Increasing cognitive load attenuates the moderating effect of attentional inhibition on the relationship between posttraumatic stress symptoms and threat-related attention bias variability

Kate Clauss a, Joseph R. Bardeen a,⁎, Robert D. Gordon a, Thomas A. Daniel b

a Auburn University, United States
b Westfield State University, United States

A R T I C L E   I N F O

Keywords
Posttraumatic stress disorder
Attentional bias
Attentional control
Cognitive load
Eye tracking
Attention bias variability

A B S T R A C T

Theory and empirical evidence suggest that those with higher posttraumatic stress (PTS) symptoms and better attentional control (i.e., the strategic control of higher-order executive attention in regulating bottom-up, stimulus driven responses to prepotent stimuli; Sarapas et al., 2017) can use that ability to disengage and shift attention away from threat stimuli and reduce threat-related attentional dysregulation (i.e., avoidance/overcontrollers). Those with relatively worse attentional control lack the requisite resources to do this, leading to prolonged attentional engagement with threat stimuli and threat-related attention dysregulation (i.e., maintenance/undercontrollers). Given that attentional control is a limited resource, strategic avoidance of threat information or reduced threat-related attention dysregulation may not be possible among those with relatively higher attentional control when cognitive load is relatively high. To test this hypothesis, the interaction between PTS symptoms, attentional control, and cognitive load was examined as a predictor of threat-related attentional bias and threat-related attention bias variability. Participants (N = 125 undergraduate students) were randomly assigned to high or low load conditions. Participants completed self-report measures of PTS symptoms, a behavioral measure of attentional control, and a novel task that assessed threat-related attentional bias via eye movements and threat-related attention bias variability via button press. The results of a series of hierarchical regressions showed that attentional control moderated the relationship between PTS symptoms and threat-related attention bias variability in the low, but not high, load condition. This mediation effect was not observed for threat-related attentional bias assessed via eye-tracking. Consistent with theory, under conditions of higher cognitive load, overcontrollers may not be able to use attentional control to consistently regulate threat-related attention. Study findings suggest that it may be important to consider contextual factors that increase cognitive load, as well as individual differences in attentional control, when developing attention bias modification interventions to reduce PTS symptomatology.

1. Introduction

Threat-related attentional bias (i.e., preferential processing of threat information) has been put forth as a core vulnerability factor for the development of posttraumatic stress (PTS) disorder (PTSD; Ehlers & Clark, 2000; Foa & Kozak, 1986). However, empirical evidence regarding the degree to which individuals with anxiety and related symptoms exhibit threat-related attentional bias has been mixed. Although meta-analytic studies suggest evidence of threat-related attentional bias in anxiety- and fear-related disorders (Armstrong & Olatunji, 2012; Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van Ijzendoorn, 2007; Lazarov et al., 2019), null findings are common. Moreover, inconsistent patterns of threat-related attentional bias have emerged in this literature, with some studies demonstrating reflexive orienting toward threat (Banerjee, Milder, & Sahraie, 2010; Fox, Derakshan, & Shoker, 2008), others showing sustained attention on threat (i.e., maintenance; Pineses, Shipherd, Welch, & Yovel, 2007), some reporting bias away from threat (i.e., avoidance; Bardeen & Daniel, 2017a), and still others reporting variable or dysregulated attention in the presence of threat (i.e., threat-related attention bias variability; Bardeen, Tull, Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van Ijzendoorn, 2007; Lazarov et al., 2019), null findings are common. Moreover, inconsistent patterns of threat-related attentional bias have emerged in this literature, with some studies demonstrating reflexive orienting toward threat (Banerjee, Milder, & Sahraie, 2010; Fox, Derakshan, & Shoker, 2008), others showing sustained attention on threat (i.e., maintenance; Pineses, Shipherd, Welch, & Yovel, 2007), some reporting bias away from threat (i.e., avoidance; Bardeen & Daniel, 2017a), and still others reporting variable or dysregulated attention in the presence of threat (i.e., threat-related attention bias variability; Bardeen, Tull, 

⁎ Corresponding author at: Department of Psychological Sciences, Auburn University, 226 Thach Hall, Auburn, AL, 36849-5214, United States.
E-mail address: jbardeen@auburn.edu (J.R. Bardeen).

https://doi.org/10.1016/j.janxdis.2021.102416
Received 10 July 2020; Received in revised form 17 April 2021; Accepted 4 May 2021
0887-6185/© 2021
Daniel, Evenden, & Stevens, 2016). These mixed findings raise concerns regarding the accuracy of commonly cited information processing models of PTSD and the use of treatments that have been developed to train individuals with PTSD to rapidly disengage attention from threat stimuli (e.g., attention bias modification; see Cristea, Kok, & Cuijpers, 2015; Jones & Sharpe, 2017 for a review). Discrepancies in the literature may be the result of failing to consider the role of top-down attentional control (i.e., the strategic control of higher-order executive attention in regulating bottom-up, stimulus driven responses to prepotent stimuli; Sarapas, Weinberg, Langenecker, & Shankman, 2017) on threat processing in PTSD. Specifically, among those with higher PTS symptoms, those with relatively better attentional control have been shown to use this cognitive resource to disengage and shift attention away from threat stimuli (i.e., avoidance) and reduce threat-related attention dysregulation, while those with relatively worse attentional control maintain attention on threat and exhibit greater threat-related attention dysregulation (i.e., maintenance; Bardeen & Daniel, 2017a; Bardeen & Orcutt, 2011; Bardeen et al., 2016). However attentional control is a limited resource (Eysenck & Derakshan, 2011; Konstantinou & Lavie, 2013; Murphy, Groeger, & Greene, 2016), and as such, individuals with higher PTS symptoms, who also have relatively better attentional control, may not be able to use this resource to avoid threat stimuli and reduce threat-related dysregulation under conditions of high cognitive load.

1.1. A working model of cognitive control (Dennis-tiwary, Roy, Denefrio, & Myraski, 2019)

Dennis-Tiwary et al. (2019) proposed a working model of cognitive control that makes specific hypotheses about the expression of threat-related attentional bias based on individual differences in attentional control. The model draws on the competing theories of threat-related attentional bias (i.e., attention maintenance and vigilance-avoidance; Weierich, Treat, & Hollingworth, 2008). In the attention maintenance model, those with higher levels of anxiety have greater difficulty disengaging attention from threat-related information compared to those with lower levels of anxiety. In contrast, the vigilance-avoidance model suggests that once threat has been detected, those with higher levels of anxiety shift away as quickly as possible. The key differentiator between these two attentional styles is proposed to be individual differences in attentional control (Dennis-Tiwary et al., 2019). Specifically, those with higher anxiety and relative deficits in attentional control may be more likely to maintain attention on threat due to disengagement difficulties (i.e., undercontrollers). Even though they may wish to disengage from threat information, they do not possess the ability to consistently do so. In contrast, those with higher anxiety and relatively better attentional control are able to use their top-down attentional resources to consistently disengage from threat stimuli as quickly as possible (i.e., overcontrollers; Dennis-Tiwary et al., 2019). This conceptualization of threat-related attentional bias could account for discrepant findings in the extant literature. Given that over- and under-controllers are proposed to display different patterns of attention in the presence of threat stimuli, failure to account for top-down attentional control could obscure the relationship between PTS symptoms and threat-related attentional bias.

