The Interactive effect of Posttraumatic Stress Symptoms, Attentional Control, and Cognitive Load on Threat-Related Attentional Bias

by

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Abstract

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, Weinberg, Langenecker, & Shankman, 2017) can use that ability to disengage and shift attention away from threat stimuli (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 (i.e., maintenance/undercontrollers). Given that attentional control is a limited resource, overcontrollers may not be able to strategically avoid threat information when cognitive load is relatively high. The interaction between PTS symptoms, attentional control, and cognitive load in predicting threat-related attentional bias was examined in the present study to test this hypothesis. In addition, due to the heterogenous nature of PTS disorder (PTSD), it may be useful to determine whether some symptom clusters are more influential than others in predicting the proposed effect. Given that abnormalities in threat-related information processing have been observed across anxiety disorders (Armstrong & Olatunji, 2012; Bar-Haim et al., 2007), it may be that the effect of PTS symptoms on threat bias is anchored to symptoms that are also prominent in anxiety disorders. Participants ($N = 149$ 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 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 effect was specific to arousal and avoidance symptoms. Thus, consistent with theory, under conditions of higher cognitive load, overcontrollers may not be able to use attentional control to disengage and shift attention away from threat. 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 modification interventions to reduce PTS symptomatology.

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The Interactive effect of Posttraumatic Stress Symptoms, Attentional Control and Cognitive Load on Threat-Related Attentional Bias

Bottom-up (e.g., automatic, reflexive) threat-related attentional bias is conceptualized as a core vulnerability factor for the development of posttraumatic stress (PTS) symptomatology (e.g., Beck, Emery, & Greenberg, 1985; Williams, Watts, MacLeod, & Matthews, 1997). However, empirical evidence regarding the degree to which individuals with anxiety and related symptoms exhibit threat-related attentional bias has been mixed. In addition to null findings, inconsistent patterns of attentional bias have emerged in this literature including reflexive orienting toward threat (Bannerman, Milders, & Sahraie, 2010; Fox, Derakshan, & Shoker, 2008), sustained attention on threat (i.e., maintenance; Pineles, Shipherd, Welch, & Yovel, 2007), and bias away from threat (i.e., avoidance; Bardeen & Daniel, 2017). 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, 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), while those with relatively worse attentional control maintain attention on threat (i.e., maintenance; Bardeen & Daniel, 2017; Bardeen, Tull, Daniel, Evenden, & Stevens, 2016; Bardeen & Orcutt, 2011). However, attentional control is a limited cognitive resource (Eysenck & Derakshan, 2011; Konstantinou & Lavie, 2013; Murphy, Groeger, & Greene, 2016), and as such, individuals with higher posttraumatic stress symptoms, who also have relatively better attentional control, may not be able to use this resource to avoid threat stimuli under conditions of higher cognitive load. Finally, it may be important to consider the heterogenous nature of PTS symptoms. There are 636,120 ways to meet criteria for PTSD, meaning that presentations can vary widely (Galatzer-Levy & Bryant, 2013). Given the transdiagnostic nature of threat-related attentional bias across anxiety disorders (Armstrong & Olatunji, 2012; Bar-Haim et al., 2007), it may be that the effect of PTS symptoms on bias is anchored to symptoms that are also prominent in anxiety disorders (i.e., hypervigilance and avoidance). The purpose of this study was to examine the yet untested hypothesis, that attentional control would moderate the effect of PTS symptoms on threat-related attentional bias at low, but not high cognitive load.

PTSD: Definition, Prevalence, and Consequences

Definition

Stress reactions predate the formal classification of PTSD by centuries. Terms like "war neuroses", "combat hysteria", and "shell shock" were used to describe the psychological and physical symptoms that resulted from combat (Crocq & Crocq, 2000; Friedman, Resick, & Keane, 2007; Jones, 2012). Although these conditions involved many symptoms that are not consistent with the current diagnostic criteria for PTSD, they were among the first attempts to synthesize the construct of traumatic stress.

PTSD made its debut as a psychological diagnosis in the anxiety disorders section of the third edition of the *Diagnostic and Statistical Manual of Mental Disorders* (*DSM-III;* American Psychiatric Association [APA], 1980) in 1980. Since then, it has undergone numerous revisions, many of which have been met with controversy (Friedman et al., 2007). *DSM-III* (APA, 1980) defined trauma as an event that would be distressing to most people and proposed 12 symptoms within three clusters, namely re-experiencing, numbing, and arousal/avoidance. This definition attempted to de-stigmatize distress after trauma and differentiated normal responses from those that might warrant intervention.

The criteria for PTSD were extensively revised in 1987 with the introduction of *DSM-III-R,* which required that symptoms result from "an event that is outside the range of usual human experience and that would be markedly distressing to almost anyone". In anchoring the diagnosis to catastrophic events, *DSM-III-R* differentiated PTSD from responses to "ordinary stressors" (i.e., divorce, financial hardship). This revision also provided exposure criteria and specified that symptoms last one month or more. Finally, *DSM-III-R* introduced significant changes to the structure of the three symptom clusters. Specifically, avoidance symptoms were removed from the arousal cluster and placed with numbing symptoms, several symptoms were revised or removed (e.g., survival guilt), and numerous symptoms were added (e.g., psychogenic amnesia, foreshortened future, avoidance of thoughts and feelings, irritability/anger, reactivity), resulting in 17 symptoms total (North, Surís, Smith & King, 2016).

When *DSM-IV* was introduced (APA, 1994), the structure of the PTSD diagnosis was largely unchanged with the exception of Criterion A, which redefined a traumatic event as involving actual or threatened death or serious injury (A1) and specified that the individual must experience helplessness or horror in response to the event (A2). In *DSM-5* (APA, 2013), PTSD was placed in a new category: Trauma and Stressor-Related Disorders. Additionally, the A1 definition of trauma was narrowed and the A2 criterion from *DSM-IV* (i.e., helplessness and horror) was removed. Avoidance and numbing were split into two separate clusters, and three symptoms were added to the PTSD diagnosis (i.e., blame, negative emotions, and recklessness; resulting in 20 total symptoms). Finally, *DSM-5* revisions introduced a dissociative subtype.

