*Journal of Articles in Support of the Null Hypothesis*
Vol. 17, No. 2
Copyright 2021 by Reysen Group. 1539–8714
`www.jasnh.com`

# Cognitive Correlates of Anxiety: A Study on Attentional Bias for Mild/High Threat and Neurocognitive Functioning

Maryann Wei
Steven Roodenrys
Leonie Miller
**School of Psychology, University of Wollongong, New South Wales, Australia**

The current study extended investigations on anxiety-related cognitive processes. There were two testing phases: an online study, and a laboratory session. Emotional attentional bias was assessed on both counts using an extended dot probe task. A neurocognitive test battery was administered in the laboratory session with the end goal of examining whether neurocognitive impairments would mediate the association between attentional bias and anxiety. Results showed attentional bias was associated with anxiety only when indexed based on sadness- (mild threat) but not fear-related (high threat) scenes. However, this selective association was apparent only in online data. As further contraindication against pursuing mediation analyses, laboratory-based neurocognitive performance did not correlate with anxiety. Implications for the measurement of anxiety-related cognitive processes are discussed.

*Keywords:* anxiety, attentional bias for threat, CogState, dot probe, cognitive assessment

---

*Corresponding author:* Maryann Wei
Email: mws396@uowmail.edu.au
Phone: +61 0401175778
Affiliation address for all authors: Northfields Ave, University of Wollongong, Building 41 Room 125,
Wollongong NSW 2522, Australia

## Introduction

There are two broadly identifiable areas of work within existing research on cognitive processes associated with anxiety: "hot" cognitive processes (emotional informational processing) and "cold" cognitive processes (non-emotional information processing, or basic neurocognitive functioning). The leading subject in the former body of work is the attentional bias for threat phenomenon, or the tendency to orient more quickly to negative compared to neutral stimuli (Cisler, Bacon, & Williams, 2009; Mogg & Bradley, 2016). This habitual pattern of attentional deployment is not seen as a mere epiphenomenon of anxiety, but has been argued to play a causal role in the development and maintenance of anxiety (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Eysenck, Derakshan, Santos, & Calvo, 2007; MacLeod, Mathews, & Tata, 1986; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Williams, Watts, MacLeod, & Mathews, 1988). However, from an evolutionary standpoint, being quicker to detect negative stimuli in the environment allows the organism to respond swiftly to potential danger, and serves to facilitate survival in the short term (Ohman, 2005; Ohman, Flykt, & Esteves, 2001; Öhman, Soares, Juth, Lindström, & Esteves, 2012). As such, a purely psychopathological view of attentional bias for threat cannot account for its adaptive function.

One account of attentional processes in anxiety that acknowledges the adaptive aspects of attentional bias for threat is the cognitive-motivational framework (Mogg & Bradley, 1998; Mogg & Bradley, 2018). Within this framework, the anxiety-related attentional bias (and anxiety more generally) is rooted in exaggerated appraisals of the threat value of the stimulus. Thus, while attentional bias for highly threatening stimuli may be the norm, attentional bias for mildly threatening stimuli may be evident only among individuals with higher levels of anxiety. In a series of experiments led by the same theorists (Mogg et al., 2000), it was demonstrated that anxious individuals did indeed only show a greater attentional bias than their non-anxious counterparts in response to mildly threatening scenes (e.g. soldier holding a gun), and not to highly threatening scenes (mutilated bodies, murder victims). Although these findings have important implications for the fundamental nature of the anxiety-related attentional bias, replication studies have been few[1]. The first aim of the current study was to further investigate the specificity of the anxiety-related attentional bias to mildly threatening (but not highly threatening) stimuli, using an alternative approach to manipulate the threat value of stimuli employed to capture attention. In Mogg et al.'s (2000) study, mildly and highly threatening stimuli were represented using negative scenes varying primarily in arousal, and thus the emotional distress they elicit. As a means to the same end, the approach adopted in the current study is to select stimuli for the discrete negative emotion they elicit. Specifically, sadness- and fear-related scenes, in conveying signals of elapsed and potential danger respectively (Calvo & Avero, 2005; Kveraga et al., 2015), are thematically used to represent threat on a continuum from mild to high in a way which does not raise ethical concerns associated with the presentation of highly arousing or emotionally distressing stimuli.

The second aim of this study was to address a gap within anxiety-related research where "cold" cognitive processes have received limited attention relative to "hot" cognitive processes (see Leonard & Abramovitch, 2019 for similar sentiments). "Cold" cognitive processes, or basic neurocognitive functions, have been shown to vary with symptom severity in many mental health conditions (Harvey, Koren, Reichenberg, & Bowie, 2006; Kleim et al., 2013; McGurk et al., 2000; Zuckerman et al., 2018). Establishing the key neurocognitive impairments associated with specific disorders thus represents a clinically relevant goal in research. In addition to being limited by a relatively small number of studies, agreement on the neurocognitive profile associated with anxiety is hampered by challenges in integrating findings across different studies. As highlighted in contemporary literature, studies on cognitive functioning in anxiety tend to examine only a select few cognitive domains (Hallion, Tolin, Assaf, Goethe, & Diefenbach, 2017; Leonard & Abramovitch, 2019; Muller, Torquato, Manfro, & Trentini, 2015), and this selected range varies from one study to the next. Where cognitive domains of interest overlap between anxiety-related studies, cross-study comparisons are complicated by the use of different tests (Leonard & Abramovitch, 2019).

Beyond descriptive purposes, the theoretical importance of understanding the neurocognitive profile associated with anxiety is enhanced by the suggestion that a purely psychopathological view on attentional bias for threat may be incomplete. Several mechanistic accounts of the association between attentional processes and anxiety propose that biased attention for threat operates to perpetuate anxiety indirectly, via impairments in basic cognitive functions. Such impairments have been articulated using varied terms across different models, including resource allocation mechanisms (Bar-Haim et al., 2007; Williams et al., 1988), goal-engagement systems (Bar-Haim et al., 2007; Mogg & Bradley, 1998), inhibitory skills (Mathews & Mackintosh, 1998), and attentional control (Eysenck et al., 2007). Thus, the second aim of this study has two aspects: (a) to add to the limited literature on the neurocognitive profile associated with anxiety, using a comprehensive, standardised neurocognitive test battery (CogState; <u>www.cogstate.com</u>); and, (b) if neurocognitive impairments are established, to examine whether these impairments mediate the association between attentional bias and self-reported anxiety measured in the same laboratory testing session.