1.2. The moderating effect of attentional control on the relationship between PTS symptoms and threat-related attention

The modulatory role of attentional control on the relationship between PTS symptoms and threat-related attentional biases has been demonstrated in multiple studies. In a sample of undergraduate students, attentional control (assessed via self-report) moderated the effect of PTS stress symptoms on threat-related attentional bias (aggregated dot probe reaction time [RT] difference scores; Bardeen & Orcutt, 2011). Specifically, among those with higher PTS symptoms, those with higher attentional control paid greater attention to neutral stimuli (versus threat stimuli), while those with lower attentional control maintained attention on threat.

These findings were extended in a community sample of trauma-exposed adults with and without PTSD (Bardeen et al., 2016). This study remedied two significant limitations of the 2011 study. First, it used a behavioral index of attentional control that produces an aggregate of the three cognitive processes that underlie attentional control (i.e., inhibitory ability, set shifting, and working memory updating; Eysenck, Derakshan, Santos, & Calvo, 2007; Miyake et al., 2000). This was done to ensure that the moderation effect of interest was a function of individual differences in attentional control ability rather than being the result of differences in perceived attentional control abilities. This extension is an important one because it may be difficult to accurately report on the use of cognitive abilities that influence bottom-up reactivity at such early stages of processing (e.g., as early as 100-150ms; Bardeen & Orcutt, 2011; Peers & Lawrence, 2009). Second, Bardeen et al. (2016) calculated threat-related attention bias variability from response times to the dot-probe task, using the trial-level bias score (TLBS) method, which exhibits superior reliability to traditional indices of threat-related attentional bias (Amir, Zvielli, & Bernstein, 2016; Schafer et al., 2016; Zvielli, Bernstein, & Koster, 2015). Similar to Bardeen and Orcutt (2011), Bardeen et al. (2016) found that behaviorally assessed attentional control moderated the association between PTS status and threat-related attention bias variability. Specifically, among those with PTSD, those with relatively worse attentional control exhibited significantly greater threat-related attention bias variability. According to Bardeen et al. (2016), these results suggest that individuals with PTSD and relatively worse attentional control exhibit a pattern of threat monitoring that allows for the constant updating of threat potential, thus resulting in greater attentional engagement with the threat stimulus over time. In contrast, it appears that individuals with PTSD and better attentional control display a more consistent pattern of attentional responding in the presence of threat.

Bardeen and Daniel (2017a) built on this line of research in two important ways. First, they utilized eye tracking to obtain an overt measure of threat-related attentional bias (i.e., proportion of dwell time on threat relative to neutral stimuli). Whereas the dot-probe task used in previous studies uses button press to make inferences about threat-related attentional bias at relatively earlier stages of processing (i.e., 500ms), eye tracking can be used to obtain reliable estimates of overt threat-processing over prolonged periods of time (i.e., 3000ms). Second, Bardeen and Daniel (2017a) utilized a self-report measure of attentional control and a cognitive battery capable of distinguishing between the three cognitive processes proposed to underlie attentional control (i.e., inhibitory ability, set shifting, and working memory updating). This ensured that the observed effects were due to actual, rather than perceived, differences in attentional control and allowed them to pinpoint which cognitive ability drives the moderating effect observed in previous studies. PTS symptoms interacted with both self-reported attentional control and behaviorally assessed inhibitory ability to predict dwell time on threat. Individuals with higher PTS symptoms and higher attentional control, and attentional inhibition specifically, exhibited reduced dwell time on threat. Results from multi-level modeling showed that the effect of inhibitory ability on the relationship between PTS symptoms and threat-related attentional bias was most pronounced from 1500 to 3000ms, emphasizing the importance of examining this effect at later stages of processing. As discussed by Bardeen and Daniel (2017a), these findings might help reconcile apparent discrepancies between the vigilance-avoidance and attention maintenance models of threat-related attentional bias. Specifically, it appears that individuals with higher PTS symptoms and lower inhibitory ability may wish to disengage from threat, but lack the ability.
to do so, thus resulting in maintenance on threat. In contrast, individuals with higher PTS symptoms and higher inhibitory ability are able to disengage from threat, which in turn, appears to down-regulate emotional arousal (Bardeen & Daniel, 2017a).

Together, these findings highlight the robust moderating effect of top-down attentional control on threat-related attention among those with PTS symptoms. This effect has been observed using different indicators of attentional control and threat-related attentional bias, at different stages of information processing, and in different samples (undergraduate versus community). However, as mentioned above, attentional control is a limited resource (Eysenck & Derakshan, 2011; Konstantinou & Lavie, 2013), and as such, taxing attentional control by increasing cognitive load may influence this moderation effect.

1.3. Considering the effect of cognitive load

As described, both theory and empirical evidence suggest that individuals with PTS symptomatology, and relatively better attentional control, can compensate for the impairing effects of anxiety and related symptoms on attention by recruiting additional cognitive resources (i.e., top-down attentional control; Eysenck et al., 2007). However, research examining this moderation effect has done so under controlled laboratory conditions free of distraction. Attention control theory suggests that one’s ability to use attentional control resources to maintain task performance will suffer under conditions of high cognitive load (i.e., conditions that tax attentional control; Eysenck et al., 2007). That is, when limited top-down resources are taxed, individuals with PTS symptomatology and relatively better attentional control may not be able to use top-down control to disengage from threat stimuli and down-regulate sympathetic nervous system arousal (Bardeen & Daniel, 2017a).

To date, only one study has examined the relation between anxiety and threat-related attentional bias (assessed via eye-tracking and the dot-probe task) at different levels of cognitive load. Booth, Mackintosh, and Sharma (2017) presented conditioned threatening and neutral Japanese characters on a computer screen to undergraduate participants for 100ms. Cognitive load was manipulated by showing participants either one (low load) or six (high load) digits before every trial of the task. Response times (i.e., button press) and eye movements to a probe that appeared following the presentation of threat and neutral stimuli were used as indices of threat-related attentional bias. Specifically, an aggregate mean difference score of RTs to a dot that appeared behind either neutral (incongruent) or threatening (congruent) stimuli was calculated. In addition, the proportion of first fixations that were made to the probe, on congruent versus incongruent trials, was calculated. There was no effect of trait anxiety on first fixations toward the probe. This could be attributed to the low reliability of eye-tracking indices at short presentation durations (Waechter, Nelson, Wright, Hyatt, & Oakman, 2014). It might also be that reflexive orienting toward threat is an evolutionary advantage observed across high and low anxious groups. Using mean difference scores as the outcome, higher trait anxiety predicted greater threat-related attentional bias in the high, but not low, load condition.

