induction (relative to control) among individuals with low (but not high) neuroticism, suggesting this personality trait may moderate the effects of mindfulness on attentional processes. Moreover, Xin et al. (2023) found experienced meditators did not show ABT on a dot-probe task, while non-experienced meditators did. Additionally, a negative relationship has been found between ABT and trait mindfulness in individuals with social anxiety disorder (Packard et al., 2023). Based on current literature and theory, greater levels of trait mindfulness may be related to lower levels of ABT. To date, no study has looked at mindfulness predictors conjointly with trait anxiety or other psychological predictors of ABT in adults.

The current project

Aim

To date, limited research has directly explored multiple predictors of ABT to identify the unique variance explained by psychological constructs in tasks that distinguish automatic and voluntary attentional processes. The present study aimed to replicate ABT in trait anxious individuals using tasks that tap into both orienting and executive control networks of attention in the same study. Tasks include a dot probe task with emotional faces (measuring bottom-up attentional processes related to the orienting network) and a novel flanker task with threatening and neutral images (measuring top-down attentional processes related to the executive control network). A large sample of individuals with varying levels of trait anxiety was used to examine the relationship between anxiety symptoms and ABT. Group differences were examined by forming high trait anxiety (those with scores within an upper range) and low trait anxiety (those with scores within a lower range) groups. A second aim was to identify unique psychological predictors of ABT among the whole

sample (e.g., personality, mindfulness, clinical symptoms, and state measures) and examine the relationship between ABT and trait anxiety after controlling for these unique predictors.

Hypotheses

It was expected that participants with high relative to low trait anxiety would show greater attentional hypervigilance to threat, as indexed by faster reaction times (RTs) in response to dots replacing angry (threat-related) relative to neutral or happy faces on an emotional dot probe task. It was expected that participants with high relative to low trait anxiety would show difficulty disengaging from threat, as indexed by slowed responses to dots replacing neutral or happy faces on trials where a non-target angry face is also present. It was expected that participants with high relative to low trait anxiety would show threat-specific interference, as indexed by slowed RTs in response to incongruent trials with threat relative to neutral flankers on an emotional flanker task.

To assess the influence of other psychological predictors on ABT, an exploratory analysis was conducted using a range of psychological measures, with a predetermined criteria used for inclusion in the analysis. Based on previous research and theory concerning anxiety, attention, and mindfulness, several directional hypotheses were made. It was hypothesised that generalised and social anxiety symptoms, and state anxiety, would be positively associated with ABT scores (higher scores indicate greater ABT) on both dot probe and flanker tasks. It was also hypothesised that self-reported attentional control, trait mindfulness, and state mindfulness would be negatively associated with ABT scores on both tasks. Given the paucity of research, no directional hypotheses were made in relation to worry, psychological distress, depression, state stress, difficulties with emotion regulation, personality traits, or aspects of punishment (i.e., BIS) and reward sensitivity (i.e., BAS). Finally, in light of theory largely pertaining to trait anxiety that has proposed a role of ABT in anxiety, and extensive research supporting the presence of ABT in high trait anxious individuals, it was hypothesised that trait anxiety would be positively associated with ABT scores and explain additional variance after controlling for other unique predictors .

Method

Participants

The study was approved by the University of Tasmania Human Research Ethics Committee and was performed in line with the ethical standards of the Declaration of Helsinki (1964).

All participants provided informed consent to participate in the present study. Participants were primarily undergraduate psychology students at the University of Tasmania who participated for course credit, and two other participants received a gift voucher for participation. Participants were excluded if they were aged under 18 years, not living in Australia, had current epilepsy, a past or current mental health diagnosis (other than depressive or anxiety disorder) as per self-report, used current psychoactive medication (other than anti-depressants), had previous brain injury or surgery, were not able to read written English fluently, or did not have normal or normal-corrected vision. Participants were also excluded if they regularly used illicit substances in the past 6 months (around weekly) or if they were intoxicated.

A total of 159 participants self-enrolled in the study. Participants were first removed due to missing questionnaire data ($n = 3$) and substantial missing task data ($n = 4$). Those with mean accuracy scores below 70% on any individual task condition ($n = 35$) and extreme outliers on any individual task condition for RT (>1.5 x IQR; $n = 2$) or accuracy (>1.5 x IQR; $n = 4$) were then removed. The final sample comprised 111 participants (78 females) aged 18–60 years ($M = 28.1$, $SD = 10.9$). Participants with scores higher than the 70th percentile (≥ 50; $n = 34$) and below the 30th percentile (scoring ≤ 37; $n = 33$) on the Trait Form of the State-Trait Anxiety Inventory (STAI; Spielberger, 1983) in the present sample, formed high and low trait anxiety groups, respectively. These cut-off scores, and the resultant group STAI-trait means, are consistent with previous studies comparing high and low trait anxiety groups (e.g., Eldar et al., 2010; Qi et al., 2014). A priori power analysis indicated that sample sizes of 14 per group were sufficient to detect moderate sized effects ($f^2 = 0.25$, $\alpha = .05$, power $= .80$) for the within-between interaction term of interest. Moderate sized effects have been observed in a previous meta-analysis of ABT (see Bar-Haim et al., 2007). A priori power analysis (G*Power 3.1.9.4; (Faul et al., 2009) indicated a sample size of 139 was sufficient to detect moderate effects ($f^2 = 0.15$, $\alpha = .05$, power $= .80$) for multiple regression with up to 15 predictors, and fewer variables were expected based on the analysis plan outlined in the data analysis section.

Materials

Questionnaire measures

The state-trait anxiety inventory form Y-2 (STAI; Spielberger, 1983) The Trait form of the STAI measures the tendency to experience apprehension, fear, and worry. Twenty items are rated on a 4-point scale (1 = almost never to 4 = almost always), with higher scores indicating greater anxiety.

Evidence of convergent validity with other anxiety inventories has been found for the trait form (e.g., Antony et al., 1998; Creamer et al., 1995). Excellent internal consistency was found for the STAI-Trait in the current sample (Cronbach's α = .95).