The extensive changes in *DSM-5* have garnered a mix of approval and concern. Importantly, removal of the A2 criterion and tightening of the types of events that meet the A1 criterion prompted concern that prevalence rates could be significantly altered. Several studies have shown that prevalence rates for *DSM-5* are comparable (Miller et al., 2013; Tsai et al., 2014) or only slightly higher than earlier versions (Calhoun et al., 2012; Carmassi et al., 2013). However, there is some concern that individuals who met criteria for PTSD under *DSM-IV* might not under *DSM-5* and vice versa, in which case stable prevalence rates do not stave off practical concerns about providing services to clients (Hoge, Riviere, Wilk, Herrell, & Weathers, 2016).

In addition, the language of criterion A was modified to indicate that an individual could be exposed to multiple traumatic events that might contribute to the overall symptom profile. Regarding changes to the structure of the diagnosis, early factor analytic work suggested that a four-factor model is appropriate (Friedman, Resick, Bryant, & Brewin, 2011; Miller et al., 2013), with the new recklessness and amnesia symptoms exhibiting weak loadings. Since the *DSM-5* criteria were introduced, alternate structures, with an increasing number of factors, have been identified in numerous studies (Gentes et al., 2014; Tsai et al., 2014). However, the clinical utility of further separating symptom clusters is not well understood. Finally, inter-rater reliability for *DSM-5* criteria is acceptable, suggesting that clinicians are able to establish consensus about the diagnosis (Freedman et al., 2013; Regier et al., 2013).

Prevalence and Consequences

PTSD is a significant psychosocial concern with considerable negative effects on personal well-being and cost to society. A systematic review revealed that, among those who directly experienced a traumatic event, 28.8% met criteria for PTSD one month after the event (Santiago et al., 2013). However, this number substantially decreased over time, with only 17% of these trauma survivors meeting full criteria for PTSD one year after the event (Santiago et al., 2013). Lifetime prevalence estimates range from 6-12% (Carmassi et al., 2013; Tsai et al., 2014). Not only does PTSD affect a considerable portion of the population, but it is associated with negative physical and mental health outcomes. For example, meta-analytic data show that higher (versus lower) PTS symptoms are associated with more health conditions and poorer quality of life (Pacella, Hruska, & Delahanty, 2013). In one study, lifetime PTSD was related to poorer sexual health (i.e., risky sexual behaviors and sexually transmitted disease/infection; Mota et al., 2019). In addition, PTSD is highly comorbid with other psychological conditions including depression (Horesh et al., 2017), suicidality (Krysinska & Lester, 2010; Panagioti, Gooding, Triantafyllou, & Tarrier, 2015), and substance use (Jacobsen, Southwick, & Kosten, 2001). The cost of PTSD to society is staggering, with one study estimating that the two-year cost of caring for Veterans with PTSD (and comorbid depressive symptoms) is anywhere from 4 to 6.2 billion dollars (Eibner, Ringel, Kilmer, Pacula, & Diaz, 2008). Given the substantial personal and societal cost of PTSD, numerous models have been developed in order to account for the progression of symptoms, many of which consider the role of information processing abnormalities.

Information Processing Models of PTSD

Fear structures, which provide information about potentially threatening stimuli, available responses, and their associated meaning, are of central importance in early information processing models of PTSD (Lang, 1977). Importantly, fear structures are thought to be activated by actual and degraded fear-relevant stimuli (Lang, 1977; Litz & Keane, 1989). That is, the same structure might be activated by a physically threatening stimulus (e.g., an angry dog), distal environmental cues (e.g., a jingling noise that sounds like a dog's collar), and more abstract cues such as words (e.g., "dog", "bite" etc.). Litz and Keane (1989) outlined the relevance of an information processing approach to PTSD, suggesting that because there is a high level of anxious arousal and hypervigilance among those with PTSD, these individuals are more likely to respond to degraded fear stimuli in addition to the primary fear cue. Thus, the fear structure and its associated responses are activated more easily and with greater frequency among individuals with PTSD. Per Foa and Kozak (1986), fear structures are a program for escape or avoidance that contains information about which available responses might be helpful. Specifically, the fear structure holds information about physiological preparation and what behavioral responses might be dangerous in response to a stimulus. They suggested that pathological fear structures differ from standard fear structures in that they involve excessive responding such as enhanced physiological reactivity and avoidance behaviors. In order to reduce psychopathology, they argued that the fear structure must be fully activated, and corrective information applied, resulting in changes to the structure.

Early information processing models of PTSD focus on a single fear structure, with an emphasis on automatic responses to the physical characteristics of trauma cues. Brewin and colleagues (Brewin, 2001; Brewin, Dalgleish, & Joseph, 1996), were among the first to propose a dual representation model, with two types of memories: situationally accessible memories (SAMs) and verbally accessible memories (VAMs). SAMs are accessed automatically based on physical features that match the fear structure. In contrast, VAMs contain some information about stimulus cues, but also encompass the emotional and physiological reactions to the stimulus, and its associated meaning. Thus, VAMs are activated via higher-level (top-down) processes and may relate to cognitive aspects of PTSD, whereas SAMs are driven by bottom-up process and may be linked to more automatic aspects of PTSD such as physiological reactivity and hypervigilance. Brewin and colleagues (1996) suggest that the two systems need to be fully integrated in order to reduce PTSD symptoms.