The null findings observed by Booth et al. (2017) in the low load condition may be the result of failing to account for individual differences in attentional control. In addition, the outcome measures used in this study differ from those used to examine the effects of attentional control on threat-related attentional bias in previous research in important ways (e.g., Bardeen et al., 2016; Bardeen & Daniel, 2017a). First, both first fixations on threat and aggregate mean difference scores have exhibited unacceptable reliability (Price et al., 2015; Schmukle, 2005), which limits the conclusions that can be drawn from this work. Second, due to the brief stimulus duration used in the above study (i.e., 100ms), these outcomes represent very early stages of attention characterized by bottom-up processes. Given that cognitive load is proposed to disrupt top-down control (Eysenck et al., 2007), an effect that is pronounced at later stages of processing (Bardeen & Daniel, 2017a), it might be more appropriate to examine these effects at longer stimulus durations.

1.4. Methodological considerations

Attentional control is often assessed via self-report (Derryberry & Reed, 2002). Top-down attentional control has been shown to influence attention to threat at relatively early stages of processing (SOA 150ms; Bardeen & Orcutt, 2011). It may be difficult to accurately report on processes that occur so quickly. Because of this, some have suggested that self-report measures might assess perceived rather than actual attentional control ability (Spada, Georgiou, & Wells, 2010). Fortunately, this limitation can be addressed by using performance-based measures to assess attentional control (e.g., Bardeen & Daniel, 2017a; Bardeen et al., 2016). In the present study, an attentional cueing task was used as an objective indicator of attentional inhibition.

The dot-probe task is a stimulus-response task that uses button press to make inferences about threat-related attentional biases. Two stimuli (one neutral and one threat-related) appear on the screen during this task for a relatively short presentation duration (e.g., 500ms). The stimuli disappear and a dot appears in the location of either the threat or neutral stimuli. Participants respond by pressing a button as quickly and accurately as possible to identify the dot’s spatial position on the screen. Response times from this task are used to calculate threat-related attentional bias in a manner that is based on the assumption that threat-related attentional biases are stable over time (i.e., calculated as aggregate mean difference scores). Not only do these traditionally calculated scores have notoriously poor reliability (Schmukle, 2005; Staugaard, 2009), but some have argued that they are not ecologically valid because they fail to account for the temporal dynamics of threat-related attentional processing (Zvielli et al., 2015). Instead, it has been suggested that attention bias variability may be a better, more ecologically valid measure of the attentional dysregulation that occurs among vulnerable individuals in the presence of threat stimuli. More specifically, vulnerable individuals (e.g., those with higher PTS symptoms) may exhibit a pattern of threat-related attentional dysregulation in which they rapidly fluctuate between attending toward and away from threat stimuli. This pattern of threat monitoring is thought to capture the phenomena by which the individual simultaneously seeks to (a) down-regulate the uncomfortable arousal associated with the threat stimulus (i.e., avoidance), and (b) stay informed regarding the threat potential of the stimulus (i.e., vigilance). This may be especially relevant in the context of PTSD because hypervigilance for, and avoidance of, trauma-related stimuli are central to the symptom profile (iacoviello et al., 2014).

The poor psychometric properties of commonly used measures of threat-related attentional bias (McNally, 2019; Schmukle, 2005) necessitate the selection of robust, reliable measures in the present study. The reader will recall that the TL-BS method (a measure of attention bias variability) exhibits superior reliability to traditional indices of threat-related attentional bias (Amir et al., 2016; Price et al., 2015; Schafer et al., 2016; Zvielli et al., 2015). Moreover, a measure of general response variability (i.e., “Fake” TL-BS), can be derived from trials that consist of only neutral stimuli in order to ensure that observed effects are specific to threat stimuli rather than being a function of general response variability (Zvielli et al., 2015). Finally, free-viewing eye tracking measures can produce reliable measures of threat-related attentional bias. Specifically, the psychometric properties of the proportion of dwell time on threat during free-viewing trial windows tends to exhibits high internal consistency and acceptable retest reliability (Lazarov, Abend, & Bar-Haim, 2016; Skinner et al., 2018), particularly at longer stimulus durations (e.g., 3,000ms; Waechter et al., 2014). Thus, TL-BS were used in the present study to measure threat-related attention bias variability.
and the proportion of dwell time on threat was used as a measure of overt attention from early to later stages of processing.

1.5. The present study and hypotheses

To summarize, the purpose of the present study was to examine the moderating influence of attentional control on the relationship between PTS symptoms and threat-related attention (i.e., threat-related attentional bias and attention bias variability) at high and low levels of cognitive load. In order to address methodological concerns in this line of research, we used a behavioral indicator of attentional inhibition and selected indices of threat-related attentional bias and attentional bias variability that have demonstrated acceptable reliability. Regarding threat-related attentional bias (assessed via eye-tracking dwell time), we hypothesized that under conditions of low cognitive load, participants with higher PTS symptoms and higher attentional control would be able to use attentional control to avoid threat, whereas those with higher PTS symptoms and relatively worse attentional control would exhibit greater maintenance of attention on threat. Regarding attention bias variability (assessed via the dot-probe task and TL-BS), based on the logic described above, we hypothesized that under conditions of low cognitive load, participants with higher PTS symptoms and higher attentional control would exhibit significantly less attention bias variability compared to those with higher PTS symptoms and relatively worse attentional control. We expected that the moderating effect of attentional control on the relations between PTS symptoms and a) threat-related attentional bias and b) attention bias variability would be attenuated in the high cognitive load condition. A block of positive images was included in the threat-related attention task to ensure that the proposed interaction effects were specific to threat stimuli and were not merely a function of emotionally arousing images in general. Preliminary eye-tracking research has shown that the interaction between PTS symptoms and attentional control does not predict biased processing of positive stimuli (Bardeen, Daniel, Gordon, Hinnant, & Weathers, 2020).

In addition to the aims described above, it is important to ensure that the images used in the present study do in fact alter the participants’ emotional state as would be expected. Images were selected from a well-established image set (Lang, Bradley, & Cuthbert, 1999) based on dimensions of arousal and affect (see Methods for more information). In order to determine whether the images had the expected effect on participants’ emotional state we examined changes in state affect before and after the threat and positive blocks of eye tracking. This is a common practice that has been used in other studies to evaluate emotional reactivity to threat images (e.g. Claus, Bardeen, Thomas, & Benfer, 2020; Tull, Kiel, McDermott, & Gratz, 2013). We expected that state affect would change in accordance with the valence of the images.