Generalized anxiety disorder 7-item scale (GAD-7; Spitzer et al., 2006) The GAD-7 measures symptoms of generalised anxiety disorder such as frequent and interfering worry, and related fear and tension. Participants indicate how much symptoms have bothered them over the last two weeks by rating seven items on a 4-point scale (0 = not at all to 3 = nearly every day). Higher scores indicate greater generalised anxiety symptoms. The GAD-7 has shown good convergent validity with other measures of anxiety (Spitzer et al., 2006) and divergent validity with measures of depression (Rutter & Brown, 2017). Excellent internal consistency was found for the GAD-7 in the current sample (Cronbach's α = .93).

Penn state worry questionnaire (PSWQ; Meyer et al., 1990) The 16-item PSWQ measures worry and the extent to which it is pervasive and excessive. Items are rated on a 5-point scale (1 = not at all typical of me to 5 = very typical of me), with higher scores indicating greater worry. The PSWQ has shown good convergent validity with other measures of anxiety and divergent validity with measures of depression (Brown et al., 1992). Excellent internal consistency was found for the PSWQ in the current sample (Cronbach's α = .95).

The social phobia inventory (SPIN; Connor et al., 2000) The 17-item SPIN assesses social anxiety symptoms (e.g., anxiety and avoidance in social contexts). Items are rated on a 5-point scale (0 = not at all to 4 = extremely), with higher scores indicating greater social anxiety. The SPIN has demonstrated good test-retest reliability (.89) and convergent validity with other measures of social anxiety (Antony et al., 2006; Connor et al., 2000). Excellent internal consistency was found for the SPIN in the current sample (Cronbach's α = .96).

The patient health questionnaire depression scale (PHQ-8; Kroenke et al., 2009) The PHQ-8 measures symptoms of depression. Participants indicate how much symptoms have bothered them over the last two weeks by rating eight items on a 4-point scale (0 = not at all to 3 = nearly every day). Higher scores indicate greater depression. Excellent internal consistency was found for the PHQ in the current sample (Cronbach's α = .92).

The Kessler psychological distress scale (K10; Kessler et al., 2002) The K10 comprises ten items to assess levels of psychological distress over the last four weeks, rated on a 5-point scale (1 = none of the time to 5 = all of the time).

Greater scores indicate higher levels of psychological distress. Excellent internal consistency was found for the K10 in the current sample (Cronbach's α = .93).

Difficulties in emotional regulation scale (DERS-18; Victor & Klonsky, 2016) The DERS-18 measures difficulties in identifying, accepting, and managing emotions and comprises 18 items rated on a 5-point scale (1 = almost never/0–10% to 5 = almost always/91–100%). The total score (Cronbach's α = .93) and six subscales of the DERS-18 were used with the current sample: nonacceptance (Cronbach's α = .93), goal-directed behaviour (Cronbach's α = .93), impulse control (Cronbach's α = .93), emotional awareness (Cronbach's α = .86), access to regulation strategies (Cronbach's α = .89), emotional clarity (Cronbach's α = .86). Higher scores are indicative of greater problems with emotion regulation. The DERS-18 has demonstrated convergent validity with other measures related to emotion dysregulation (Victor & Klonsky, 2016).

The mini-international personality item pool (mini-IPIP; Donnellan et al., 2006) The mini-IPIP was used as a brief measure of the 'big five' personality factors in the current sample: agreeableness (Cronbach's α = .62), openness to experience (Cronbach's α = .69), neuroticism (Cronbach's α = .71), conscientiousness (Cronbach's α = .61), extraversion (Cronbach's α = .80). Twenty items are rated on a 5-point scale (1 = very inaccurate to 5 = very accurate). For each subscale, higher scores indicate greater levels of the respective personality trait. IPIP subscales have reasonable to good test-retest reliability (r = .62–.87) and good convergent validity with measures of self-esteem and other personality dimensions (Donnellan et al., 2006).

The behavioural inhibition system/behavioural activation system scales (BIS/BAS Scales; Carver & White, 1994) BIS/BAS Scales measure aspects of personality related to punishment and reward sensitivities, respectively (Carver & White, 1994). The BIS/BAS scales include 24 items rated on a 4-point scale (1 = very true for me to 4 = very false for me). The four subscales for this questionnaire were used with the current sample: BIS total (Cronbach's α = .48), BAS total (Cronbach's α = .85), BAS Drive (Cronbach's α = .84), BAS Fun Seeking (Cronbach's α = .66), BAS Reward Responsiveness (Cronbach's α = .66). Convergent and divergent validity has been demonstrated through stronger associations with related personality dimensions (e.g., BIS and neuroticism, BAS and positive affect) compared to symptoms of depression and anxiety (Campbell-Sills et al., 2004).

Five-facet mindfulness questionnaire (FFMQ-15; Baer et al., 2006) The 15-item FFMQ measures trait mindfulness. The total score (Cronbach's α = .86) and five subscales for the FFMQ-15 were used with the current sample: observing

(Cronbach's α = .68), describing (Cronbach's α = .85), acting with awareness (Cronbach's α = .75), non-judgement of inner experience (Cronbach's α = .87), and non-reactivity to inner experience (Cronbach's α = .76). Items are rated on a 5-point scale (1 = never or very rarely true to 5 = very often or always true), where higher scores reflect greater mindfulness ability.

The attentional control scale (ACS; Derryberry & Reed, 2002) The ACS is a self-report measure of attentional control. The total score (Cronbach's α = .89) and two subscales of the ACS were used with the current sample: focusing (Cronbach's α = .83) and shifting (Cronbach's α = .84). Twenty items are rated on a 4-point scale (1 = almost never to 4 = always). Higher scores indicate greater attentional control. ACS items have demonstrated reasonable to good test-retest reliability (r = .45–.73) (Fajkowska & Derryberry, 2010).