---

[1] To the authors' knowledge, there is only one other study to have pursued similar investigations (Li, Wang, Poliakoff, & Luo, 2007). This study found that attentional bias for highly threatening stimuli was not modulated by anxiety, in keeping with findings from the study by Mogg et al. (2000).

Although detailed in the Methods section below, several methodological aspects of the current study are worth introducing here. First, there were two testing phases in the current study: an online session, and a laboratory testing session. In both these phases, measures of attentional bias and anxiety were administered, with the laboratory testing session further involving the administration of the CogState test battery. While data from the laboratory testing session specifically informed the second aim, data from both testing phases were used to address the first aim of the current study (i.e., specificity of the anxiety-related attentional bias to mildly threatening stimuli/sadness-related scenes) for comprehensiveness. Second, traditionally-computed indices of attentional bias were supplemented with indices derived from a computational modelling technique known as drift-diffusion modelling. These indices are described in full below, within the context of their supporting behavioural paradigm.

## Methods

### *Participants and Procedures*

Data collection for the current study occurred in two phases. The first testing phase occurred online (i.e., data was collected remotely). A call for participants was circulated via the research participation scheme at the School of Psychology, University of Wollongong (New South Wales, Australia) as well as several community forums on the online platform Reddit designated for connecting researchers and voluntary survey respondents. In this testing phase, participants completed measures of anxiety, attentional bias, and several other psychological variables as part of a larger project to understand psychological factors involved in the link between biased attention for threat and anxiety. Cognitive functioning (i.e. the current research) sits within this project as one psychological factor of interest.

Participants who completed the online study (*N* = 647) were invited to attend a laboratory testing session at the institution where the current research occurred (University of Wollongong, New South Wales, Australia). The same measures of anxiety and attentional bias, along with measures of neurocognitive functioning (i.e., the CogState test battery) were administered in this session. Participants were offered either university course credit points (where applicable) or a $20 shopping gift card for their time. 100 individuals (66 female, Mean Age = 24.80, *SD* = 9.38) who completed the online study signed up to participate in the laboratory testing session. As recruitment emails specified an in-person testing session at the University of Wollongong, individuals who signed up were predominantly enrolled undergraduate students (*N* = 87). The remaining 13 sign-ups were members of the local Wollongong community. 14 participants, of which 11 were undergraduate students, reported the current use of antidepressants. To account for potential effects of educational differences and pharmaceutical influences on cognitive functioning, both entry site (university vs. community) and medication status (currently using vs. not using antidepressants) were coded for control purposes in analyses involving CogState tests.

### *Measures*

#### Anxiety

The Anxiety subscale from the Depression, Anxiety and Stress Scales-21 (DASS-21; (S. Lovibond & Lovibond, 1995) was used to measure self-reported anxiety. Reliability and validity of the DASS-21 Anxiety subscale has previously been established in both clinical (Brown, Chorpita, Korotitsch, & Barlow, 1997; Clara, Cox & Enns, 2001; Antony, Bieling, Cox, Enns, & Swinson, 1998) and nonclinical samples (Antony et al., 1998; Crawford & Henry, 2003; Sinclair et al., 2011). Although only the Anxiety subscale was of interest in the current study, participants completed the full DASS-21 questionnaire so as not to alter the order of presented items. On a scale of 0 to 3, participants reported on the extent to which a series of statements applied to them over the past week. The Anxiety subscale includes statements such as "*I was worried about situations in which I might panic and make a fool of myself.*" Scores are summed across seven items and range from 0 to 21. Participants completed the DASS-21 in both the online study (Cronbach's alpha = .86) and laboratory testing session (Cronbach's alpha = .78). The DASS-21 has been shown to be temporally stable and suitable for capturing individual differences in baseline anxiety (Gomez, Summers, Summers, Wolf, & Summers, 2014; Jafari, Nozari, Ahrari, & Bagheri, 2017; P. Lovibond, 1998; Lu et al., 2018). For classification of the current sample according to DASS-21 severity ranges for anxiety, see Appendix A.

#### Attentional Bias for Fear- and Sadness-Related Scenes

A dot probe task was used to assess attentional biases for fear- and sadness-related scenes. This task was programmed and administered within a web-based browser using Psytoolkit (www.psytoolkit.org). Each trial began with a fixation cross (500 ms) followed by the presentation of a pictorial stimulus pair on opposite sides of the screen (500 ms). A probe (i.e. a dot) then quickly replaced one of the stimuli. Participants were tasked to indicate the location of the probe as quickly as possible via a keyboard press ('E' for left, and 'I' for right). Trials with incorrect responses were excluded from analyses, and trials where responses were not received within 2000 ms were automatically considered incorrect and excluded from further analyses (see Britton et al., 2015; Zhang, Dong, & Zhou, 2018, for similar data pre-processing procedures).

There were four types of trials, appearing in a randomised order for each participant: 24 fear-neutral, 24 sad-neutral, 24 happy-neutral and 40 neutral-neutral filler trials. The current study examined the negative-neutral (i.e., fear-neutral and sad-neutral) trials. Whether the negative stimulus appeared on the left or right of the screen, and whether the probe replaced the negative or neutral stimulus was counterbalanced across trials. The 24 trials for each negative-neutral condition were created using six unique image pairs repeated four times across the experiment. Images used (resized to approx. 307 x 230 px) were predominantly scenes drawn from the International Affective Pictures System; (IAPS: Bradley & Lang, 2007) and pre-validated for their emotional content in a pilot study (Wei, Roodenrys, Miller, & Barkus, 2020).[2] Negative and neutral images were paired so that both scenes in a given negative-neutral stimulus pair either consistently featured human persons or did not. Standardized valence ratings (Fear: $M = 3.30$, $SD = .92$; Sad: $M = 2.28$, $SD = .29$) and arousal ratings (Fear: $M = 6.03$, $SD = .79$; Sad: $M = 4.87$, $SD = .30$) from the IAPS norming study did not differ between the two classes of negative stimuli, $t(4) = 2.35$, $p = .12$ and $t(4) = 1.82$, $p = .19$ respectively.