2. Method

2.1. Participants and procedure

Participants were undergraduate students recruited from a South-eastern university in the United States via an online research sign-up system. Students were deemed eligible to participate in this study if they were between the ages of 18–65, had normal or corrected vision, and were fluent in English. In order to be included in the final analyses participants had to report experiencing at least one traumatic event, as per Criterion A for a diagnosis of PTSD per the Diagnostic and Statistical Manual of Mental Disorders (5th ed.; DSM-5; American Psychiatric Association, 2013). Nine participants (6%) who did not report a Criterion A event were removed from the sample. In addition, 14 participants were removed from the sample due to concerns regarding inattentiveness and/or task performance, including poor accuracy on the letter recall portion of the attentional bias task (< 60 %; see below), drowsiness/sleeping during the study, and other task performance concerns (e.g., impaired keyboard use, colorblind). The final sample (N = 125; 73 % female) had an average age of 19.37 years (SD = 1.69, range = 18–27). In terms of race, 89.6 % self-identified as White, followed by Asian (4.8 %), Other (3.2 %), and Black or African American (2.4 %). Additionally, one participant identified their ethnicity as Hispanic or Latino (.8%).

The study was conducted in a laboratory setting. After informed consent, participants provided demographic and health information. Next, they completed the attentional cueing task. Participants then completed the PANAS (Time 1 [T1]) before proceeding with the attentional bias task. The PANAS was re-administered after block one of the attentional bias task in order to detect changes in state affect (Time 2 [T2]). Next, participants completed the second block of the attentional bias task and a final PANAS (Time 3 [T3]). Lastly, participants completed a battery of self-report measures that included the LEC-5 and PCL-5. Participants were debriefed, provided with a handout on local mental health resources, and thanked for their participation before leaving the laboratory. Participants were compensated with research credit toward the psychology course of their choosing.

2.2. Self-report measures

2.2.1. Demographics and health information

Participants provided demographic information including sex, age, race, and ethnicity. They also provided information about stimulant medication and caffeine use the day of the study, which have been shown to impact visual attention to tasks such as those used in the present study (Connell, Thompson, Turuwihenu, Hess, & Gant, 2017). As such, stimulant medication and/or caffeine use was included as a covariate in the analyses.

2.2.2. Life events checklist for DSM-5 (LEC-5; Weathers, Blake et al., 2013)

The LEC-5 is a self-report measure of lifetime exposure to traumatic events. Participants indicated whether each of 17 potentially traumatic events happened to them, they witnessed it happen to someone else, they learned about it happening, it happened as part of their job, they don’t know, or it does not apply to them. As part of the extended version of the LEC-5, participants provided a brief narrative of each event and responded to follow-up questions designed to determine whether an event meets Criterion A (APA, 2013). Participants were included in the final sample if they endorsed at least one event that met Criterion A for a diagnosis of PTSD per DSM-5 (APA, 2013). The event types endorsed were summed to serve as an index of cumulative trauma to be examined as a potential covariate in study analyses (Smith, Summers, Dillon, & Cougle, 2016).

2.2.3. PTSD checklist (PCL-5; Weathers, Litz et al., 2013)

The PCL-5 is a 20-item self-report measure designed to assess DSM-5 PTSD criteria (APA, 2013). Participants rated how much they were bothered by each symptom in the past month on a 5-point scale from 0 (not at all) to 4 (extremely). The PCL-5 has demonstrated adequate psychometric properties, including internal consistency, test-retest reliability over a one-week period, and convergent and discriminant validity (Blevins, Weathers, Davis, Witte, & Domino, 2015). In the present study, the PCL-5 score demonstrated acceptable internal consistency (α = .93, M = 16.10, SD = 13.85).

2.2.4. Positive and negative affective schedule (PANAS; Watson, Clark, & Tellegen, 1988)

The PANAS is a 20-item self-report that assesses both positive (PANAS-PA; e.g., attentive, excited, enthusiastic) and negative affect (PANAS-NA; e.g., afraid, distressed, jittery). The PANAS-NA subscale is
sensitive to within-session mood inductions (Rusting & Larsen, 1997; Schneider, Gur, Gur, & Muenz, 1994), and thus, was administered before and after each block of the attentional bias task to determine whether viewing threat (Block 1: T1 to T2) and positive (Block 2: T2 to T3) images resulted in expected changes in state affect. Items of the PANAS are scored on a 5-point scale (1 = very slightly or not at all to 5 = extremely) to indicate the degree to which the participant was currently experiencing each emotion. Both subscales have shown adequate psychometric properties in prior research, including internal consistency, and convergent and criterion-related validity (Crawford & Henry, 2004; Watson et al., 1988). Internal consistency was adequate at each time point for the PANAS-PA scale (T1: $\alpha = .93$, $M = 24.39$, $SD = 8.95$; T2: $\alpha = .91$, $M = 20.37$, $SD = 8.06$; T3: $\alpha = .94$, $M = 21.17$, $SD = 8.95$) and the PANAS-NV scale (T1: $\alpha = .73$, $M = 14.22$, $SD = 3.81$; T2: $\alpha = .86$, $M = 17.21$, $SD = 6.20$; T3: $\alpha = .72$, $M = 12.94$, $SD = 3.55$).

2.3. Assessing attentional inhibition

The attentional cueing task is a modification of Posner's cueing paradigm (Posner, 1980). In the present study it consisted of 100 trials. At the beginning of each trial an arrow appeared at the center of the screen for 500ms. Next, a star appeared on either the left or right side of the arrow. Participants used the left and right arrow key on the computer keyboard to indicate which side of the screen the star appeared on. The arrow presented at the beginning of the trial pointed in the direction of the star 80% of the time (congruent trials) and opposite the star 20% of the time (incongruent trials). Response times for incongruent trials were averaged and used as a moderator variable, while response times for congruent trials were averaged and used as a control variable in study analyses. This approach accounts for baseline differences in responding and avoids the pitfalls of difference scores (Peter, Churchill, & Brown, 1993).

2.4. Assessing attentional bias

Instead of presenting two separate tasks that would take considerably longer to complete, the dot-probe and free-viewing tasks were combined to reduce participant burden and avoid the effects of depleted attentional control on the task that would have been presented second. This approach also decreased the likelihood that participants would become desensitized to the threat images, which might occur if they were to be presented in two different tasks. This approach is consistent with calls to assess threat-related with combined tasks, tasks that include both (a) button press to make inferences about early threat-related attention and (b) eye tracking to obtain an overt measure of threat-related attention at relatively later stages of processing (Amir et al., 2016; Bardeen & Daniel, 2017b).

The set of images used in the present study included 40 threat (e.g., vicious dog, car accident), 40 positive (e.g., puppies, ice cream), and 80 neutral images (e.g., broom, busy pedestrian sidewalk). These images were developed by The National Institute of Mental Health (i.e., Internationally Affective Picture System slides; IAPS; Lang et al., 1999). General threat images had negative valence ($M = 2.2$) and high arousal ($M = 6.5$), positive images had positive valence ($M = 7.3$) and high arousal ($M = 6.1$), and neutral images had neither negative nor positive valence ($M = 5.1$) and low arousal ($M = 3.0$; Lang et al., 1999).