State measures State anxiety was measured using the *Subjective Units of Distress Scale* (SUDS; Wolpe, 1969). Participants rate their current subjective level of anxiety using a single-item scale from 0 to 100 (0 = no anxiety, totally relaxed to 100 = highest anxiety that you have ever felt). *Visual analogue scales (VAS)* were used to assess state measures of mood, attention and arousal. Using a horizontal slider, participants indicated their current level of the following states: alert, distracted, calm, stressed, accepting, aware, present-focused, disinterested, fatigued, attentive, on a scale of 0–100, with 'strongly disagree' anchored at one end and 'strongly agree' at the other end. State mindfulness was measured using a 5-item *Mindful Attention Awareness Scale - State* (MAAS-state; Brown & Ryan, 2003) (Cronbach's α = .84). For the current study, participants provided ratings with reference to the cognitive tasks, following completion. Items are rated on a 6-point scale (0 = not at all to 6 = very much) and are all reverse scored. Higher scores indicate greater state mindfulness.

Cognitive tasks

Dot probe task A dot probe task with emotional faces measured two facets of ABT; hypervigilance to threat and difficulty with disengagement. Face stimuli were sets of colour photos of 16 different individuals (8 females) conveying each of three emotional expressions: neutral, happy, angry. These were obtained from the Chicago Face Database (Ma et al., 2015). Six face pair conditions were presented on a black background: neutral-neutral, happy-happy, angry-angry, neutral-happy, neutral-angry, angry-happy (see Supplementary Materials, Fig. S1). Each emotion expression appeared equally on the left and right. There were 384 trials in total, with 64 trials per condition. Each face image was 405px x 284px in size with a 121px gap between each image

pair. The probe was a white dot measuring 34px in diameter, presented on either the left or right side of the screen, directly behind the centre of the preceding face. The fixation cross (18px x 18px) was presented centrally within the gap between the face pairs.

The dot probe task began with 8 practice trials followed by four blocks of 96 trials with a short rest break in between. Each trial commenced with a variable fixation of 500-700 ms followed by the image pair for 100 ms (see Supplementary Materials, Fig. S2). The interstimulus interval was 100 ms. The dot probe then appeared for 150 ms and a response could be made for up to 1000 ms before moving to the next trial. The intertrial interval was 900 ms. Face pair stimuli were counterbalanced across blocks and presented randomly within blocks. Participants were instructed to focus on the fixation cross and make left and right keyboard responses with the corresponding forefinger when the dot appeared on the left and right side, respectively.

Flanker task A novel emotional flanker task was developed to measure executive control processes. Stimuli comprised a string of three images. The middle target comprised an image of either acorns or wood. The flanker images were either another image of acorns or wood (i.e., neutral congruent condition) or another image of a neutral (neutral incongruent condition) or threatening (threat incongruent condition) valence. In total, five different acorn and wood target images and 10 different neutral and threatening flanker images were used. Five additional acorn and wood images were used as neutral congruent flankers. Six target-flanker conditions were used in the task: acorns-acorns, acorns-neutral, acorns-threat, wood-wood, wood-neutral, wood-threat (see Supplementary Materials, Fig. S3). Images were obtained from the Open Affective Standardised Image Set (OASIS; Kurdi et al., 2017) and selected based on normative valence and arousal ratings. Additional acorn and wood images were obtained from the Creative Commons (CC) database. On completion of the study, participants rated each individual image used in the flanker task in terms valence (0 = highly pleasant to 10 = highly unpleasant) and arousal (0 = low arousing [not at all exciting] to 10 = highly arousing [very exciting]). Overall, threat images were rated as significantly ($p < .05$) more negative and arousing compared to neutral, wood and acorn images, with no differences between the trait anxiety groups (full results are provided in Supplementary Materials, Flanker Task Image Ratings and Fig. S5).

There were 360 trials in total, with 60 trials for each condition. Each flanker and target image were presented an equal number of times. Each individual image was 174px x 139px in size with the three-image string measuring 522px x 139px. A fixation cross (18px x 18px) was presented centrally on the screen. All stimuli were presented on a black

background. The flanker task began with a practice block of eight trials followed by three blocks of 120 trials. Between each block was a short rest break. Each trial commenced with a fixation of 500 ms followed by the image string for 250 ms (see Supplementary Materials, Fig. S4). A response could be made for up to 1000 ms before moving to the next trial. The intertrial interval varied from 800 to 1300 ms. Stimuli were counterbalanced between blocks and presented randomly within blocks. Participants were instructed to focus on the fixation cross and make a left keyboard response (with left forefinger) when the middle target image displayed acorns, and to make a right response (with right forefinger) when the middle target image displayed wood.

Procedure

Participants were first directed to an information sheet and then completed basic eligibility questions online. The information sheet included instructions on implementing experimental conditions prior to commencing. Participants were asked to complete the study in an environment free from distraction, with adequate lighting, and to complete the cognitive tasks sitting upright with their eyes level with the centre of the screen in a landscape orientation. Guidelines were provided on how far to sit from the computer during the cognitive tasks, depending on the size of their monitor: 40-50 cm from a screen of approximately 11–14 in.; 75-90 cm from a screen of approximately 21–28 in.; 100 cm from a screen of approximately 32–34 in.; +100 cm where possible from screens more than 32–34 in..

Eligible participants accessed the study via a URL on their own computer. The study was delivered through © Psychstudio Pty Ltd. (Psychstudio, 2019). Participants first provided demographic and health information and completed the questionnaire measures. Participants were then reminded about implementing experimental conditions (e.g., distance from screen, etc) and completed state measures of mood, attention, and arousal (i.e., SUDS and VAS) just before completing the cognitive tasks in a standard order (dot probe first, then flanker). Following completion of tasks, participants completed a measure of state mindfulness during the tasks (i.e., MAAS-state) and then rated images from the flanker task (valence and arousal).

Design and data analysis

Data were analysed using SPSS Statistics (Version 27; IBM Corp, 2020). The dependent variables reaction time (RT) and accuracy were obtained for each task. While no hypotheses were made regarding accuracy, we conducted

analyses with this dependent variable to assess for potential confounding due to a speed-accuracy trade-off (see Heitz, 2014). Individual RTs less than 150 ms were not recorded. To assess group differences for the first set of hypotheses, for each task, a mixed ANOVA was performed with the independent variable of group (Group: high anxiety, low anxiety), with repeated measures on RT and accuracy. The dot probe task analysis included the additional independent variables: 3 (Target Face Valence: neutral, happy, angry) × 3 (Non-Target Face Valence: neutral, happy, angry). The flanker task analysis included the additional independent variables: 2 (Target Object: acorns, wood) × 3 (Flanker: neutral congruent, neutral incongruent, threat incongruent).