Finally, Ehlers and Clark (2000) proposed an information processing model of PTSD, wherein trauma exposed individuals perceive a pervasive state of threat, which arises from a) negative appraisals of the trauma and its consequences, and b) disturbances in memory functioning (i.e., fear structures). They describe a dual-process memory system akin to that of Brewin and colleagues (1996). Specifically, they argued that fear memories are activated by both bottom-up, stimulus-driven processes, and top-down, intentional processes. Among individuals who experience trauma, but do not develop PTSD, the trauma is thought to be incorporated into memory in a way that allows for intentional retrieval but lessens automatic retrieval. In contrast, PTSD is characterized by trauma memories that are poorly integrated, making them difficult to retrieve intentionally, and easily activated by overgeneralized cues. Therefore, recovery from trauma requires the memory to be organized and placed appropriately in autobiographical memory, so that it is not unintentionally activated through bottom-up means.

As described, information processing models provide a framework for understanding the role of threat-related attention in PTSD. Specifically, attention is required for the detection of threat stimuli and activation of the fear structure. Of note, these models differ in the extent to which they emphasize bottom-up versus top-down processing. Whereas earlier models primarily emphasized bottom-up reactivity to trauma-relevant stimuli, there is increasing emphasis on the influence of top-down processes, such as meaning and the generalization of cues that activate the trauma memory. As with information processing models, newer theories of attentional processing in emotional disorders describe the interactive effects of bottom-up and top-down processing.

Dual Process Models of Threat-Related Attentional Bias

Information processing models implicate threat-related AB in the development and maintenance of emotional disorders (e.g., Beck et al., 1985; Williams et al., 1997). Specifically, stress and anxious arousal are proposed to a) increase bottom-up attention to threatening stimuli and b) impair top-down attentional control, which reduces processing efficiency for goal-relevant information and prolongs emotional distress (e.g., Attentional Control Theory; Eysenck & Derakshan, 2011; Eysenck, Derakshan, Santos, & Calvo, 2007). Bottom-up processes occur rapidly, in response to the physical characteristics of threat stimuli, and are proposed to be outside volitional control (Theeuwes, 1993). In contrast, top-down processes (i.e., inhibition and shifting) are volitional and goal-oriented. The effect of anxiety on threat-related attentional bias has been described as a disruption of the balance between bottom-up and top-down processes (Eysenck et al., 2007). This disruption can produce different patterns of threat-related attentional bias. Two prominent models account for the varied expression of bias observed in the larger literature (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, per the vigilance-avoidance model, 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 may be individual differences in top-down attentional control (Dennis-Tiwary, Roy, Denefrio, & Myruski, 2019). Theory suggests that when available, additional top-down resources can be recruited to counteract bottom-up influences on attention (Eysenck & Derakshan, 2011). Availability may depend on individual differences in ability (Dennis-Tiwary et al., 2019) and environmental demands on top-down processes (Eysenck et al., 2007). 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). That is, even though they may wish to disengage from threat information, they do not possess the ability to do so. In contrast, those with higher anxiety and relatively better attentional control may be able to use top-down attentional resources to disengage from threat stimuli relatively quickly (i.e., overcontrollers; Dennis-Tiwary et al., 2019), at least under conditions of low cognitive load. 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 anxiety- and fear-related symptoms and threat-related attentional bias.

The Moderating Effect of Attentional Control on the Relationship Between PTS Symptoms and Threat-Related Attentional Biases

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 posttraumatic 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 replicated and extended in a community sample of trauma-exposed adults with and without PTSD (Bardeen et al., 2016). Two significant limitations of the 2011 study were remedied. First, Bardeen et al. (2016) 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 et al., 2007; Miyake, Friedman, Emerson, Witzki, & Howerter, 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 100-150*ms*; Bardeen & Orcutt, 2011; Peers & Lawrence, 2009). Second, Bardeen et al. (2016) calculated threat-related attentional bias from response times to the dot-probe task, using the trial-level bias score (TL-BS) method, which exhibits better reliability than threat-related attentional bias scores calculated using the traditional difference score method (Schmukle, 2005). Additionally, the TL-BS method more accurately represents the temporal dynamics of threat-related attentional bias (i.e., a rapid succession of shifts toward and away from threat stimuli; Zvielli, Bernstein, & Koster, 2015).

Consistent with Bardeen and Orcutt (2011), Bardeen et al. (2016) found that behaviorally assessed attentional control moderated the association between PTSD status and threat-related attentional bias. Specifically, among those with PTSD, those with relatively worse attentional control exhibited significantly greater threat-related attentional bias. According to Bardeen et al. (2016), these results suggest that individuals with PTSD and relatively worse attentional control have greater difficulty disengaging from threat stimuli; they 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 (2017) 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 estimates covert threat-related attentional bias at relatively earlier stages of processing (i.e., 500*ms*), eye tracking can be used to obtain reliable estimates of overt threat-processing over prolonged periods of time (i.e., 3000*ms*). Second, Bardeen and Daniel (2017) 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.

Bardeen and Daniel (2017) found that 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 3000*ms*, emphasizing the importance of examining this effect at later stages of processing. As discussed by Bardeen and Daniel (2017), 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 disengage from threat, which in turn, appears to down-regulate emotional arousal (Bardeen & Daniel, 2017).

Together, these findings highlight the robust moderating effect of top-down attentional control on threat-related attentional bias. 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, it is possible that the moderation effect of interest is more specific to symptoms that are prominent in anxiety- and fear-related symptomatology (i.e., hyperarousal and avoidance).