The task began with a calibration/validation process, which required participants to follow a dot with their eyes, as it moved to 13 locations on the screen. Following successful calibration/validation, task instructions were presented. The task was an adapted version of that used by Booth et al. (2017) in their examination of the effects of cognitive load on threat-related attentional bias. The first block of the task consisted of threat and neutral images and the second block of the task consisted of positive and neutral images. The threat and positive stimuli were placed in separate blocks because we were most interested in threat-related attention and wanted to decrease the likelihood that participant fatigue would impact our ability to assess this construct. Additionally, blocked presentation may maximize the hypothesized effect. Specifically, scrambling stimulus types within the same block can result in carryover effects from trial to trial, which may be one reason why blocked presentations produce significantly larger effect sizes than within block randomized presentations (e.g., Bar-Haim et al., 2007; Holle, Neely, & Heinberg, 1997).

The following describes task elements for the threat block (see Fig. 1 for a graphic depiction). To begin the task, participants were presented with a series of uppercase consonants (either two [low load] or six [high load]) to memorize. This is a common cognitive load manipulation that has previously demonstrated effects on outcomes of interest (Booth et al., 2017; Hester & Garavan, 2005; Van Dillen & Derks, 2012). In keeping with Booth et al. (2017), participants in the high load condition had 2000ms to memorize the string, and participants in the low load condition had 500ms. A fixation cross appeared next and remained on the screen until the participant fixated on it for 200ms. Next, two images appeared on the screen for 3000ms (either a threat-neutral or neutral-neutral image pairing). Neutral-neutral image pair-

---

![Fig. 1. Attentional Bias Task in High Load Condition.](image-url)
ings were presented in both blocks to increase task engagement and reduce the expectancy of seeing a threat image. Participants were instructed to view task images freely during the task, at their own discretion. Eye tracking variables were derived from this portion of the task. After 3000ms, a fixation cross appeared and remained on the screen until the participant fixated on it for 200ms. Next, a second image pair (either a threat-neutral or neutral-neutral image pairing) appeared on the screen for 500ms. After 500ms, a dot appeared behind one of the images and participants were asked to use the left or right arrow key (< >) to quickly and accurately indicate whether the dot appeared behind the left or right image. Reaction time data was used from this portion of the task to calculate attention bias variability scores. Neutral-neutral trials were used to create “Fake” TL–BS parameters (Zvielli et al., 2015). On the final screen, participants were presented with a single letter and asked whether it had been presented to them in the string of consonants at the beginning of the trial. On 50% of trials, the letter had been a part of the original list. This final element helped to ensure that participants were storing the original consonant string in short-term memory while completing each trial, thus taxing cognitive resources. Responders with low accuracy (< 60%) were removed from the final analyses. The task consisted of 65 total trials: 5 practice trials, after which participants were able to ask questions, 20 neutral-threat trials where the dot appeared behind the threatening image (congruent), 20 neutral-threat trials where the dot appeared behind the neutral image (incongruent), and 20 neutral-neutral trials. The positive block was identical to that described above, except that it displayed positive images in place of threatening ones.

2.5. Deriving indices of threat-related AB

TL–BS were used in the present study to assess threat-related attentional biases at a relatively earlier stage of threat processing (i.e., 500ms). Consistent with Zvielli et al. (2015), trials with error responses, trials indicating anticipatory responses (response times [RTs] < than 200ms), and outlier trials (RTs > 1,500 ms or > 3 SDs above a participant’s individual mean) were discarded. TL–BS were calculated from response time data by subtracting each incongruent trial from the temporally nearest congruent trial. Consistent with Zvielli et al. (2014), a maximum of five trials between these incongruent-congruent pairs was allowed. This process produces a sequence of difference scores that are summed and divided by the total number of scores to produce an attention bias variability (ABV) score. In the present study, TL–BS exhibited adequate internal consistency in the high (threat-related TL–BS $\alpha = .81$ and positive-related TL–BS $\alpha = .85$) and low (threat-related TL–BS $\alpha = .85$ and positive-related TL–BS $\alpha = .80$) load conditions. We also calculated a “Fake” TL–BS using only neutral-neutral trials to ensure that any observed effects were due to the presence of threat stimuli rather than being a function of variability in responding more generally (Zvielli et al., 2015). Fake TL–BS exhibited adequate internal consistency in the high (fake threat-related TL–BS $\alpha = .84$ and fake positive-related TL–BS $\alpha = .77$) and low (fake threat-related TL–BS $\alpha = .78$ and fake positive-related TL–BS $\alpha = .84$) load conditions.

Dwell time was used as an indicator of threat-related attentional biases from early to later stages of threat processing (i.e., 3000ms). Fixations longer than 100ms on a valid area of interest (i.e., the threat, positive, and neutral stimuli described above) were used to calculate dwell time. Specifically, dwell time was calculated as the proportion of time spent attending to affective versus neutral stimuli during the 3000ms free viewing period. Higher scores indicate a greater proportion of time spent attending to affective versus neutral stimuli. Proportion of dwell time on threat versus neutral stimuli exhibits high internal consistency and acceptable test-retest reliability (Lazarov et al., 2016; Skinner et al., 2018). In the present study, dwell time exhibited adequate internal consistency in the high (dwell time on threat $\alpha = .95$ and dwell time on positive $\alpha = .75$) and low (dwell time on threat $\alpha = .94$ and dwell time on positive $\alpha = .77$) load conditions.

2.6. Equipment

Participants completed self-report measures and the attentional cueing task on a Hewlett Packard Z230 desktop computer with a 24-inch BenQ XL2430 monitor. All tasks were completed using the computer mouse and keyboard. Questionnaires were presented via Qualtrics (http://qualtrics.com). E-Prime 3.0 (Psychology Software Tools, Pittsburgh, PA, 2016) was used to present the attentional cueing task. The attentional bias task was created using Eyelink’s Experiment Builder (SR Research, 2017) and was presented on a Hewlett Packard Z230 desktop computer with a 24-inch View Sonic monitor. Participants were seated at a viewing distance of 60cm and their heads were secured in a chinrest throughout the task. Eye movements were recorded using a desktop mounted EyeLink 1000 plus tracking system (SR Research, 2017). During tracking, the EyeLink 1000 Plus eye-tracking system uses pupil center and corneal reflection to record monocular gaze position at 1000 Hz (1000 samples per second), with up to 0.25° accuracy and 0.01° spatial resolution.

3. Results

3.1. Descriptive statistics

Demographic variables including, age, sex, race and ethnicity did not significantly differ by load condition (all $p$s $> .05$). In addition, PTS symptoms did not significantly differ by load condition $F(1, 125) = .48, p = .49$, suggesting adequate randomization. Participants reported an average of 7.44 potentially traumatic event types ($SD = 3.15$). The average score on the PCL was 16.10 ($SD = 13.85$), with symptom scores ranging from zero to 63. These scores are similar to those observed in other laboratory studies using undergraduate samples (e.g., Bardeen & Daniel, 2017a). Correlations between study variables are presented in Table 1. Although measures of attention inhibition, threat-related attention bias variability, and threat-related attentional bias were not significantly associated with PTS symptoms at the bivariate level, as is described above, it was expected that several of these relationships would be conditional based on the cognitive load manipulation and interaction effects.