Indices of attentional bias for fear- and sadness-related scenes were computed by traditional means, i.e., by subtracting mean reaction times on incongruent trials (probe replaces neutral stimulus) from mean reaction times on congruent trials (probe replaces emotional stimulus). More extreme bias scores (i.e., differences scores) denote more extreme attentional biases for the given class of emotional stimuli. Additionally, these traditional bias scores were complemented with bias scores computed based on *extra-decisional* reaction times. Extra-decisional reaction times are derived from drift-diffusion modelling of trial-level reaction time data (see Ratcliff & McKoon, 2008 for theory and origin, and A. Voss & J. Voss, 2007 for processing software used), and are thought to capture the time taken for an individual to orient attention to the probe location with irrelevant features of task performance removed (Price, Brown, & Siegle, 2019). In the context of a dot probe paradigm, extra-decisional bias scores may provide a purer behavioural measure of attentional bias compared to traditional bias scores (Price et al., 2019). For bias scores and extra-decisional bias scores, outliers were identified using an extreme values approach (+/- 3D from the mean; see Nozadi et al., 2016 for a similar approach).

### Cognitive Functioning

The CogState computerised test battery (www.cogstate.com) was used to index neurocognitive functioning across several domains. The full test battery comprises 13 tests (full test descriptions are available for public access on the CogState website) assessing neurocognitive functioning across eight unique domains: *International Shopping List Test* (verbal learning), *Groton Maze Chase Test* (processing speed), *Groton Maze Learning Test* (executive function), *Detection Test* (processing speed), *Identification Test* (attention), *One Card Learning Test* (visual memory), *One-Back Test* (working memory), *Two-Back Test* (working memory), *Set-Shifting Test* (executive function), *Continuous Paired Associate Learning Test* (visual memory), *Socio-Emotional Cognition Test* (emotional recognition), *Groton Maze Learning Test – Delayed Recall* (visual memory), *International Shopping List Test – Delayed Recall* (verbal memory). Tests are stated in the order of administration recommended by CogState guidelines. Test-retest reliability estimates for CogState tests range between .84 and .91 (Collie, Maruff, Darby, & McStephen, 2003; Falleti, Maruff, Collie, & Darby, 2006), where practice effects have been demonstrated to be negligible (Falleti et al., 2006). Outliers for CogState test outcomes were identified using an extreme values approach (+/- 3 *SD* from the mean; see Bartlett et al., 2019 for a similar approach).

## Results

### Correlations Between Indices of Attentional Bias and Anxiety

Table 1 gives accuracy rates and mean reaction times used to calculate bias scores and extra-decisional bias scores based on dot probe task performance, as well as mean DASS-21 Anxiety scores, for both testing phases in the current study[3]. Test-retest reliability estimates for measures between testing phases were also assessed, yielding significant positive coefficients ($r$) for all measures (see Table 1). It should be noted that systematically lower test-retest reliability estimates for the extra-decisional parameter derived from drift-diffusion modelling have been previously documented as normative (Shahar et al., 2019; Lerche & Voss, 2017). Correlations between bias scores and DASS-21 Anxiety were performed separately for the online study and laboratory testing session. Mean Fear and Sad bias scores are given in Table 2, along with their correlations with DASS-21 Anxiety scores obtained at each testing phase. There was a selective association between bias scores and DASS-21 Anxiety, such that only Sad bias score but not Fear bias score was significantly correlated with DASS-21 Anxiety. However, as shown in Table 2, this selective association was apparent only when bias scores were computed using extra-decisional reaction times, when measures of attentional bias and anxiety were obtained via remote data collection methods (i.e., online).[4]

### Correlations Between Neurocognitive Functioning and Anxiety

Mean performance outcomes on CogState tests and their correlations with DASS-21 are also given in Table 2. As seen, none of the test scores correlated with DASS-21 Anxiety. The inclusion of entry site (university vs. community) and medication status (currently using vs. not using antidepressants) as control variables did not alter this pattern of findings.

---

[2] IAPS identification codes for images used in negative-neutral trials: Fear – 1120, 1930, 5971, 2770, 6250, 6370; Sad – 9184, 9340, 9561, 2141, 2205, 2900; Neutral – 7185, 7500, 7705, 7550, 7050, 7080, 7187, 2440, 2575, 2745.1. Two neutral images were sourced from free online stock photo databases and are available upon request. All pictures used were assigned a common emotional label by > 75% of viewers ($N = 103$).

[3] There was an overall upward shift in means for both DASS-21 Anxiety scores and reaction times on the dot probe task (shorter response latencies) moving from the online to laboratory testing session. Influxes in baseline anxiety (Purves et al., 2019) and decreases in response latencies (Hilbig, 2016; Semmelmann & Weigelt, 2017) moving from online to laboratory test settings have been previously documented, and are likely to reflect normative shifts from baseline due to increased contextual demands.

[4] Given known relationships between attentional biases for sadness-related information and depressive syndromes (and the availability of DASS-21 Depression subscale scores on hand), the correlation between the extra-decisional Sad bias score and DASS-21 Depression was also examined within the online dataset. This association was not significant, $r = .026$, $p = .801$, supporting the specificity of the presently observed attentional bias to anxiety.