The Role of Specific Posttraumatic Symptom Clusters

As described, PTSD is a highly heterogenous construct (Galatzer-Levy & Bryant, 2013). Given that correlations have been observed between threat-related attentional bias and a wide range of anxiety symptoms (Armstrong & Olatunji, 2012), it may be that the effect of PTS on threat-related attentional bias is specific to those symptoms that cut across anxiety disorders (i.e., hyperarousal and avoidance). Indeed, PTS-related hyperarousal and avoidance symptoms have exhibited large magnitude correlations with anxiety disorder symptom measures, including panic disorder, social phobia, and generalized anxiety disorder (Gootzeit & Markon, 2011; Zelazny & Simms, 2015). The correlations between these symptom measures and PTS symptoms were generally larger for hypervigilance than avoidance. Taken together, the transdiagnostic nature of threat-related AB, and large magnitude correlations between hyperarousal and measures of multiple forms of fear- and anxiety-related pathology, suggest that threat-related attentional bias might be driven by hyperarousal. Recall that bottom-up recognition of threat stimuli is required to activate the fear structure (Foa & Kozak, 1986). Hypervigilance, a cardinal symptom of PTSD housed within the hyperarousal cluster, involves scanning the environment for potential threat and preferential processing of threat once it has been detected. Thus, individuals with higher levels of hyperarousal might be more likely to detect threat, thereby activating the fear structure. Following threat detection, the extent to which individuals with relatively higher hyperarousal symptoms exhibit maintenance of attention on threat versus threat avoidance might depend on avoidance symptoms and individual differences in attentional control (Bardeen, Daniel, Gordon, Hinnant, & Weathers, 2020). Specifically, individuals with relatively greater avoidance symptoms and higher levels of attentional control might use their attentional control ability to disengage attention from threat. Moreover, some have suggested that heterogeneity in the expression of bias (i.e., towards and away from threat) might be attributable to symptom clusters relating to approach versus avoidance (i.e., hypervigilance and avoidance; Iacoviello et al., 2014). Specifically, because PTSD involves both approach and avoidance, we might expect attention for threat to oscillate in this manner (e.g., attention bias variability).

To date, two studies have used eye tracking to examine the effects of PTSD symptom clusters on threat-related attentional bias. One was conducted with a sample of female trauma survivors who reported low socio-economic status and were primarily African American (Powers et al., 2019). Eye tracking data were obtained from a dot probe task, in which pairs of images (neutral and angry faces) were presented for 5,000*ms*. Powers and colleagues (2019) found that greater avoidance symptoms were associated with a higher proportion of first fixations on threat (early stages of processing) and greater intrusive symptoms were associated with a higher proportion of dwell time on threat (bias from early to later stages of processing). Regarding their findings for intrusive symptoms, Powers and colleagues (2019) suggest that the cross-sectional nature of the study might preclude understanding the directional nature of the effect. It is possible that maintenance of attention on threat triggers more intrusive symptoms. The significant effect of avoidance symptoms on first fixations on threat should be interpreted cautiously, as this outcome generally demonstrates poor reliability (Waechter, Nelson, Wright, Hyatt, & Oakman, 2014); however, it may be understood in the context of the vigilance-avoidance model of threat-related attentional bias. Specifically, the model suggests that avoidance is preceded by rapid threat detection. Thus, this finding might capture earlier stages of processing associated with threat avoidance. A significant limitation of this study is that it does not consider the effects of top-down attentional control. As described, dual-process models emphasize the interplay between bottom-up and top-down processes on the expression of threat-related attentional bias. As such, it may be particularly important to measure individual differences in top-down control in order to understand the expression of threat-related attentional bias.

Bardeen and colleagues (2020) examined the interactive effects of symptom cluster and attentional control on the proportion of dwell time on threat derived from a 3,000*ms* free-viewing task. They found that among individuals with higher hyperarousal symptoms, those with relatively worse attentional control maintained attention on threat while those with better attentional control shifted their attention from threat to neutral stimuli. This is consistent with the hypothesis that individuals who endorse greater hyperarousal symptoms might be more likely to attend to threat in the environment, unless they are able to use top-down control to direct their attention away from threat. The above findings highlight the need to examine whether the moderating effect of attentional control on threat-related attentional bias might vary by PTS symptom cluster. Moreover, attentional control is a limited resource (Eysenck & Derakshan, 2011; Konstantinou & Lavie, 2013), and as such, taxing attentional control by increasing cognitive load may influence the moderating effect of attentional control on the relationship between threat-related attentional bias and PTS symptoms.

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). This moderation effect has been examined under controlled laboratory conditions free of distraction, but theory suggests that one's ability to use attentional control resources to maintain task performance will suffer under conditions of higher 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, 2017).

The relationship between anxiety and threat-related attentional bias has been examined using eye tracking and response time data (via the dot-probe task), at different levels of cognitive load, in one study. Booth, Mackintosh, and Sharma (2017) presented conditioned threatening and neutral Japanese characters on a computer screen to undergraduate participants for 100*ms*. 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 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 fixations that were made to the probe, on congruent versus incongruent trials was calculated. There was no effect of trait anxiety on the proportion of first fixations toward the probe. This could be attributed to the low reliability of eye tracking indices at short presentation durations (Waechter et al., 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. 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, 2017). 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, 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, 2017), it might be more appropriate to examine these effects at longer stimulus durations.

Methodological Considerations

In advancing this line of research, selecting robust, reliable, measures of attentional control and threat-related attentional bias is of the utmost importance. As described (McNally, 2019; Rodebaugh et al., 2016), the poor psychometric properties of commonly used measures of threat-related attentional bias prevent us from clearly understanding its role in anxiety and related disorders. Specifically, it is unclear whether null findings are conceptually meaningful, or the product of poor measurement.

A common limitation in this line of research is overreliance on self-report measures to assess attentional control. Top-down attentional control has been shown to influence attention to threat at relatively early stages of processing (150*ms*; Bardeen & Orcutt, 2011), leading some to suggest that it may be difficult to provide accurate self-reports of a process that occurs so quickly. With this in mind, it has been suggested that self-report measures of attentional control might measure perceived ability rather than actual ability (Spada, Georgiou, & Wells, 2010). Objective measures of the attentional control have been used in previous research (see Bardeen & Daniel, 2017; Bardeen et al., 2016) to ensure that the observed effects can be attributed to actual ability.