3.2. Assessing affective change

A series of dependent t-tests were conducted to examine changes in affect from T1 to T2 and T2 to T3. As expected, and consistent with previous research (Clauss et al., 2020), viewing threat-related IAPS images resulted in a significant increase in negative affect from T1 ($M = 14.22, SD = 3.81$) to T2 ($M = 17.21, SD = 6.20$; $t(125) = -6.84, p < .001$) and a significant decrease in positive affect from T1 ($M = 24.39, SD = 8.95$) to T2 ($M = 20.37, SD = 8.06$; $t(125) = 8.30, p < .001$). Additionally, there was a significant decrease in negative affect from T2 ($M = 17.21, SD = 6.20$) to T3 ($M = 12.94, SD = 3.55$; $t(125) = 8.96, p < .001$), but the change in positive affect that occurred from T2 to T3 did not reach statistical significance at $p < .05$ (T2: $M = 20.37, SD = 8.06$; T3: $M = 21.17, SD = 8.95$; $t(125) = -1.72, p = .088$).

3.3. Potential covariates

Stimulant use (e.g., medication, caffeine) on the day of the study was correlated with threat-related and positive-related TL–BS ($r = -.19, p = .031$ and $r = -.22, p = .02$, respectively). Specifically, those who had used stimulants exhibited significantly less ABV (Threat $M = 170.48$ and Positive $M = 144.92$) than those who had not
Table 1
Correlations between study variables.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. LEC total</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Stimulant Use</td>
<td>-.06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Task Accuracy-TB</td>
<td>.10</td>
<td>.03</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Task Accuracy-PB</td>
<td>.09</td>
<td>.01</td>
<td>.75</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Cueing Congruent</td>
<td>-.09</td>
<td>.06</td>
<td>.19</td>
<td>.06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. PCL-S</td>
<td>.25</td>
<td>.13</td>
<td>-.07</td>
<td>-.04</td>
<td>.08</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Cueing Incongruent</td>
<td>-.01</td>
<td>.03</td>
<td>.12</td>
<td>.04</td>
<td>.83</td>
<td>.12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Condition</td>
<td>-.04</td>
<td>-.02</td>
<td>-.50</td>
<td>-.56</td>
<td>-.12</td>
<td>.06</td>
<td>-.14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. TL-Bs Threat</td>
<td>.15</td>
<td>-.19</td>
<td>-.03</td>
<td>-.01</td>
<td>.26</td>
<td>.02</td>
<td>.24</td>
<td>.13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. TL-Bs Positive</td>
<td>.01</td>
<td>-.22</td>
<td>-.15</td>
<td>.25</td>
<td>-.13</td>
<td>.04</td>
<td>.22</td>
<td>.15</td>
<td>.52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Dwell Threat</td>
<td>-.03</td>
<td>-.14</td>
<td>.13</td>
<td>.08</td>
<td>.09</td>
<td>-.04</td>
<td>-.00</td>
<td>-.03</td>
<td>.13</td>
<td>.07</td>
<td></td>
</tr>
<tr>
<td>12. Dwell Positive</td>
<td>-.09</td>
<td>-.09</td>
<td>-.03</td>
<td>-.04</td>
<td>-.04</td>
<td>-.11</td>
<td>-.04</td>
<td>.01</td>
<td>.05</td>
<td>.06</td>
<td>.01</td>
</tr>
</tbody>
</table>

Note. N = 125. Bolded values significant at p < .05 (two-tailed). LEC Total = Life Events Checklist, total number of potentially traumatic event types endorsed; Stimulant Use = Stimulant medication or caffeine use the day of the study; Task Accuracy = letter recall percent correct for the attentional bias task (TB = threat block, PB = positive block); Cueing Congruent = RTs from congruent trials of the Attentional Cueing Task; PCL-S = PTSD Checklist; Cueing Incongruent = RTs from incongruent trials of the Attentional Cueing Task; Condition = Load condition; TL-Bs threat = trial-level bias scores for threat block; TL-Bs positive = trial-level bias scores for positive block; Dwell threat = proportion of dwell time on threat versus neutral images, Dwell positive = proportion of dwell time on positive versus neutral images.

(Threat M = 197.57, Positive M = 173.66). Cumulative trauma was correlated with the PCL-5 total score (r = .25, p = .005); as trauma exposure increased, so did PTS symptoms. Finally, the accuracy with which participants identified the letter that appeared at the end of each trial of the attentional bias task during the positive block was correlated with positive-related TLBS (r = -.25, p = .006); as accuracy decreased, ABV increased. As such, these three variables served as covariates in subsequent analyses.

3.4. Regression analyses

Hierarchical regression was used to test study hypotheses. Significant three-way interactions were evaluated using the PROCESS macro for SPSS (Hayes, 2013). PROCESS generates simple slopes between the predictor (i.e., PTS symptoms) and outcome variable (i.e., threat-related TLBS, fake TLBS, positive-related TLBS, dwell time on threat, or dwell time on positive) at high and low levels (+ 1 SD) of both moderators (i.e., attentional cueing incongruent and load condition). This allows for the conditional effects of the independent variable to be interpreted.

3.4.1. Predicting TLBS

Threat-related TLBS served as the outcome variable in the first model. Covariates (i.e., stimulant use, total number of traumas, task accuracy, attentional cueing congruent), the predictor (PCL-5 total score), and moderators (attentional cueing incongruent, load condition) were entered into the first step of the model. Two-way interactions were entered into the second step of the model (i.e., PCL-5 by load condition, PCL-5 by attentional cueing incongruent, and attentional cueing incongruent by load condition). The three way interaction between the PCL-5, attentional cueing incongruent, and load condition was entered into the third step of the model. Lower order effects (see Table 2) were qualified by a significant 3-way interaction (β = -.23, SE = .015, t = 2.50, p = .01). The association between PTS symptoms and threat-related TLBS was significant at the combination of low load and better inhibitory ability (r = -2.28, SE = .95, p = .02). The interaction between PTS symptoms and threat-related TLBS was not significant at the combinations of low load and worse inhibitory ability (r = .64, SE = .72, p = .52), high load and better inhibitory ability (r = .52, SE = .85, p = .60), or high load and worse inhibitory ability (r = -1.33, SE = .97, p = .19). Individuals with higher PTS symptoms and better inhibitory ability exhibited less ABV in the low load condition (see Fig. 2), but inhibitory ability did not moderate the relationship between PTS symptoms and ABV in the high load condition (see Fig. 3).