For statistically significant ($p < .05$) interactions, Bonferroni adjusted pairwise comparisons ($\alpha = .050$) were conducted to control the Type I error rate for analyses of simple main effects. Greenhouse-Geisser corrections were applied where appropriate to adjust for likely violations of sphericity. For interactions, partial eta squared (η^2_p) is reported as a measure of effect size, reflecting the proportion of variance explained by an independent variable, excluding that explained by other analysis variables (.01 = small, .06 = moderate, .14 = large) (Cohen, 1988; Field, 2013). Cohen's d was reported as a measure of effect size for one-way comparisons and interpreted according to Cohen's (Cohen, 1992) guidelines (0.20 = small, 0.50 = moderate, 0.80 = large).

To address the second set of hypotheses regarding predictors of ABT, ABT scores were computed from reaction time data among the full sample. For the dot probe task, a difference score was computed from neutral-angry trials (neutral target with angry non-target - angry target with neutral non-target) as a measure of attentional bias to angry faces. A difficulty with disengagement score was also computed for the dot probe task (neutral target with angry non-target - neutral target with neutral non-target). These score calculations are consistent with previous literature (e.g., O'Toole & Dennis, 2012). For the flanker task, firstly, a RT average score was computed for the threat incongruent trials (wood and acorns). Secondly, a difference score was computed (threat incongruent trials – neutral incongruent trials) as a measure of threat-related interference. For all scores computed, greater values were taken to indicate greater ABT.

Regression analyses were performed using the whole sample ($N = 111$). Initially, a correlation matrix was constructed for each ABT score to examine their relationship with each psychological construct (i.e., trait anxiety, GAD symptoms, depression symptoms, worry, social anxiety, psychological distress, emotion regulation, big five personality traits [IPIP], BIS/BAS, trait mindfulness, attentional control, SUDS, state mindfulness, VAS state measures). Those constructs that shared a statistically significant ($p < .05$) relationship of at least small-to-moderate strength ($r \geq .2$) were included in a hierarchical multiple regression analysis for the respective ABT

score at Step 1 to examine their combined contribution. For each analysis, trait anxiety was included at Step 2 to examine any unique contribution after accounting for the former variables. However, if age shared a statistically significant ($p < .05$) relationship with an ABT score, it was entered at Step 1 alone to first control for a potential demographic confound, given that age has been shown to impact inhibitory control processes (e.g., Ferguson et al., 2021). Effect sizes for bivariate correlations were interpreted according to Cohen's (Cohen, 1988) guidelines (.10 = small, .30 = moderate, .50 = large).

Results

Demographic information

Descriptive statistics for demographics and mental health information are shown in Table 1. Overall, there was a greater proportion of females in both the high and low anxiety groups, but there were no differences in proportions between the groups. The high anxiety group included a greater proportion of individuals who self-reported a current anxiety or depressive diagnosis. Further, the high relative to low anxiety group reported significantly higher levels of trait anxiety, generalised anxiety, depression, worry, and psychological distress, with large effect sizes. Groups did not significantly differ in age.

Dot probe task

Accuracy

The Target Face Valence x Group interaction was statistically significant (see Fig. 1), $F(2, 130) = 4.64$, $p = .011$, $\eta^2_p = .067$. For the low anxiety group, there was greater

accuracy for happy target faces, as compared to neutral ($p = .007$, $d = 0.40$) but not angry ($p = .260$, $d = 0.17$) target faces, $F(2, 63) = 3.88$, $p = .026$ ($\alpha = .017$, Bonferroni corrected). For the high anxiety group, the were no significant differences in accuracy between neutral, happy and angry target faces ($p > .05$), $F(2, 63) = 1.63$, $p = .204$, $\eta^2_p = .047$ ($\alpha = .017$, Bonferroni corrected). Furthermore, for happy target faces, there was greater accuracy for low relative to high anxiety participants, $F(1, 65) = 5.68$, $p = .020$, $d = 0.58$ ($\alpha = .025$, Bonferroni corrected). However, there were no group differences for either angry or neutral target faces (both $p > .05$). No other main effects or interactions reached statistical significance ($p > .05$).

Reaction time

The Target Face Valence x Group interaction was statistically significant (see Fig. 2), $F(2, 125) = 3.85$, $p = .025$, $\eta^2_p = .056$. For the low anxiety group, RTs were faster in response to happy target faces as compared to neutral
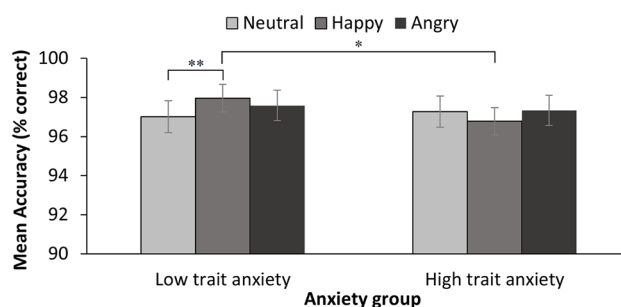

Fig. 1 Mean Accuracy (% correct) for Neutral, Happy and Angry Target Faces in the Dot Probe Task for both High and Low Trait Anxiety Groups (error bars represent 95% CIs). *Note*. * $p < .050$; ** $p < .010$

Table 1 Demographic and mental health characteristics of high and low trait anxiety groups

Variable	Low anxiety ($n = 33$) %	High anxiety ($n = 34$) %	x^2	df	p
Sex (female %)	75.8%	76.5%	0.01	1	.945
Current anxiety disorder	0%	52.9%	25.85	2	<.001
Current depressive disorder	0%	38.2%	22.19	2	<.001
	M(SD)	*M(SD)*	$F(1, 65)$	p	d
Age (years)	30.3(12.8)	26.5(10.6)	1.79	.186	0.33
Trait anxiety (STAI)	30.1(5.0)	58.1(6.6)	381.32	<.001	4.77
Generalised anxiety (GAD-7)	2.2(2.1)	12.0(5.1)	103.33	<.001	2.48
Worry (PSWQ)	34.4(9.6)	64.1(9.1)	170.15	<.001	3.19
Depression (PHQ-8)	2.4(2.7)	13.3(5.8)	94.83	<.001	2.38
Psychological distress (K10)	13.0(2.6)	28.6(8.5)	101.80	<.001	2.47