Table 1

*Mean reaction times used to calculate bias scores and extra-decisional bias scores based on dot probe task performance, and mean DASS-21 Anxiety scores for both testing phases (N = 100). Test-retest reliability estimates (r) were all significant at p-threshold .05.*

| | | **Online Study** | **Laboratory Testing Session** | **Test-Retest Reliability Estimates (*r*)** |
|---|---|---|---|---|
| **Acccuracy (%)** | | 97.86 [3.06] | 98.06 [2.56] | .708 |
| **Reaction Time** | **Trial Type** | **Mean in *ms* [SD]** | **Mean in *ms* [SD]** | |
| **Traditional** | **Sad – Congruent** | 430.21 [83.11] | 397.11 [63.95] | .648 |
| | **Sad – Incongruent** | 426.32 [67.92] | 396.59 [65.32] | .607 |
| | **Fear – Congruent** | 435.58 [78.07] | 394.82 [63.84] | .550 |
| | **Fear – Incongruent** | 432.03 [73.06] | 396.82 [69.70] | .671 |
| **Extra-decisional** | **Sad – Congruent** | 363.34 [57.41] | 337.13 [50.37] | .250 |
| | **Sad – Incongruent** | 373.38 [68.60] | 336.82 [54.71] | .314 |
| | **Fear – Congruent** | 367.75 [65.92] | 343.03 [53.06] | .398 |
| | **Fear – Incongruent** | 366.36 [61.96] | 339.54 [53.08] | .495 |
| | **DASS-21 Anxiety** | 3.90 [4.05] | 4.62 [4.22] | .671 |

In the present case, targeted mediator variables (performance outcomes on CogState tests) and independent variables (in-lab bias scores) were not associated with the dependent variable (in-lab DASS-21 Anxiety scores). Since basic assumptions for mediation analyses were not met (Baron & Kenny, 1986; James & Brett, 1984; Judd & Kenny, 1981), further tests were not conducted. For comprehensiveness, correlations between possible mediator and independent variables (i.e., CogState outcomes and in-lab bias scores) are given in Appendix B.

## Discussion

The present study sought to address two aims. The first aim was to examine whether previous findings on the specificity of the anxiety-related attentional bias to mildly threatening stimuli (Mogg et al., 2000) would be replicated, when sadness- and fear-related scenes (i.e. scenes which convey signals of elapsed and potential danger) are used to thematically represent mild and high threat respectively. The second aim was two-fold: (a) to examine the neurocognitive profile associated with anxiety, and (b) if neurocognitive impairments are established, whether they would mediate the association between attentional bias and self-reported anxiety measured in the same laboratory testing session.

Pertaining to the first aim, a selective association between indices of attentional bias and self-reported anxiety was presently observed, such that attentional bias was associated with anxiety only when indexed based on sadness- but not fear-related scenes. These findings support and extend on previously established empirical evidence (Mogg et al., 2000) for predictions made based on the cognitive-motivational framework (Mogg & Bradley, 1998; Mogg & Bradley, 2018): Namely, that the anxiety-related attentional bias is specific to mildly threatening stimuli, while attentional bias for highly threatening stimuli may represent a normative function that is not modulated by anxiety. However, this selective association was apparent only when indices of attentional bias were computed using extra-decisional reaction times derived from drift-diffusion modelling, when measure of attentional bias and anxiety were obtained via web-based data collection methods (i.e. in the online study, but not the laboratory testing session). Besides adding to previously established support for the utility of applying drift-diffusion modelling techniques to dot probe data in anxiety-related research (Price et al., 2019), the current pattern of findings have other methodological implications for the measurement of the anxiety-related attentional bias, which has been documented with notable inconsistency across studies (see Van Bockstaele et al., 2014 for a review).

First, negative stimuli of differing threat value may not be equally sensitive to anxiety when implemented in behavioural measures of attentional bias, and should be systematically controlled for in the study of attentional bias in anxiety. To this end, current findings point to sadness- and fear-related stimuli as a plausible thematic approach to represent threat on a continuum of mild to high, without evoking ethical concerns associated with the presentation of highly arousing or emotionally distressing stimuli. Second, although incidental to the main aim, the association between attentional bias and anxiety was presently observed only

Table 2

*Mean Fear and Sad bias scores, performance outcomes on CogState tests, and their correlations with DASS-21 Anxiety. Outliers for bias scores and CogState test scores were identified as data points +/- 3 SD from the mean, where N below denotes the number of observations after outliers were removed. Initial N = 100 unless otherwise stated.*

| | **Online Study** | | | **Laboratory Testing Session** | | |
|---|---|---|---|---|---|---|
| | ***N*** | **Mean [SD]** | **Correlation *(r)* with DASS-21 Anxiety [*p*-value]** | ***N*** | **Mean [SD]** | **Correlation *(r)* with DASS-21 Anxiety [*p*-value]** |
| **Bias Scores** | | | | | | |
| Traditional – Fear | 93 | -1.37 [28.85] | .127 [.224] | 92 | -0.59 [31.70] | -.054 [.607] |
| Traditional – Sad | 92 | -2.19 [28.72] | .044 [.647] | 90 | 0.81 [26.23] | -.005 [.961] |
| ED – Fear | 97 | -2.31 [36.22] | .116 [.260] | 94 | 1.17 [34.19] | -.100 [.335] |
| ED - Sad | 97 | 5.01 [33.14] | .205* [.044] | 95 | 2.82 [32.54] | -.026 [.803] |
| **CogState tests [Outcome Variable]** | | | | | | |
| Continuous Paired Associate Learning Test [err] | - | - | - | 97 | 59.14 [42.52] | -.067 [.516] |
| Detection Test [lmn] | - | - | - | 93 | 2.58 [.089] | .077 [.462] |
| Groton Maze Chase Test [mps] | - | - | - | 93 | 1.36 [.53] | -.100 [.339] |
| Groton Maze Learning Test [err] | - | - | - | 93 | 49.10 [17.29] | .007 [.950] |
| Groton Maze Learning Test – Delayed Recall [err] | - | - | - | 93 | 5.78 [4.80] | .077 [.464] |
| Identification Test [lmn] | - | - | - | 93 | 2.71 [.06] | -.003 [.976] |
| International Shopping List Test [cor] | - | - | - | 92 | 27.48 [3.86] | -.168 [.110] |
| International Shopping List Test – Delayed Recall [cor] | - | - | - | 91 | 9.95 [1.73] | -.089 [.400] |
| One Card Learning Test [acc] | - | - | - | 100 | .967 [.13] | .018 [.859] |
| One-Back Test [lmn] | - | - | - | 98 | 2.87 [.09] | -.070 [.494] |
| Socio-Emotional Cognition Test [acc] | - | - | - | 78[a] | 1.13 [.12] | -.098 [.394] |
| Two-Back Test [acc] | - | - | - | 73[a] | 1.14 [.10] | .015 [.897] |
| Set-Shifting Test [err] | - | - | - | 71[a] | 28.43 [15.11] | -.207 [.083] |