Regarding the assessment of threat-related attentional bias, numerous studies have shown that traditionally calculated aggregate difference scores derived from the dot-probe task exhibit poor reliability (Schmukle, 2005; Staugaard, 2009). Aggregate difference scores are calculated by subtracting average reaction time to probes behind threat cues (incongruent trials) from average reaction time to probes behind neutral cues (congruent trials; Macleod, Mathews, & Tata, 1986). This assumes that attention is a stable characteristic that can be captured by a single value. Recent conceptualizations of threat-related attentional bias suggest that it is more accurate to depict attention as temporally variable. For example, Iacoviello and colleagues (2014) noted that PTSD symptoms include hypervigilance and avoidance; thus, we might expect PTSD samples to exhibit attentional patterns that include attending toward and away from threat. Zvielli and colleagues (2015) also presented a rationale for conceptualizing threat-related attentional bias as dynamic and variable, noting that "work to date has relied on what may be a suboptimal way to map and analyze the possible dynamic nature of emotional attention".

In an innovative attempt to improve the assessment of threat-related attentional bias, Iacoviello and colleagues (2014) proposed that dot probe data be separated into eight sequential bins. Bias scores were calculated for each bin ($\text{MeanRT}_{\text{Incongruent}} - \text{MeanRT}_{\text{Congruent}}$), then the standard deviation of bias scores across all bins was divided by the individual's overall mean reaction time to account for variance in reaction time. The resulting score was proposed to provide an index of attention bias variability (ABV) across the task. Iacoviello and colleagues found that ABV scores predicted PTSD symptoms. That is, a pattern of more frequent shifts toward and away from threat was associated with greater PTS symptoms.

Naim and colleagues (2015) refined the binning technique using a moving average algorithm. They created blocks of 10 sequential trials of the same type (threat or neutral), rather than bins that might include a variable number of each trial type due to randomization. Then they followed the procedure proposed by Iacoviello and colleagues (2014). Results suggested that participants with PTSD had the greatest ABV compared to those with social anxiety disorder, high trait anxiety, and healthy controls. Moreover, greater ABV was positively associated with PTSD severity.

In a further refinement of the calculation of ABV, Zvielli and colleagues (2015) proposed the use of trial-level bias scores (TL-BS). In order to obtain a TL-BS, incongruent trials are subtracted from the temporally nearest congruent trial, which cannot be more than 5 trials before or after the incongruent trial. This process produces a sequence of difference scores that represent temporal variability in attention. The variability of attention toward and away from threatening stimuli is calculated as the sum of all distances between TL-BS. In addition, a "Fake" TL-BS can be calculated using trials that contain stimuli that are neither negatively nor positively valenced and have low arousal ratings (i.e., "neutral" stimuli). Fake TL-BS is a measure of general response variability and can be used to ensure that any observed effects are due to the presence of threat stimuli rather than being a function of variability in responding more generally (Zvielli et al., 2015). Price and colleagues (2015) found that TL-BS exhibited better reliability than traditional bias scores across three independent samples, regardless of the method for handling outliers. As such, TL-BS were used in the present study to assess threat-related attentional biases at a relatively earlier stage of threat processing (i.e., 500*ms*).

As with the dot probe task, it is important to select eye tracking indices that have exhibited strong reliability. Using free-viewing tasks, researchers have shown that the proportion of dwell time on threat versus neutral stimuli exhibits high internal consistency and acceptable retest reliability (Lazarov, Abend, & Bar-Haim, 2016; Skinner et al., 2018). While reliability for eye tracking indices derived before 500*ms* is generally poor, it greatly improves at longer stimulus durations (Waechter et al., 2014). For this reason, dwell time was used as an indicator of threat-related attentional biases from early to later stages of threat processing (i.e., 3,000*m*s).

Finally, it is necessary to consider what processes underlie measures of threat-related attentional bias (MacLeod & Grafton, 2016). For example, although the dot-probe task and free-viewing tasks are both used to measure threat-related attentional bias, they do so at different stimulus durations, and via different indicators. Thus, the conclusions that can be drawn from each measure are different. Specifically, dot-probe reaction times provide information about covert attention, or internal shifts in attention that precede eye movements. These measures are most often derived at 500*ms*, a single point in time, whereas the proposed TL-BS scores represent variability in covert attention across the entire task, which is consistent with the perspective that attention might oscillate toward and away from threat over time. In contrast, free-viewing outcomes measure overt eye movements across the entire trial window (e.g., 3,000*ms* window). Thus, the conclusions drawn from this measure of threat-related attentional bias represent both early and later stages of information processing. Finally, it is important to distinguish between responses to threat versus responses to affective stimuli more generally. This hypothesis can be examined by including trials that incorporate positive, rather than threat, stimuli. If bias is specific to threat, the interaction should not significantly predict response time or eye tracking outcomes for positive stimuli.

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 (both total and subscale scores) and threat-related attentional bias at higher and lower levels of cognitive load. In order to address the methodological concerns described above, I used a behavioral indicator of attentional control and selected indices of threat-related attentional bias that have demonstrated acceptable reliability. I hypothesized that under conditions of lower cognitive load, participants with higher PTS symptoms and higher attentional control would be able to use attentional control to disengage from threat, whereas those with higher PTS symptoms and relatively worse attentional control would exhibit greater maintenance of attention on threat. I expected that the moderating effect of attentional control on the relation between threat-related attentional bias and PTS symptoms would be attenuated in the high cognitive load condition. Moreover, based on theory and previous research, I hypothesized that the effect might be specific to hyperarousal and avoidance symptoms. I included a block of positive images in the novel attentional bias task to test the hypothesis that the proposed interaction effect was specific to threat stimuli and not merely a function of emotionally arousing images more generally. Finally, I calculated fake TL-BS scores in order to test the hypothesis that the proposed three-way interaction was not a function of response time variability.