STAI State Trait Anxiety Inventory, *GAD-7* Generalised Anxiety Disorder 7-item Scale, *PSWQ* Penn State Worry Questionnaire, *PHQ-8* 8-item Patient Health Questionnaire for depression, *K10* Kessler Psychological Distress Scale

($p = .001$, $d = 0.13$) and angry ($p = .014$, $d = 0.10$) target faces, $F(2, 51) = 7.99$, $p = .002$ ($\alpha = .017$, Bonferroni corrected). For the high anxiety group, there were no significant differences in RTs for neutral, happy or angry target faces ($p > .05$), $F(2, 56) = 0.47$, $p = .595$, $\eta^2_p = .014$ ($\alpha = .017$, Bonferroni corrected). There were no group differences for neutral, happy or angry target faces (all $p > .05$). No other main effects or interactions reached statistical significance ($p > .05$).

Flanker task

Accuracy

There was a significant main effect of Flanker type, $F(2, 127) = 6.41$, $p = .002$, with greater accuracy for neutral congruent trials ($M = 91.7$, $SD = 5.1$, 95% CI [90.5, 93.0]) as compared to neutral incongruent ($M = 90.1$, $SD = 5.3$, 95% CI [88.8, 91.4], $p = .001$, $d = 0.31$) and threat incongruent trials ($M = 90.4$, $SD = 5.7$, 95% CI [89.0, 91.8], $p = .010$, $d = 0.25$). There were no significant differences between neutral incongruent and threat incongruent trials ($p = .594$, $d = 0.06$). No other main effects or interactions reached statistical significance ($p > .05$).

Reaction time

There was a significant main effect of Flanker type, $F(2, 125) = 29.60$, $p < .001$. RTs were slower for threat incongruent trials ($M = 548.5$, $SD = 64.2$, 95% CI [532.8, 564.1]) compared to neutral congruent trials ($M = 531.2$, $SD = 57.1$, 95% CI [517.2, 545.1]) ($p < .001$, $d = 0.29$) and neutral incongruent trials ($M = 543.2$, $SD = 62.2$, 95% CI [528.0, 558.3]) ($p = .034$, $d = 0.08$). RTs were also slower for neutral incongruent trials compared to neutral congruent trials ($p < .001$, $d = 0.20$). The hypothesised Group x Flanker interaction did
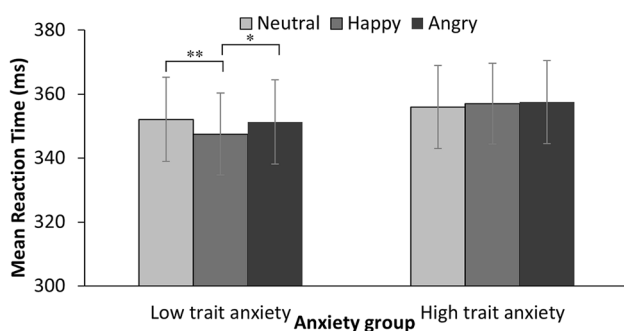
not reach statistical significance (see Fig. 3), $F(2, 125) = 0.24$, $p = .778$, $\eta^2_p = .004$. However, there was a significant main effect of Group, whereby high ($M = 558.6$, $SD = 60.3$, 95% CI [537.9, 579.2]) relative to low ($M = 523.3$, $SD = 60.3$, 95% CI [502.3, 544.2]) anxiety participants had slower RTs overall, $F(1, 65) = 5.75$, $p = .019$, $d = 0.59$. No other interactions reached statistical significance ($p > .05$).

Hierarchical multiple linear regression

ABT score (dot probe task)

A two-step hierarchical multiple linear regression was conducted. All model coefficients and comparisons are presented in Table 2. All intercorrelations between variables included in the model are provided in Supplementary Materials (Table S1). In addition to the BAS total score ($r = .233$, $p = .014$), the Drive ($r = .202$, $p = .033$) and Fun Seeking ($r = .232$, $p = .014$) subscales of the BIS/BAS questionnaire both showed significant, small-moderate, positive relationships with ABT score. However, to meet the assumption of singularity, only the BAS total score was retained in the analysis.

At Step 1, BAS total score, the FFMQ Awareness subscale and the IPIP Openness to Experience subscale were regressed on ABT score. The model described a significant, moderate, positive relationship, accounting for approximately 8.6% of variability in ABT score, $r = .333$, $F(3, 107) = 4.46$, $p = .005$. At Step 2, trait anxiety (STAI) was added to the model. The model continued to describe a significant, moderate, positive relationship, accounting for approximately 8% of variability in ABT score, $r = .337$, $F(4, 106) = 3.39$, $p = .012$. However, this did not lead to significant improvement to the final model, $\Delta R^2 = .002$, $F(1, 106) = 0.27$, $p = .603$, with no single variable contributing significant unique variance.
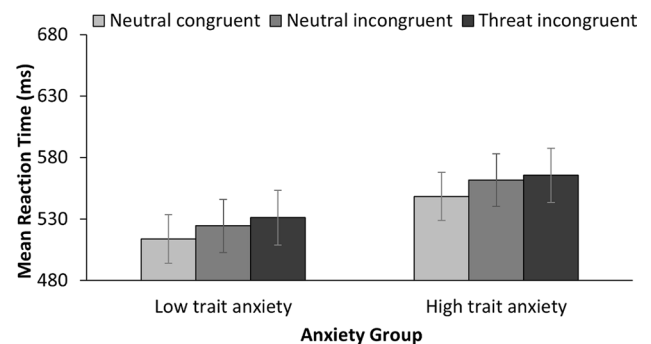
Fig. 2 Mean Reaction Times (ms) for Neutral, Happy and Angry Target Faces in the Dot Probe Task for Both High and Low Trait Anxiety Groups (error bars represent 95% CIs). *Note.* * $p < .050$; ** $p < .010$