*$^*p < .05$.*

[a] *Initial N for these variables was 79 due to errors in data saving.*

*lmn = Speed of performance, $\log_{10}$ milliseconds; acc = Accuracy of performance, arsine proportion; err = Error count; cor = Number of correct responses; mps = Moves per second.*

within web- but not lab-collected data for the same participants. Where findings from web-based experiments and their laboratory counterparts do not corroborate, possible explanations include technical and situational variation (Hilbig, 2016; Semmelmann & Weigelt, 2017). The latter seems more likely in the present case, since the same browser-based dot probe task was administered in both the online study and laboratory testing session. It has previously been suggested that undertaking experiments in unfamiliar environments (and with unfamiliar equipment) adds a cognitive load to the task at hand (Kim, Gabriel, & Gygax, 2019). Relatedly, studies have shown that differences between anxious and non-anxious individuals in the processing of emotional information taper off with increasing task demands (Vytal, Cornwell, Arkin, & Grillion, 2012; Vytal, Cornwell, Letkiewicz, Arkin, & Grillion, 2013). There are several potential accounts (not mutually exclusive) for these findings, including that increased cognitive load may inhibit anxiety-related mechanisms from operating (Vytal et al., 2012), or reduce emotional influences on attention and cognition more generally (Pessoa, 2010). It is possible that the different patterns of association between dot probe task performance and anxiety as presently observed between web- and lab-collected data may in part be explained by different cognitive loads in the two settings (lower vs. higher respectively). In addition to systematic control over the threat value of stimuli, current findings suggest that thoughtful consideration should be given to the experimental setting in endeavours to capture attentional bias associated with anxiety.

Pertaining to the second aim, performance across all CogState tests did not correlate with anxiety, indicating that neurocognitive functioning did not vary with anxiety on the whole. The finding that neurocognitive impairments are not more extreme at the higher end of anxiety severity is not novel, but rather adds to the count of null findings (e.g., Castaneda et al., 2011; Jarros et al., 2011; Leonard & Abramovitch, 2019; Troller-Renfree, Barker, Pine, & Fox, 2015) which sit within a larger body of inconsistent findings on neurocognitive functioning in anxiety. One possible account for such null findings, is that cognitive impairments in anxiety are more readily apparent on less conventionally-used neurocognitive tests. According to a corollary in one prominent account of cognitive functioning in the ABT-anxiety link (Attentional Control Theory; Eysenck et al., 2007), anxiety promotes enhanced cognitive effort to ensure performance effectiveness is maintained on a given task, often at the cost of processing speed. Thus, anxiety-related impairments are more likely to be observed on cognitively-demanding tasks where processing speed is assessed (Derakshan & Eysenck, 2009). While the CogState test battery has its merits in comprehensiveness and standardisation, composite tests are predominantly accuracy-based, where tests which evaluate processing speed only entail minimal cognitive load. Chiaravalloti et al. (2003) draw a distinction between neurocognitive tasks which assess simple and complex processing speed: While the former requires only a simple motor response to a single presented stimulus, the latter requires the simultaneous and continuous manipulation of information in mind. It is possible that tasks which tap complex processing speed might be better able to differentiate anxious from non-anxious individuals (see Zainal & Newman, 2018) for a similar proposition), and should be considered in the prospective search for neurocognitive domains associated with anxiety.

Alternatively, but not mutually exclusively, the experimental setting may also partially explain the lack of correlations between CogState tests and anxiety as presently observed. Pertaining to the current study's second aim, mediation analyses were not pursued partly on the grounds that correlations could not be established between targeted independent variables and the dependent variable. That is, bias scores and DASS-21 Anxiety measured during the laboratory testing session were not correlated, although significant associations were observed (albeit selectively) between the two measures when obtained within the online setting. It is possible that the association between cognitive performance and anxiety may also vary according to context (Robinson, Vytal, Cornwell, & Grillon, 2013). The current study lacks an online counterpart to speak to this speculative hypothesis, which may be worth incorporating in the design of future studies.

Other limitations of the present study include its sampling methods, which favoured the recruitment of university students among whom the association between cognitive functioning and anxiety might be unique. Although the inclusion of entry site (university vs. community) did not alter the current pattern of findings, this might in part be explained by the modest sample size. This sample size was compromised for some CogState tests due to technology failures. A more demographically diverse and larger sample would help offset doubts in the generalizability of study findings in future research. Additionally, although anxiety was presently treated as a unitary construct, separate measures of trait and state anxiety would have been helpful to partition situationally-driven effects (a notion of particularly relevance to the current study) and should be considered in future investigations.

## References

Antony, M. M., Bieling, P. J., Cox, B. J., Enns, M. W., & Swinson, R. P. (1998). Psychometric properties of the 42-item and 21-item versions of the Depression Anxiety Stress Scales in clinical groups and a community sample. *Psychological Assessment, 10*(2), 176–181. https://doi.org/10.1037/1040-3590.10.2.176

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & van IJzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: a meta-analytic study. *Psychological Bulletin, 133*(1), 1–24. https://doi.org/10.1037/0033-2909.133.1.1

Baron, R., & Kenny, D. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology, 51,* 1173–1182. https://doi.org/10.1037//0022-3514.51.6.1173

Bartlett, E., Shaw, M., Schwarz, C., Feinberg, C., DeLorenzo, C., Krupp, L. B., & Charvet, L. E. (2019). Brief computer-based information processing measures are linked to white matter integrity in pediatric-onset multiple sclerosis. *Journal of Neuroimaging, 29*(1), 140–150. https://doi.org/10.1111/jon.12566

Bradley, M. M., & Lang, P. J. (2007). The International Affective Pictures System (IAPS) in the study of emotion and attention. In *Handbook of emotion elicitation and assessment* (pp. 29–46). Oxford University Press.