A second regression was conducted with the same predictors and covariates as above, but substituting Fake TL-BS as the outcome. This
Finally, a third regression was conducted with the same predictors and covariates as above, but positive-related TL-BS served as the outcome variable. The 3-way interaction did not predict positive-related TL-BS (β = -0.14, SE = 0.01, t = -1.56, p = .12). This suggests that the interactive effect between PTS symptoms, attentional inhibition, and cognitive load is specific to threatening stimuli.

3.4.2. Predicting dwell time

Proportion of dwell time on threat versus neutral stimuli served as the outcome variable in the first model. Covariates (i.e., stimulant use, total number of traumas, task accuracy, attentional cueing congruent), the predictor (PCL-5 total score), and moderators (attentional cueing incongruent, load condition), were entered into the first step of the model. Two-way interactions were entered into the second step of the model (i.e., PCL-5 by load condition, PCL-5 by attentional cueing incongruent, and attentional cueing incongruent by load condition). The three way interaction between the PCL-5, attentional cueing incongruent, and load condition was entered into the third step of the model. None of the predictor variables significantly predicted dwell time on threat (see Table 2). The model was also run with proportion of dwell time on positive images as the outcome. None of the predictor variables significantly predicted dwell time on positive images (see Table 2).

4. Discussion

This study is the first to support the theoretical assumption from attentional control theory that top-down regulation of threat-related attentional processing can be disrupted by increasing cognitive load (Eysenck et al., 2007). Using TL-BS derived from the dot probe task, we found that top-down attentional control moderated the relationship between PTS symptoms and threat-related attention bias variability under low, but not high load. In the low load condition, individuals with higher PTS symptoms and relatively worse attentional control exhibited greater threat-related attention bias variability (i.e., rapid fluctuations between attending toward and away from threat stimuli) than those with higher PTS symptoms and relatively better attentional control. Bardeen et al. (2016), who observed the same result in a community sample of adults, interpreted this finding as suggesting that individuals with PTSD and relatively worse attentional control exhibit a pattern of threat monitoring that allows for the constant updating of threat potential, thus resulting in greater attentional engagement with the threat stimulus over time. In contrast, those with higher PTS symptoms and relatively better attentional control display a more consistent pattern of attentional responding in the presence of threat. By examining variability on trials for which only neutral stimuli were presented (i.e., Fake TL-BS), we were able to ensure that the significant moderation effect observed in the low load condition was specific to the presence of threat stimuli and not merely a function of general variability in response times. Finally, as predicted, in the high cognitive load condition, where top-down resources were taxed to a higher degree, individuals with relatively better attentional control were not able to use top-down control to reduce threat-related attention dysregulation.

Our findings are consistent with dual process models of threat-related attentional bias which suggest that, different patterns of threat-related attentional processing will be observed among those with higher levels of PTS symptoms based on individual differences in attentional control (e.g., Dennis-Tiwary et al., 2019; Eysenck et al., 2007). Specifically, individuals with relatively worse attentional control are more likely to exhibit attention dysregulation in the presence of threat because they lack the top-down resources to disengage, and maintain disengagement, from such stimuli. Thus, under conditions where top-down resources are minimally taxed (i.e., low load condition), failing to account for individual differences in attentional control will obscure the relationship between PTS symptoms and threat-related attention bias variability.

---

1 The approach used to account for non-specific response time variability, where fake TL-BS was substituted of positive and negative TL-BS as the outcome variable, is consistent with the approach used in the seminal work of Zvieli et al. (2015). At the request of an anonymous Reviewer, who was interested in whether the effect of interest would be significant after controlling for non-specific response time variability, we re-ran the primary regression using TL-BS as the outcome, while entering fake TL-BS as an additional covariate in the first step of the model. Consistent with our primary analysis, the 3-way interaction between PTS symptoms, attentional control, and cognitive load predicting TL-BS remained significant (β = -0.20, SE = 0.01, t = -2.57, p = .01). The association between PTS symptoms and threat-related TL-BS was significant at the combination of low load and better inhibitory ability (t = -2.59, SE = 0.81, p = .01). The interaction between PTS symptoms and threat-related TL-BS was not significant at the combinations of low load and worse inhibitory ability (t = .73, SE = 0.61, p = .46), high load and better inhibitory ability (t = .90, SE = .73, p = .37), or high load and worse inhibitory ability (t = -.74, SE = .84, p = .46). In the low load condition, participants with higher PTS symptoms and better inhibitory ability exhibited less attention bias variability.
The reader will recall that Booth et al. (2017) did not find evidence of a significant association between trait anxiety and threat-related attentional bias, assessed using first fixations to threat and dot-probe difference scores, in their low load condition. However, there were some notable methodological differences between our study and that of Booth et al. (2017). First, and most importantly, individual differences in attentional control were assessed in the present study, but not in the study conducted by Booth et al. (2017). As described, individual differences in top-down attentional control predict disparate patterns of attention when cognitive resources are minimally taxed (i.e., low load). When individual differences are unaccounted for, the effect of anxiety-related pathology on threat-related attentional bias is obscured. This explanation accounts for both the interactive effect of PTS and attentional control on threat-related attentional bias observed in the present study and Booth et al.’s (2017) failure to find an association between trait anxiety and threat-related attentional bias in their low load condition. Other methodological considerations may have prevented Booth et al. (2017) from observing this effect. As described, both first fixations on threat and aggregate mean difference scores, which were used by Booth et al. (2017), exhibit poor reliability (Price et al., 2015; Schmukle, 2005). The notoriously poor reliability of common indices of threat-related attentional bias makes it difficult to discern whether null findings are conceptually meaningful, or are instead the byproduct of poor psychometric properties. Additionally, Booth and colleagues used a 100ms presentation duration, whereas the present study assessed threat-related attention bias variability at 500ms. It may be that early bias toward threatening information is universally adaptive and is observed across persons, with anxiety-specific differences emerging at later stages of processing. If so, the likelihood of observing anxiety-based differences in threat-related attention would increase from earlier to later stages of processing.

In contrast to our threat-related attention bias variability outcome, we did not observe the hypothesized interaction effect when the eye tracking outcome was used in the analysis. Although it is possible that the interaction effect of interest is specific to threat-related attention bias variability, and not threat-related attentional bias (as assessed via dwell time), we believe that this explanation is unlikely given that the proposed effect has been observed in two different studies when a standard free-viewing task was used (Bardeen & Daniel, 2017a, 2017b; Bardeen et al., 2020). Instead, the most likely explanation for the null effect for dwell time was our use of a novel task designed to simultaneously assess threat-related attentional bias and attention bias variability. Specifically, we combined the dot probe task and the free viewing task in order to obtain estimates of threat-related attention at both earlier (500ms) and later (3000ms) stages of processing. Additionally, participants were required to memorize a letter string at the beginning of each trial (i.e., either two (low load) or six letters (high load)). The free viewing tasks used by Bardeen and Daniel (2017a) and Bardeen et al. (2020) did not include a cognitive load manipulation, nor did they require button press during each trial. Thus, it’s possible that this methodological approach negatively impacted our ability to detect an effect using the eye tracking outcome. At both levels of the load manipulation (high and low), participants in the present study needed to engage in rehearsal to hold the string of letters in working memory throughout the free-viewing task. The results of the present study suggest that the moderation effect observed in previous research may be attenuated by relatively small increases in cognitive load. It will be important to include a no load condition in future studies to test this hypothesis.