Fig. 3 Mean Reaction Times (ms) for Neutral Congruent, Neutral Incongruent and Threat Incongruent Trials in the Flanker Task for both High and Low Trait Anxiety Groups (error bars represent 95% CIs)

Table 2 Results of hierarchical multiple linear regression for the ABT score

Variable	B	95% CI [LL, UL] B	$SE\ B$	β	p value
Step 1 ($R^2_{adj} = .086$)					
Intercept	−37.47	−58.85, −16.09	10.79	–	.001
Awareness (FFMQ)	0.99	−0.12, 2.10	0.56	0.17	.080
BAS total score	0.47	−0.02, 0.95	0.25	0.18	.062
Openness (IPIP)	0.73	−0.21, 1.66	0.47	0.15	.127
Step 2 ($R^2_{adj} = .080$, $\Delta R^2 = .002$)					
Intercept	−43.52	−74.99, −12.05	15.87	–	.007
Awareness (FFMQ)	1.16	−0.13, 2.46	0.65	0.20	.077
BAS total score	0.51	−0.01, 1.02	0.26	0.19	.054
Openness (IPIP)	0.71	−0.24, 1.65	0.48	0.14	.139
Trait anxiety (STAI)	0.07	−0.20, 0.35	0.14	0.06	.603

CI confidence interval, *LL* lower limit, *UL* upper limit, *FFMQ* Five Facet Mindfulness Questionnaire, *BAS* Behavioural Activation System subscale, *IPIP* International Personality Item Pool, *STAI* State Trait Anxiety Inventory

Difficulty with disengagement score (dot probe task)

The total ACS score ($r = .192$, $p = .044$) and the ACS focusing subscale score ($r = .189$, $p = .047$) both showed a significant, small, positive relationship with the difficulty with disengagement score. The DERS-18 impulse ($r = −.191$, $p = .045$) and DERS-18 strategies ($r = −.199$, $p = .036$) subscale scores both showed a significant, small, negative relationship with the difficulty with disengagement score. However, no variable met our criteria for inclusion in the regression analysis ($p < .05$, $r \geq .2$). Furthermore, with trait anxiety (STAI) alone included, the model described a non-significant, small, negative relationship, accounting for approximately 1.1% of variability in the difficulty with disengagement score, $r = −.104$, $F(1, 109) = 1.19$, $p = .277$.

Threat-average score (flanker task)

A three-step hierarchical multiple linear regression was conducted. The variable neuroticism was initially included in the model but was removed due to high multicollinearity with trait anxiety ($r = .746$). All model coefficients and comparisons are presented in Table 3. Age initially showed a significant, small-moderate, positive relationship with the threat-average RT score ($r = .234$, $p = .013$). In attempt to control for a potential demographic confound, age was regressed on the threat-average RT score at Step 1 and a correlation matrix was examined again, controlling for age. All intercorrelations between variables included in the model, including intercorrelations while controlling for age, are provided in Supplementary Materials (Tables S2 and S3).

At Step 1, the model described a significant, small-moderate, positive relationship, accounting for approximately 4.6% of variability in threat-average RT score, $r = .234$, $F(1, 109) = 6.32$, $p = .013$. Controlling for age, significant relationships of small-moderate strength were detected between threat-average RT score and state anxiety (SUDS), stress (VAS), and calmness (VAS). These variables were regressed on the threat-average RT score at Step 2. The model now described a significant, moderate, positive relationship, accounting for approximately 10.9% of variability in threat-average RT score, $r = .377$, $F(4, 106) = 4.38$, $p = .003$. The addition of state anxiety (SUDS), stress (VAS) and calmness (VAS) led to a significant improvement in the model, $\Delta R^2 = .087$, $F(3, 106) = 3.58$, $p = .016$, with age contributing significant unique variance. At Step 3, trait anxiety (STAI) was added to the model. The model continued to describe a significant, moderate, positive relationship, accounting for approximately 10.1% of variability in threat-average RT score, $r = .377$, $F(5, 105) = 3.47$, $p = .006$. However, this did not lead to significant improvement to the final model, $\Delta R^2 = .000$, $F(1, 105) = 0.00$, $p = .948$, with only age contributing significant unique variance.

Threat-difference score (flanker task)

State stress showed a significant, small, negative relationship with the threat-difference score ($r = −.197$, $p = .038$). No other variable shared a significant relationship with the threat-difference score. Thus, no variable met our criteria for inclusion in a regression analysis ($p < .005$, $r \geq .2$). Furthermore, with trait anxiety (STAI) alone included, the model described a non-significant, negligent relationship, accounting for approximately 0.5% of variability in the threat-difference score, $r = .066$, $F(1, 109) = 0.48$, $p = .489$.

Table 3 Results of hierarchical multiple linear regression for threat-average RT score

Variable	B	95% CI B	$SE\ B$	β	p value
Step 1 ($R^2_{adj} = .046$)					
Intercept	499.44	466.22, 532.67	16.76	–	<.001
Age	1.40	0.30, 2.51	0.56	0.23	.013
Step 2 ($R^2_{adj} = .109$, $\Delta R^2 = .087$)					
Intercept	483.51	420.54, 546.47	31.76	–	<.001
Age	1.75	0.65, 2.86	0.56	0.29	.002
State anxiety (SUDS)	0.58	−0.26, 1.41	0.42	0.15	.172
State stress (VAS)	0.03	−0.03, 0.09	0.03	0.12	.317
State calmness (VAS)	−0.02	−0.08, 0.03	0.03	−0.09	.394
Step 3 ($R^2_{adj} = .101$, $\Delta R^2 = .000$)					
Intercept	485.25	402.75, 567.76	41.61	–	<.001
Age	1.75	0.64, 2.86	0.56	0.29	.002
State anxiety (SUDS)	0.59	−0.32, 1.49	0.46	0.15	.199
State stress (VAS)	0.03	−0.03, 0.09	0.03	0.12	.326
State calmness (VAS)	−0.02	−0.08, 0.03	0.03	−0.10	.396
Trait anxiety (STAI)	−0.04	−1.32, 1.23	0.64	−0.01	.948