Method

Participants

Participants were undergraduate psychology students recruited from a Southeastern university 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 *DSM-5* (APA, 2013). Nine participants (6%) who did not report a Criterion A event were removed from the sample. In addition, 15 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 student identified their ethnicity as Hispanic or Latino (.8%).

Self-Report Measures

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, Turuwhenua, Hess, & Gant, 2017). As such, stimulant medication and/or caffeine use was included as a covariate in the analyses.

Life Events Checklist for DSM-5 (LEC-5; Weathers et al., 2013a)

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 do not 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). Bardeen and Benfer (2019) found that using this approach, versus the worst event approach, resulted in correctly identifying an additional 25% of their sample as meeting Criterion A. 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). Of note, this variable reflects the total number of trauma types the individual endorsed, rather than total instances of trauma exposure.

PTSD Checklist (PCL-5; Weathers et al., 2013b)

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*). Therefore, higher scores indicate greater PTS symptom severity. In its initial evaluation in a Veteran sample, the PCL-5 demonstrated adequate psychometric properties, including internal consistency (α = .94 - .95), retest reliability over a one-week period (r = .82), and convergent (e.g., large correlations with the Detailed Assessment of Posttraumatic Stress [Breire, 2001]; *rs* = .83-.92) and discriminant validity (e.g., medium correlations with the Personality Assessment Inventory [Morey, 2007] somatic scale, r = .39; Blevins, Weathers, Davis, Witte, & Domino, 2015). Follow-up studies have confirmed that the PCL-5 has strong psychometric properties. For example, in a Veteran sample the PCL-5 showed high internal consistency (α = .96) and retest reliability over a one-month period (r = .84). It also showed construct validity through bivariate correlations with various self-report measures of psychopathology (i.e., Patient Health Questionnaire [Spitzer, Kroenke & Williams, 1999]; depression r = .74, generalized anxiety r = .67, panic r = .50) and in relation to PTSD diagnostic status based on a gold-standard clinical interview (Bovin et al., 2016). In the present study, the PCL-5 total (α = .93, M = 16.10, SD = 13.85) and subscale (intrusions α = .85, M = 4.27, SD = 4.08; avoidance α = .88, M = 2.61, SD = 2.52; cognitions α = .87, M = 5.01, SD = 5.59; and arousal α = .78, M = 4.32, SD = 4.30) scores demonstrated acceptable internal consistency. Of the final sample, 20% (n = 25) scored above the threshold for probable PTSD (i.e., PCL-5 scores > 31; Bovin et al., 2016).

Positive and Negative Affective Schedule (PANAS; Watson, Clark, & Tellegen, 1988)

The PANAS is a 20-item self-report measure that assesses both positive (PANAS-PA; e.g., attentive, excited, enthusiastic) and negative affect (PANAS-NA; e.g., afraid, distressed, jittery), with higher scores indicating greater levels of each construct. 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: Time 1 [T1] to Time 2 [T2]) and positive (Block 2: T2 to Time 3 [T3]) images resulted in expected changes in state affect. I expected that negative affect would increase and positive affect would decrease from T1 to T2. Conversely, I expected negative affect to decrease and positive affect to increase from T2 to T3. 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 the PANAS-NA and PANAS-PA subscales have shown adequate psychometric properties in prior research, including internal consistency (α = .85 and .89, respectively), and construct validity (i.e., PANAS-NA with Depression Anxiety and Stress Scales [DASS; Lovibond & Lovibond, 1995] Depression r = .60 and DASS Anxiety r = .60; PANAS-PA with DASS Depression r = -.48 and DASS Anxiety r = -.30; Crawford & Henry, 2004). Internal consistency was adequate at each time point for the PANAS-PA scale (T1: α = .93, M = 24.39, SD = 8.95; T2: α = .91, M = 20.37, SD = 8.06; T3: α = .94, M = 21.17, SD = 8.95) and the PANAS-NA scale (T1: α = .73, M = 14.22, SD = 3.81; T2: α = .86, M = 17.21, SD = 6.20; T3: α = .72, M = 12.94, SD = 3.55) in the present study.

Assessing Attentional Inhibition

The attentional cueing task was used in the present study to obtain a behavioral measure of attentional control. 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 500*ms*. 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).

Assessing Attentional Bias

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., International Affective Picture System slides; IAPS; Lang, Bradley, & Cuthbert, 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 following describes task elements for the threat block (see Figure 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 2000*ms* to memorize the string, and participants in the low load condition had 500*ms*. A fixation cross appeared next and remained on the screen until the participant fixated on it for 200*ms*. Next, two images appeared on the screen for 3000*ms* (either a threat-neutral or neutral-neutral image pairing). Neutral-neutral image pairings 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 3,000*ms*, a fixation cross appeared and remained on the screen until the participant fixated on it for 200*ms*. Next, a second image pair (either a threat-neutral or neutral-neutral image pairing) appeared on the screen for 500*ms*. After 500*ms*, 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 trails 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.

Deriving Indices of Threat-Related AB

As described above, TL-BS were used in the present study to assess threat-related attentional biases at a relatively earlier stage of threat processing (i.e., 500*ms*). TL-BS were calculated from response time data by subtracting each incongruent trial from the temporally nearest congruent trial. Consistent with Zvielli et al. (2015), 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. Finally, a “Fake” TL-BS was calculated 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).

For the eye tracking component of this task, dwell time was used as an indicator of threat-related attentional biases from early to later stages of threat processing (i.e., 3,000*m*s). Dwell time was calculated as the proportion of time spent attending to affective versus neutral stimuli during the 3,000*ms* 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 retest reliability (Lazarov et al., 2016; Skinner et al., 2018).