Britton, J. C., Suway, J. G., Clementi, M. A., Fox, N. A., Pine, D. S., & Bar-Haim, Y. (2015). Neural changes with attention bias modification for anxiety: A randomized trial. *Social Cognitive and Affective Neuroscience, 10*(7), 913–920. https://doi.org/10.1093/scan/nsu141

Brown, T.A., Corpita, B. F., Korotitsch, W., & Barlow, D. H. (1997). Psychometric properties of the Depression Anxiety Stress Scales (DASS) in clinical samples. *Behavior Research and Therapy,* 35(1), 79–89. https://doi.org/10.1016/s0005-7967(96)00068-x

Calvo, M. G., & Avero, P. (2005). Time course of attentional bias to emotional scenes in anxiety: Gaze direction and duration. *Cognition and Emotion, 19*(3), 433–451. https://doi.org/10.1080/02699930441000157

Castaneda, A. E., Suvisaari, J., Marttunen, M., Perala, J., Saarni, S. I., Aalto-Setala, T., . . . Tuulio-Henriksson, A. (2011). Cognitive functioning in a population-based sample of young adults with anxiety disorders. *European Psychiatry, 26*(6), 346–353. https://doi.org/10.1016/j.eurpsy.2009.11.006

Chiaravalloti, N. D., Christodoulou, C., Demaree, H. A., & DeLuca, J. (2003). Differentiating simple versus complex processing speed: influence on new learning and memory performance. *Journal of Clinical and Experimental Neuropsychology, 25*(4), 489–501. https://doi.org/10.1076/jcen.25.4.489.13878

Cisler, J. M., Bacon, A. K., & Williams, N. L. (2009). Phenomenological characteristics of attentional biases towards threat: A critical review. *Cognitive Therapy and Research, 33*(2), 221–234. https://doi.org/10.1007/s10608-007-9161-y

Clara, I. P., Cox, B. J., & Enns, M. W. (2001). Confirmatory factor analysis of the Depression–Anxiety–Stress Scales in depressed and anxious patients. *Journal of Psychopathology and Behavioral Assessment, 23*(1), 61–67. https://doi.org/10.1023/A:1011095624717

Collie, A., Maruff, P., Darby, D. G., & McStephen, M. (2003). The effects of practice on the cognitive test performance of neurologically normal individuals assessed at brief test-retest intervals. *Journal of the International Neuropsychological Society, 9*(3), 419–428. https://doi.org/10.1017/s1355617703930074

Crawford, J. R., & Henry, J. D. (2003). The Depression Anxiety Stress Scales (DASS): Normative data and latent structure in a large non-clinical sample. *British Journal of Clinical Psychology, 42*(pt. 2), 111–131. https://doi.org/10.1348/014466503321903544

Derakshan, N., & Eysenck, M. W. (2009). Anxiety, processing efficiency, and cognitive performance: New developments from attentional control theory. *European Psychologist, 14*(2), 168–176. https://doi.org/10.1027/1016-9040.14.2.168

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion, 7*(2), 336–353. https://doi.org/10.1037/1528-3542.7.2.336

Falleti, M. G., Maruff, P., Collie, A., & Darby, D. G. (2006). Practice effects associated with the repeated assessment of cognitive function using the CogState battery at 10-minute, one week and one month test-retest intervals. *Journal of Clinical and Experimental Neuropsychology, 28*(7), 1095–1112. https://doi.org/10.1080/13803390500205718

Gomez, R., Summers, M., Summers, A., Wolf, A., & Summers, J. (2014). Depression Anxiety Stress Scales-21: measurement and structural invariance across ratings of men and women. *Assessment, 21*(4), 418–426. https://doi.org/10.1177/1073191113514106

Hallion, L. S., Tolin, D. F., Assaf, M., Goethe, J., & Diefenbach, G. J. (2017). Cognitive control in generalized anxiety disorder: Relation of inhibition impairments to worry and anxiety severity. *Cognitive Therapy and Research, 41*(4), 610–618. https://doi.org/10.1007/s10608-017-9832-2

Harvey, P. D., Koren, D., Reichenberg, A., & Bowie, C. R. (2006). Negative symptoms and cognitive deficits: what is the nature of their relationship? *Schizophrenia Bulletin, 32*(2), 250–258. https://doi.org/10.1093/schbul/sbj011

Hilbig, B. E. (2016). Reaction time effects in lab- versus Web-based research: Experimental evidence. *Behaviour Research Methods, 48*(4), 1718–1724. https://doi.org/10.3758/s13428-015-0678-9

Jafari, P., Nozari, F., Ahrari, F., & Bagheri, Z. (2017). Measurement invariance of the Depression Anxiety Stress Scales-21 across medical student genders. *International Journal of Medical Education, 8,* 116–122. https://doi.org/10.5116/ijme.58ba.7d8b

James, L. R., & Brett, J. M. (1984). Mediators, moderators, and tests for mediation. *Journal of Applied Psychology, 69*(2), 307–321. https://doi.org/10.1037/0021-9010.69.2.307

Jarros, R., Salum, G., Silva, C., Costa, M., Becker, N., Toazza, R., . . . Manfro, G. (2011). Neuropsychological assessment in adolescents with anxiety disorders. *Revista Brasileira de Psiquiatria, 33,* S27.

Judd, C. M., & Kenny, D. A. (1981). Process analysis: Estimating mediation in treatment evaluations. *Evaluation Review, 5*(5), 602–619. https://doi.org/10.1177/0193841X8100500502

Kim, J., Gabriel, U., & Gygax, P. (2019). Testing the effectiveness of the Internet-based instrument PsyToolkit: A comparison between web-based (PsyToolkit) and lab-based (E-Prime 3.0) measurements of response choice and response time in a complex psycholinguistic task. *PLoS ONE, 14*(9): e0221802. https://doi.org/10.1371/journal.pone.0221802

Kleim, B., Grey, N., Wild, J., Nussbeck, F. W., Stott, R., Hackmann, A., . . . Ehlers, A. (2013). Cognitive change predicts symptom reduction with cognitive therapy for posttraumatic stress disorder. *Journal of Consulting and Clinical Psychology, 81*(3), 383–393. https://doi.org/10.1037/a0031290

Kveraga, K., Boshyan, J., Adams, R. B., Jr., Mote, J., Betz, N., Ward, N., . . . Barrett, L. F. (2015). If it bleeds, it leads: Separating threat from mere negativity. *Social Cognitive and Affective Neuroscience, 10*(1), 28–35. https://doi.org/10.1093/scan/nsu007