CI confidence interval, *LL* lower limit, *UL* upper limit, *SUDS* Subjective Units of Distress Scale, *VAS* Visual Analogue Scales, *STAI* State Trait Anxiety Inventory

Discussion

The first aim of the present study was to replicate ABT in trait anxious participants using tasks that distinguish bottom-up (dot probe task) and top-down (flanker task) attentional processes, related to the orienting and executive control networks of attention, respectively. The second aim was to identify psychological predictors of ABT for each of the tasks. Unexpectedly, the present study did not find evidence of attentional hypervigilance towards threat or difficulty disengaging from threat in the dot probe task. High relative to low trait anxiety participants did not show faster RTs in response to dots replacing angry relative to neutral or happy faces. Nor did they demonstrate slower responses to dots replacing neutral or happy faces on trials where a non-target angry face was present. Instead, low anxiety participants showed faster RTs and greater accuracy in response to dots replacing happy faces, suggesting attentional bias towards positive stimuli. While a facet of trait mindfulness was associated with an ABT score for the dot probe task, unexpectedly, this was in the positive direction. Further, other aspects of personality (BAS, openness to experience) were also positively related to this ABT score. For the novel flanker task, there was evidence of threat-related interference overall, but this was not greater for high trait anxiety participants specifically. Both groups showed slowed responding to trials with threatening distractors as compared to neutral distractors. However, high relative to low trait anxiety participants did show slowed responding overall, suggesting general interference. As expected, state anxiety was positively related to the flanker (threat-average) ABT score. Additionally, high

state stress and low calmness were associated with greater ABT score. In contrast to hypotheses, trait anxiety was not positively related to any ABT score for either task and did not explain additional variance when included in the regression models.

The present study found evidence of attentional bias to happy but not angry faces in the dot probe task in low trait anxiety participants, with small effects. This contrasts with previous findings of attentional biases to angry faces among participants with high trait anxiety (Eldar et al., 2010) and GAD (Bradley et al., 1999). Increased vigilance to both angry and happy faces compared to neutral faces has also been found in participants with GAD (e.g., Bradley et al., 1999). However, Wirth and Wentura (2020) did report biased attention to happy faces in a non-specified sample. They suggested that visual attention is biased to information that is potentially relevant in general (Wirth & Wentura, 2020). In line with the broaden-and-build theory, positive emotions broaden the range of mindsets an individual has available to guide actions which, in turn, build personal coping resources (Fredrickson, 2004). Moreover, a Behavioural Activation System (BAS) has been proposed to underly approach behaviours driven by reward (Gray, 1987). While this may explain increased responding to positive stimuli among low anxiety participants, the absence of ABT in high trait anxiety participants is unclear. In several studies that found ABT in anxious participants, only incongruent trials were presented for emotional expressions (e.g., angry-neutral, happy-neutral; e.g., Bradley et al., 1999; Eldar et al., 2010). Possibly, the inclusion of congruent trials for emotional expressions (e.g., angry-angry, happy-happy)

in the present study provided participants with a greater opportunity to habituate to angry faces and preferentially attend to happy faces. Additionally, it is possible that the short stimuli exposure duration (i.e., 100 ms) may have further contributed to issues regarding discrimination of facial expressions and the lack of association with ABT and trait anxiety. While other studies have found ABT at this stimulus duration, not all have included happy faces or congruent trials for emotional expressions (e.g., Bar-Haim et al., 2007; Cisler & Koster, 2010; Cooper & Langton, 2006; Koster et al., 2005). Future research could seek to replicate the current findings and further examine differences in task effects according to facial expression and type of trial condition. Furthermore, it is possible that individuals with trait anxiety may not be as sensitive to socially relevant threats as those with high levels of social anxiety (Mogg et al., 2004; Vogt et al., 2022). Although, it is worth noting that social anxiety was not shown to have a significant relationship with the dot-probe ABT score. Future work may seek to further examine this in participants classified with high social anxiety symptoms.

The awareness facet of trait mindfulness, trait BAS, and openness to experience explained approximately 8.6% of variability in the dot probe ABT score, with higher scores on these variables related to greater ABT scores. It is important to note that none of these variables reached statistical significance in contributing unique variance in the model. Nonetheless, the positive relationship between these variables and ABT score contrasts with previous findings of 'non-reacting' trait mindfulness being linked to faster disengagement of attention from emotional stimuli (Makowski et al., 2019). Variables such as trait mindfulness and openness to experience are associated with less affective symptoms (e.g., see Carpenter et al., 2019) and greater resilience (e.g., Williams et al., 2009). Further, mindfulness practice is thought to train attention regulation processes (Hölzel et al., 2011; Tang et al., 2015). Therefore, it was expected that such constructs would be protective of attentional hypervigilance to threat. In past work where attentional bias to happy faces has been found in anxious participants, it has been suggested that this may either reflect a strategy to regulate mood (e.g., by focusing on positive stimuli) or a misappraisal of happy faces as angry across the task (Bradley et al., 1999). The present findings showing that trait anxiety was not related to ABT for angry faces and that only low anxiety participants showed attentional bias to happy faces gives weight to the possibility that angry faces were not viewed in a threatening nature and did not elicit an expected fear-based attentional response. Future research could explore whether this reflects a process of habituation to angry faces and/or self-regulation of attention towards rewarding stimuli.

For the flanker task, the present study found evidence of threat-related interference in both groups. However, when comparing RTs for trials with threat incongruent flankers to neutral incongruent flankers, the magnitude of this effect was negligible, while the effect size for neutral incongruent compared to neutral congruent trials was small in magnitude, suggesting interference was largely due to incongruency in general. In contrast, previous work has found threat-specific interference in samples with high social anxiety (Chen et al., 2016) and a diagnosed anxiety disorder (Lichtenstein-Vidne et al., 2017). However, high relative to low trait anxiety participants did show slowed responding overall, with moderate effect. This is in line with similar effects found in studies using both neutral (e.g., Qi et al., 2014) and emotional stimuli (Yu et al., 2018). These findings support the idea that anxiety causes detriment to attentional control and cognitive performance, but not specifically in response to threat-related information as suggested by attentional control theory (Eysenck et al., 2007).