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) 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 60*cm* 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.

Procedure

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 (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 (T2). Next, participants completed the second block of the attentional bias task and a final PANAS (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.

Results

Descriptive Statistics

Demographic variables including, age, sex, race and ethnicity did not significantly differ by condition (all *ps* ≥ .05). In addition, PTS symptoms did not significantly differ by 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, 2017). There was no missing data to contend with.

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, Bardeen, Thomas, & Benfer, 2019), 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, $p < .001$, *d* = -.60) 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, $p < .001$, *d* = .74). 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, $p < .001$, *d* = .80), 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, $p = .088$, *d* = -.15).

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 threat-related attention bias variability (Threat *M* = 170.48 and Positive *M* = 144.92) than those who had not (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 TL-BS (*r* = -.25, *p* = .006); as accuracy decreased, threat-related attentional bias variability increased. As such, these three variables served as covariates in subsequent analyses.

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 TL-BS, fake TL-BS, positive-related TL-BS, or 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.

Predicting TL-BS using the PCL-5 Total Score

Threat-related TL-BS 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 condition, PCL-5 by attentional cueing incongruent, and attentional cueing incongruent by condition). The three-way interaction between the PCL-5, attentional cueing incongruent, and condition was entered into the third step of the model. Lower order effects (see Table 1) were qualified by a significant three-way interaction (β = -.23, B = -

.04, SE = .015, t = -2.50, 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 = -2.28, SE = .95, p = .02). The association between PTS symptoms and threat-related TL-BS was not significant at the combinations of low load and worse inhibitory ability (t = .64, SE = .72, p = .52), high load and better inhibitory ability (t = .52, SE = .85, p = .60), or high load and worse inhibitory ability (t = -1.33, SE = .97, p = .19). Individuals with higher PTSD symptoms and better inhibitory ability exhibited less threat-related attentional bias variability in the low load condition (see Figure 2), but inhibitory ability did not moderate the relationship between PTS symptoms and threat-related attentional bias variability in the high load condition.

A second regression was conducted with the same predictors and covariates as above but substituting Fake TL-BS as the outcome. This technique is designed to ensure that findings are due to the presence of threat stimuli and are not a biproduct of overall variability in responding (Zvielli et al., 2015). The three-way interaction was not significant (β = -.06, B = -.01, SE = .02, t = -.58, p = .57) and none of the lower order effects accounted for significant variance in Fake TL-BS (all ps > .05, see Table 1, column 3), suggesting that the above interaction is not attributable to non-specific response time variability.

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 three-way interaction did not predict positive-related TL-BS (see Table 1, column 2; β = -.14, B = -.02, SE = .01, t = -1.56 p = .12). This suggests that the interactive effect between PTS symptoms, attentional inhibition, and cognitive load is specific to threat stimuli.

Predicting TL-BS using PCL-5 Subscale Scores

Threat-related TL-BS served as the outcome variable in four models examining the effect of PCL-5 subscale scores on threat-related attentional bias. Covariates (i.e., stimulant use, total number of traumas, task accuracy, attentional cueing congruent), the predictor (PCL-5 subscale score), and moderators (attentional cueing incongruent, load condition) were entered into the first step of each model. Two-way interactions were entered into the second step of each model (i.e., PCL-5 subscale score by condition, PCL-5 subscale score by attentional cueing incongruent, and attentional cueing incongruent by condition). The three-way interaction between PCL-5 subscale score, attentional cueing incongruent, and condition, was entered into the third step of each model.

Three of the four three-way interactions were significant (see Tables 2-5, column 1). The three-way interaction was significant using the arousal (β = -.31, B = -.17, *SE* = .06, t = -3.11, p < .01), avoidance (β = -.21, B = -.18, *SE* = .08, t = -2.16, p = .03), and cognitive (β = -.22, B = -.08, *SE* = .03, t = -2.28, p = .03) scales as predictors, but not the intrusions scale (β = .02, B = .01, *SE* = .07, t = .15, p = .88). The association between PTS symptoms and threat-related TL-BS was significant at the combination of low load and better inhibitory ability for both the arousal (t = -2.11, *SE* = 3.65, p = .04, see Figure 3) and avoidance subscales (t = -2.10, *SE* = 4.61, p = .04, see Figure 4), but did not reach statistical significance for the cognitive subscale (t = -1.91, *SE* = 2.36, p = .06). The interaction between PTS symptoms and threat-related TL-BS was not significant at the combinations of low load and worse inhibitory ability (arousal t = 1.09, *SE* = 2.31, p = .28; avoidance t = .71, *SE* = 3.66, p = .48; cognitive t = .47, *SE* = 1.97, p = .63), high load and better inhibitory ability (arousal t = 1.29, *SE* = 2.67, p = .20; avoidance t = .58, *SE* = 5.43, p = .56; cognitive t = .62, *SE* = 2.23, p = .53), or high load and worse inhibitory ability (arousal t = -1.75, *SE* = 3.64, p = .08; avoidance t = -.98, *SE* = 5.80, p = .33; cognitive t = -1.23, *SE* = 1.78, *p* = .22). Consistent with the pattern of results for the total score, individuals with higher arousal and/or avoidance symptoms and better inhibitory ability exhibited less threat-related attention bias variability in the low load condition, but inhibitory ability did not moderate the relationship between arousal and/or avoidance symptoms and threat-related attention bias variability in the high load condition.

A second set of regressions were conducted with the same predictors and covariates as above but substituting Fake TL-BS as the outcome. None of the three-way interactions were significant (*βs* = -.13 - .06, Bs = -.08 - .06, *p*s > .05; see Tables 2-5, column 3). This suggests that the above interactions are not attributable to non-specific response time variability.