Findings from the dot-probe portion of this study could have important implications for treatment, particularly attention bias modification (ABM) programs. ABM operates on the assumption that attentional bias toward threat produces negative emotional arousal that maintains PTS symptoms. As such, participants receive a one-size-fits-all treatment that encourages threat avoidance. Past research (Bardeen & Daniel, 2017a; Bardeen & Orcutt, 2011), and the results from the present study, suggest that the expression of threat-related attentional bias depends on individual differences attentional control. Therefore, training individuals with relatively higher PTS symptoms to disengage and shift attention from threat stimuli, without considering whether or not they exhibit attention maintenance, avoidance, or some combination of the two at baseline, seems problematic. In fact, it may be detrimental to train individuals with greater PTS symptoms to use attentional control to chronically and rigidly avoid threat as this pattern of responding to threat stimuli is associated with PTS symptom maintenance over time (Bardeen & Daniel, 2017a; Bardeen et al., 2020). Failing to account for different patterns of threat-related attention (i.e., maintenance, avoidance, or both) might contribute to null and inconsistent findings in the ABM literature. By assessing these differences prior to treatment, practitioners may be able to provide patient-specific interventions that improve treatment outcomes. Finally, some studies have begun to explore the use of cognitive load in the delivery of ABM. Booth, Mackintosh, Mobini, Oztup, and Nunn (2014) found that ABM produced threat avoidance when delivered under low load, but not high load. They suggest that ABM procedures might encourage the use of top-down control to inhibit and disengage from threat, but that under high load top-down control is over-taxed effectively eliminating the ability to disengage. Our data are consistent with this perspective. As noted by Booth et al. (2014), this might indicate that it is necessary to administer ABM procedures in distraction-free environments in order for them to be effective. When environmental stimuli increase cognitive load, limited top-down resources cannot be used to re-direct attention. This may suggest that at-home delivery of ABM, which is likely accompanied by greater and more frequent distractions, could be less effective than ABM delivered in laboratory or clinical settings.

In addition to ABM procedures, this study might have important implications for the treatment of PTS symptoms via prominent psychotherapies. Persistent use of attentional control to disengage and shift attention away from threat has been linked to greater PTS symptoms over time (Bardeen & Daniel, 2017a; Bardeen et al., 2020). It has been suggested that the rigid application of attentional control in favor of avoidance might be particularly problematic because it prevents the natural oscillation between approach and avoidance that is characteristic of natural recovery from trauma (Orcutt, Reffi, & Ellis, 2020). In contrast, more flexible use of attentional control could allow for gradual processing of traumatic information. This is consistent with prominent models of emotion regulation that identify the flexible use of attentional control as central to psychological well-being (Gross, 1998). Our findings suggest that individuals who are accustomed to down-regulating negative affect and physiological arousal by using top-down attentional control to disengage from threat might not be able to do so under conditions that tax cognitive resources. An unwillingness to experience emotional distress, might make cognitively taxing therapeutic approaches, such as prolonged exposure for PTSD, particularly difficult to effectively engage in. In such cases, it may be beneficial to supplement traditional exposure with approaches that could augment emotion regulation such as dialectical behavior therapy (Becker & Zayfert, 2001) or Skills Training in Affective and Interpersonal Regulation (STAIR; Hassija & Cloitre, 2015).

This study is not without limitations. As described, the use of a novel threat-related attentional bias task may have limited our ability to detect the hypothesized effect for the free-viewing portion of the task. Additionally, the number of trials used in this task was relatively low. Although using a greater number of trials is preferred for response time assessments of threat-related attention (e.g., Miller & Ulrich, 2013; Price et al., 2015), it would not have been feasible to incorporate substantially more trials into our task while simultaneously assessing overt attentional biases via eye-tracking with the trial window of 3000ms. Importantly, the reliability estimates for all of our attentional bias indices were adequate. Additionally, participants did not provide ratings of arousal and valence for the images that were presented during this
task. As such, the degree to which these stimuli were unrelated to the traumatic experiences of our participants is unknown. Because participants reported experiencing a wide range of traumas, and the large majority of the sample reported multiple traumatic events, it would not have been feasible to use trauma-specific images or attempt to remove any image that may have been traumatic relevant to any one participant. Instead, to reduce trauma-specific responding, we used general threat images of a wide variety that were pre-tested elsewhere (IAPS; Lang et al., 1999). These images, which have been used in previous examinations of threat-related attentional bias (Bardeen & Daniel, 2017a), have been shown to induce negative affective states (Bardeen, 2015). Threat-related attentional bias is a polysemous construct that has been assessed with a wide variety of methods. It may be important to consider using other methods of assessing threat-related attentional biases (e.g., assessing the N2pc component using electroencephalography; Torrence & Troup, 2018) in future studies to determine whether the null effects of the present study are not a function of the method of assessing threat-related attentional bias that was used.

Although empirical evidence supports a dimensional, rather than categorical conceptualization of PTS (e.g., Bromman-Fulks et al., 2006; Forbes, Haslam, Williams, & Creamer, 2005; Ruscio, Ruscio, & Keane, 2002), replicating study findings in a more symptomomatic clinical sample will be important to ensure that these findings are generalizable to individuals who meet DSM-5 criteria for PTSD (American Psychiatric Association, 2013). Additionally, it will be beneficial in future research to conduct a more comprehensive assessment of PTSD and commonly co-occurring disorders to clarify whether results from the present study are PTSD specific. Some evidence suggests that the moderation effect of interest may be broadly relevant to anxiety- and fear-related pathologies (Derryberry & Reed, 2002; Ho, Yeung, & Mak, 2017; Taylor, Cross, & Amir, 2016). Finally, although some meta-analytic tasks that require button press are often used as objective measures of attentional control, button press introduces additional error variance because individual differences in motor speed contribute to the scores that are calculated from these tasks. As such, it may be beneficial to use eye-tracking technology to assess attentional control in future research (i.e., the antisaccade task; Hallett, 1978).

To our knowledge, the present study is the first to provide evidence that increasing cognitive load attenuates the moderating effect of top-down attentional control on threat-related attention bias variability among those with higher PTS symptoms. Study findings highlight the importance of assessing individual differences in attentional control in this line of research. Specifically, failing to account for individual differences in attentional control may obscure patterns of threat processing among those with anxiety- and fear-related pathology. Moreover, study findings suggest that factors that tax top-down cognitive resources should be incorporated into models of threat-related attention to improve the predictive utility of these models.

References

Konstantinou, N., & Lavie, N. (2013). Disociable roles of different types of working