Leonard, K., & Abramovitch, A. (2019). Cognitive functions in young adults with generalized anxiety disorder. *European Psychiatry, 56*, 1–7. https://doi.org/10.1016/j.eurpsy.2018.10.008

Lerche, V., & Voss, A. (2017). Retest reliability of the parameters of the Ratcliff diffusion model. *Psychological Research, 81*(3), 629–652. https://doi.org/10.1007/s00426-016-0770-5

Li, X., Poliakoff, E., Wang, M., & Luo, Y.-J. (2007). Attention to threat in high and low trait-anxious individuals: A study using extremely threatening pictorial cues. *Perceptual and Motor Skills, 104,* 1097–1106. https://doi.org/10.2466/pms.104.4.1097-1106

Lovibond, P. (1998). Long-term stability of depression, anxiety, and stress syndromes. *Journal of Abnormal Psychology, 107*(3), 520–526. https://doi.org/10.1037//0021-843x.107.3.520

Lovibond, S., & Lovibond, P. (1995). *Manual for the depression, anxiety, stress scales.* Sydney: Psychology Foundation.

Lu, S., Hu, S., Guan, Y., Xiao, J., Cai, D., Gao, Z., . . . Margraf, J. (2018). Measurement invariance of the Depression Anxiety Stress Scales-21 across gender in a sample of Chinese university students. *Frontiers in Psychology, 9*(2064). https://doi.org/10.3389/fpsyg.2018.02064

MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology, 95*(1), 15–20. https://doi.org/10.1037//0021-843x.95.1.15

Mathews, A., & Mackintosh, B. (1998). A cognitive model of selective processing in Anxiety. *Cognitive Therapy and Research, 22*(6), 539–560. https://doi.org/10.1023/A:1018738019346

McGurk, S. R., Moriarty, P. J., Harvey, P. D., Parrella, M., White, L., Friedman, J., & Davis, K. L. (2000). Relationship of cognitive functioning, adaptive life skills, and negative symptom severity in poor-outcome geriatric schizophrenia patients. *The Journal of Neuropsychiatry and Clinical Neurosciences, 12*(2), 257–264. https://doi.org/10.1176/jnp.12.2.257

Mogg, K., & Bradley, B. P. (1998). A cognitive-motivational analysis of anxiety. *Behaviour Research and Therapy, 36*(9), 809–848. https://doi.org/10.1016/s0005-7967(98)00063-1

Mogg, K., & Bradley, B. P. (2016). Anxiety and attention to threat: Cognitive mechanisms and treatment with attention bias modification. *Behavior Research and Therapy, 87*, 76–108. https://doi.org/10.1016/j.brat.2016.08.001

Mogg, K., & Bradley, B. P. (2018). Anxiety and threat-related attention: Cognitive-motivational framework and treatment. *Trends in Cognitive Sciences, 22*(3), 225–240. https://doi.org/10.1016/j.tics.2018.01.001

Mogg, K., McNamara, J., Powys, M., Rawlinson, H., Seiffer, A., & Bradley, B. P. (2000). Selective attention to threat: A test of two cognitive models of anxiety. *Cognition and Emotion, 14*(3), 375–399. https://doi.org/10.1080/026999300378888

Muller, J. L., Torquato, K. I., Manfro, G. G., & Trentini, C. M. (2015). Executive functions as a potential neurocognitive endophenotype in anxiety disorders: A systematic review considering DSM-IV and DSM-5 diagnostic criteria classification. *Dementia & Neuropsychologia, 9*(3), 285–294. https://doi.org/10.1590/1980-57642015dn93000012

Nozadi, S. S., Troller-Renfree, S., White, L. K., Frenkel, T., Degnan, K. A., Bar-Haim, Y., Pine, D., & Fox, N. A. (2016). The moderating role of attention biases in understanding the link between behavioral inhibition and anxiety. *Journal of Experimental Psychopathology, 7*(3), 451–465. https://doi.org/10.5127/jep.052515

Ohman, A. (2005). The role of the amygdala in human fear: Automatic detection of threat. *Psychoneuroendocrinology, 30*(10), 953–958. https://doi.org/10.1016/j.psyneuen.2005.03.019

Ohman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: detecting the snake in the grass. *Journal of Experimental Psychology: General, 130*(3), 466–478. https://doi.org/10.1037//0096-3445.130.3.466

Öhman, A., Soares, S. C., Juth, P., Lindström, B., & Esteves, F. (2012). Evolutionary derived modulations of attention to two common fear stimuli: Serpents and hostile humans. *Journal of Cognitive Psychology, 24*(1), 17–32. https://doi.org/10.1080/20445911.2011.629603

Pessoa L. (2010). Emergent processes in cognitive-emotional interactions. *Dialogues in Clinical Neuroscience*, *12*(4), 433–448. Retrived from https://pubmed.ncbi.nlm.nih.gov/21319489/

Price, R. B., Brown, V., & Siegle, G. J. (2019). Computational modeling applied to the dot-probe task yields improved reliability and mechanistic insights. *Biological Psychiatry, 85*(7), 606–612. https://doi.org/10.1016/j.biopsych.2018.09.022

Purves, K. L., Constantinou, E., McGregor, T., Lester, K. J., Barry, T. J., Treanor, M., . . . Eley, T. C. (2019). Validating the use of a smartphone app for remote administration of a fear conditioning paradigm. *Behavior Research and Therapy, 123,* 103475–103475. https://doi.org/10.1016/j.brat.2019.103475

Ratcliff, R., & McKoon, G. (2008). The diffusion decision model: Theory and data for two-choice decision tasks. *Neural Computation, 20*(4), 873–922. https://doi.org/10.1162/neco.2008.12-06-420

Robinson, O. J., Vytal, K., Cornwell, B. R., & Grillon, C. (2013). The impact of anxiety upon cognition: Perspectives from human threat of shock studies. *Frontiers in Human Neuroscience, 7,* 203–203. https://doi.org/10.3389/fnhum.2013.00203

Semmelmann, K., & Weigelt, S. (2017). Online psychophysics: Reaction time effects in cognitive experiments. *Behavior Research Methods, 49*(4), 1241–1260. https://doi.org/10.3758/s13428-016-0783-4