The present study found that state measures of anxiety, stress (positively) and calmness (negatively) were associated with the threat-average score for the flanker task, and together with age, explained approximately 10.9% variability. However, it is important to note that only age contributed significant unique variance in the model. In line with these findings, Norris et al. (2018) found those with low but not high levels of neuroticism showed greater flanker task performance following brief mindfulness induction. Possibly, the mindfulness induction elicited a state of calm or reduced negative affect. Interestingly, in the current study, trait anxiety did not positively predict the threat-average score as expected. The present findings combined with the absence of threat-specific interference in the high trait anxiety group suggest that state anxiety and mood may be more important in predicting ABT on the flanker task than a pervasive pattern of anxiety. In their review, MacLeod et al. (2019) argue the importance of state anxiety, sufficient threat intensity, and personal relevance of stimuli in yielding ABT under experimental conditions. While at a posteriori inspection we found arousal (but not valence) ratings for threat stimuli were positively associated with both state and trait anxiety, there were no group differences for arousal or valence ratings (see Supplementary Materials). Interestingly, the threat-average score showed no association with either arousal or valence mean ratings for threat images. Thus, the present findings indicate that negative affect in combination with the presence of threat images may be particularly important in the expression of ABT. While negative affect induction procedures have resulted in reduced attentional biases in previous studies (e.g., Finucane, 2011; Jiang et al., 2017), these have not involved tasks with a variety of threat-related images. Future experimental research is needed to investigate whether mood induction moderates the effect of relevant traits (e.g., trait mindfulness, neuroticism, attentional control, trait anxiety) and symptoms on

ABT expression. Additionally, it is important to acknowledge that significant associations were found only for the threat-average score and not the threat-difference score. Thus, as this outcome measure is not a difference score, as is traditionally used to index ABT, it is possible that the predictors identified are reflective of overall reaction time more generally, rather than of ABT specifically. Future research could further investigate this by examining psychological predictors of behavioural measures of executive control in general.

The present research has a number of strengths and implications for future research and theory. While ABT has been extensively researched as a potential mechanism involved in the aetiology of anxiety, issues with replicating this phenomenon have been noted (e.g., Kruijt et al., 2019; MacLeod et al., 2019; McNally, 2019) yet research has not yet comprehensively explored some of the individual differences that may account for this. This is important given research on ABT may inform the treatment of anxiety. For example, attentional bias modification (ABM) training has been increasingly researched over the last decade and shown to reduce anxiety symptoms when ABT is successfully reduced (Hakamata et al., 2010; MacLeod & Clarke, 2015). When ABM has not led to a reduction in ABT, anxiety reduction is also typically not observed (MacLeod & Clarke, 2015). It has been suggested that executive functioning and sensitivity to emotional valence may contribute to variability in attentional bias malleability (MacLeod & Clarke, 2015). The current findings contribute to knowledge in this area by providing preliminary evidence of predictors of ABT in a non-specified sample, using the present tasks. Furthermore, the present findings show the potential importance of measuring state and trait psychological experiences when investigating ABT in experimental settings. Such practice would allow for statistical control of these variables. Further confirmatory research is needed to clarify predictors of most importance to ABT.

There are several limitations of this study to acknowledge. Firstly, while participants were given instructions to manage their environment to be conducive with a controlled, experimental setting, we were not able to verify compliance. Due to the online delivery, it is not possible to rule out potential environmental distractions or strategies participants used to regulate their emotions when completing the questionnaires and experimental tasks. Nonetheless, covert forms of attention (shifting focus without eye movement) may present as a threat to internal validity in controlled laboratory studies (e.g., Britton & Anderson, 2021; Weierich et al., 2008). Furthermore, participants have been found to respond similarly in both laboratory and online experimental settings, with only small differences observed (Buso et al., 2021). Moreover, online research offers several benefits (e.g., illness contagion minimisation, efficiency, broader recruitment targets, inclusivity) and is likely to remain in the field. It is also possible

that between-group differences or predictors of ABT that are not observable with behavioural measures alone have been missed in the present study. A number of studies have found anxiety-related group differences in attention using event-related potentials (ERPs; e.g., Li et al., 2005; Qi et al., 2014; Yu et al., 2018). Future research could implement a face-to-face design and consider using ERPs or visual eye-tracking technology to overcome potential behavioural compensation in anxious participants. Another limitation is the reliance on self-report measures. While the online and anonymous nature of our study may have limited social desirability reporting, other limitations can include participant insight and comprehension of instrument items (e.g., Sleep et al., 2019). Future research may seek to include a clinically defined sample using structured diagnostic interview tools. Further, inclusion of physiological measures of arousal (e.g., heart rate variability, skin conductance response) would help to increase objectivity of state measures. It is also important to note that while the present exploratory analyses identified variables that predicted ABT using the current tasks, future replication is needed to have confidence in these findings, as well as explore potential predictors in other tasks using emotional stimuli.

In conclusion, the present study did not replicate ABT in high trait anxious participants using two online tasks that distinguish bottom-up (dot probe) and top-down (flanker) attentional processes. Instead, there was evidence of attentional bias to positive stimuli in low trait anxiety participants, modest threat-related interference in both groups, and general interference (slowed RT) in high trait anxiety participants. Findings highlight issues with capturing ABT in anxiety using behavioural tasks. Furthermore, the present study found state (anxiety, stress, calmness) and trait (i.e., awareness facet of trait mindfulness, openness, BAS) variables were associated with ABT scores using the present tasks. Based on these findings, it is possible that state and trait variables may serve to mitigate or contribute to the expression of ABT, and this may depend on the nature of the emotional stimuli used in a given task. Further, the present findings suggest state anxiety and mood may be more important in predicting ABT than pervasive anxiety symptoms. While further investigation and replication is needed, future ABT research may seek to routinely measure relevant trait and state characteristics and, where feasible, include neurocognitive measures of attention to enhance precision of measurement.

Declarations

Ethics approval The authors' institutional ethics committee approved this study. The study was performed in line with the ethical standards of the Declaration of Helsinki (1964).

Consent to participate All participants provided informed consent to participate in the present study.

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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