Shahar, N., Hauser, T. U., Moutoussis, M., Moran, R., Keramati, M., NSPN consortium, & Dolan, R. J. (2019). Improving the reliability of model-based decision-making estimates in the two-stage decision task with reaction-times and drift-diffusion modeling. *PLoS Computational Biology, 15*(2), e1006803. https://doi.org/10.1371/journal.pcbi.1006803

Sinclair, S. J., Siefert, C. J., Slavin-Mulford, J. M., Stein, M. B., Renna, M., & Blais, M. A. (2011). Psychometric evaluation and normative data for the Depression, Anxiety, and Stress Scales-21 (DASS-21) in a nonclinical sample of U.S. adults. *Evaluation & The Health Professions, 35*(3), 259–279. https://doi.org/10.1177/0163278711424282

Troller-Renfree, S. V., Barker, T. V., Pine, D. S., & Fox, N. A. (2015). Cognitive functioning in socially anxious adults: Insights from the NIH Toolbox Cognition Battery. *Frontiers in Psychology, 6*(764). https://doi.org/10.3389/fpsyg.2015.00764

Van Bockstaele, B., Verschuere, B., Tibboel, H., De Houwer, J., Crombez, G., & Koster, E. H. (2014). A review of current evidence for the causal impact of attentional bias on fear and anxiety. *Psychological Bulletin, 140*(3), 682–721. https://doi.org/10.1037/a0034834

Voss, A., & Voss, J. (2007). Fast-dm: A free program for efficient diffusion model analysis. *Behavior Research Methods, 39*(4), 767–775. https://doi.org/10.3758/BF03192967

Vytal, K., Cornwell, B., Arkin, N., & Grillon, C. (2012). Describing the interplay between anxiety and cognition: from impaired performance under low cognitive load to reduced anxiety under high load. *Psychophysiology*, *49*(6), 842–852. https://doi.org/10.1111/j.1469-8986.2012.01358.x

Vytal, K. E., Cornwell, B. R., Letkiewicz, A. M., Arkin, N. E., & Grillon, C. (2013). The complex interaction between anxiety and cognition: insight from spatial and verbal working memory. *Frontiers in Human Neuroscience, 7*. https://doi.org/10.3389/fnhum.2013.00093

Wei, M., Roodenrys, S., Miller, L., & Barkus, E. (2020). Complex scenes from the International Affective Picture System (IAPS): Agreement-based emotional categories. *Experimental Psychology, 67*(3), 194–201. https://doi.org/10.1027/1618-3169/a000488

Williams, J. M. G., Watts, F. N., MacLeod, C., & Mathews, A. (1988). *Cognitive psychology and emotional disorders*. Oxford, England: John Wiley & Sons.

Zainal, N. H., & Newman, M. G. (2018). Executive function and other cognitive deficits are distal risk factors of generalized anxiety disorder 9 years later. *Psychological Medicine, 48*(12), 2045–2053. https://doi.org/10.1017/s0033291717003579

Zhang, X., Dong, Y., & Zhou, R. (2018). Examination stress results in attentional bias and altered neural reactivity in test-anxious individuals. *Neural Plasticity,* 3281040. https://doi.org/10.1155/2018/3281040

Zuckerman, H., Pan, Z., Park, C., Brietzke, E., Musial, N., Shariq, A. S., . . . McIntyre, R. S. (2018). Recognition and treatment of cognitive dysfunction in major depressive disorder. *Frontiers in Psychiatry, 9*. https://doi.org/10.3389/fpsyt.2018.00655

## Appendix A

The following table classifies the current sample according to DASS-21 severity ranges for anxiety.

| DASS Severity Rating (Anxiety Subscale) | Range | Classification of Current Sample – Phase 1 (Frequency) | Classification of Current Sample – Phase 2 (Frequency) |
|---|---|---|---|
| Normal | 0-3 | 53 | 46 |
| Mild | 4-5 | 22 | 24 |
| Moderate | 6-7 | 8 | 10 |
| Severe | 8-9 | 5 | 7 |
| Extremely Severe | 10+ | 12 | 13 |

## Appendix B

The table below gives correlations between possible mediator variables (performance outcomes on CogState tests) and independent variables (in-lab bias scores), given in the format *r* [*p*-value].

| | ***N*** | **Traditional bias score** | | **Extra-decisional bias score** | |
|---|---|---|---|---|---|
| **CogState tests [Outcome Variable]** | | **Fear** | **Sad** | **Fear** | **Sad** |
| Continuous Paired Associate Learning Test [err] | 97 | .282* [.005] | .086 [.392] | -.005 [.962] | .050 [.622] |
| Detection Test [lmn] | 93 | .052 [.611] | .086 [.392] | -.117 [.247] | .053 [.601] |
| Groton Maze Chase Test [mps] | 93 | -.088 [.385] | .103 [.308] | .180 [.073] | -.020 [.845] |
| Groton Maze Learning Test [err] | 93 | .152 [.132] | -.219* [.029] | -.005 [.962] | -.022 [.826] |
| Groton Maze Learning Test – Delayed Recall [err] | 93 | .021 [.839] | -.090 [.378] | -.142 [.160] | .153 [.130] |
| Identification Test [lmn] | 93 | .174 [.083] | -.061 [.548] | -.009 [.928] | .170 [.092] |
| International Shopping List Test [cor] | 92 | -.120 [.233] | -.002 [.986] | .007 [.945] | -.106 [.292] |
| International Shopping List Test – Delayed Recall [cor] | 91 | -.067 [.512] | -.007 [.944] | .025 [.804] | -.081 [.425] |
| One Card Learning Test [acc] | 100 | -.206* [.040] | .177 [.078] | .193 [.054] | .203* [.042] |
| One-Back Test [lmn] | 98 | .000 [.999] | .124 [.219] | -.038 [.711] | .159 [.115] |
| Socio-Emotional Cognition Test [acc] | 78[a] | .016 [.892] | .133 [.243] | .019 [.868] | .068 [.554] |

Submitted: 9.29.2020
Revised: 12.18.2020
Accepted: 12.19.2020