Finally, a third set of regressions were conducted with the same predictors and covariates as above, but positive-related TL-BS served as the outcome variable. The three-way interaction was significant using the avoidance scale (*β* = -.21, B = -.17, *SE* = .08, *t* = -2.10, *p* = .03), but not the arousal (*β* = -.13, B = -.07, *SE* = .05, *t* = -1.26, *p* = .21, cognitive (*β* = -.11, B = -.04, *SE* = .03, *t* = -1.10, *p* = .27), or intrusions (*β* = -.02, B = -.01, *SE* = .07, *t* = -.20, *p* = .84) scales. The association between avoidance symptoms and positive-related TL-BS was significant at the combination of high load and worse inhibitory ability (*t* = -2.12, *SE* = 5.52, *p* = .04). The association between avoidance symptoms and positive-related TL-BS was not significant at the combinations of low load and better inhibitory ability (*t* = -.27, *SE* = 4.38, *p* = .79), low load and worse inhibitory ability (*t* = -.39, *SE* = 3.48, *p* = .69), or high load and better inhibitory ability (avoidance *t* = 1.57, *SE* = 5.17, *p* = .12). Importantly, this suggests that the effects observed for the arousal and avoidance subscales at the combination of low load and better inhibitory ability are specific to threat, not positive, images.

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 or subscale scores), 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 total or subscale scores by condition, PCL-5 total or subscale scores by attentional cueing incongruent, and attentional cueing incongruent by condition). The three-way interaction between the PCL-5 total or subscale scores, attentional cueing incongruent, and condition was entered into the third step of the model. None of the predictor variables significantly predicted dwell time on threat (see Tables 2-5, column 4). 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 Tables 2-5, column 5).

Discussion

This study is the first to support the theoretical assumption from attentional control theory that top-down regulation of threat-related attentional bias can be disrupted by increasing cognitive load (Eysenck et al., 2007). Top-down attentional control moderated the relationship between PTS symptoms and threat-related attentional bias variability (assessed via TL-BS from the dot-probe task) 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. Accounting for variability on trials for which only neutral stimuli were presented (i.e., Fake TL-BS) ensured 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.

Results from the subscale analyses suggest that the pattern of effects described above is specific to PTS symptoms of arousal and avoidance. The relationship between threat-related attentional bias variability and both arousal and avoidance can be understood within an information processing framework. As described in information processing models of PTSD, hyperarousal is associated with the unintentional activation of pathological fear structures. Specifically, frequent scanning of the environment results in bottom-up recognition of threat, which activates the fear structure. Avoidance, in turn, prevents the memory from being processed and stored appropriately. Without effortful engagement, the fear structure is not appropriately labelled as a *past* memory. Thus, it continues to be activated through bottom-up recognition of threat (Foa & Kuzak, 1986; Ehlers & Clark, 2000). Therefore, per information processing models, the interplay between bottom-up threat-related attentional bias and the top-down control involved in attentional avoidance are imbedded in the maintenance of, versus recovery from, PTS symptoms. Moreover, the specificity of the three-way interaction to arousal and avoidance makes conceptual sense, given that attention bias variability is an attentional embodiment of the approach and avoidance behaviors assumed to be linked to arousal and avoidance symptoms (Zvielli et al., 2015). Moreover, anxiety symptoms have been shown to relate to threat-related attentional bias in numerous studies (Armstrong & Olatunji, 2012; Bar-Haim et al., 2007), and avoidance and arousal symptoms cut across anxiety- and fear-related disorders. The specificity of this effect to arousal and avoidance is important because the arousal cluster tends to be the most stable over time and the most predictive of functional impairment, PTS symptom severity, and the later development of other symptom clusters (Able & Benedek, 2019). In addition, greater hypervigilance, one of the hallmark symptoms of the hyperarousal cluster, predicts greater startle response and avoidance symptoms the following week (Hoffart, Langkaas, Øktedalen, & Johnson, 2019). Finally, the avoidance cluster has been shown to relate to processes that prevent fear extinction, making it a valuable treatment target (Sripada, Garfinkel, & Liberzon, 2013).

Study findings are consistent with dual process models of threat-related attentional bias which suggest that differential patterns of threat-related attentional bias 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 lower attentional control are more likely to experience prolonged attentional engagement with threat stimuli because they lack the top-down resources to effectively disengage, and maintain disengagement, from such stimuli. In contrast, those with higher attentional control have the top-down resources to effectively disengage and shift attention from threat to neutral stimuli in an attempt to down-regulate threat-related emotional arousal (Bardeen & Daniel, 2017). 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 attentional bias.

Note that the three-way interaction between attentional control, cognitive load, and PTS avoidance symptoms significantly predicted positive-related attentional bias variability. Specifically, those with relatively lower avoidance symptoms and relatively worse inhibitory ability exhibited greater fluctuations in attention between neutral and positive stimuli, but only in the high load condition. Although TL-BS scores provide information about attention bias variability (i.e., a rapid succession of shifts toward and away from target stimuli) and not the static direction of attention, it may be that individuals with greater PTS avoidance symptoms display a more consistent pattern of attentional responding than those with relatively lower PTS avoidance symptoms who fluctuate between positive and neutral stimuli because they are more likely to avoid affective stimuli. This tendency would be magnified for those with worse attentional control under high cognitive load. PTSD is associated with decreased interest and pleasure in reward-related stimuli, otherwise known as decreased reward functioning (Nawijn et al., 2015). For example, greater PTS symptoms are associated with greater behavioral avoidance of happy faces (Clausen et al., 2016). Thus, it's possible that individuals with greater PTS avoidance symptoms are more likely to exhibit attentional avoidance of positive stimuli. Importantly, the effect of PTS avoidance symptoms on positive-related attentional bias was not significant at the combination of low load and better inhibitory ability, which suggests that the three-way interaction observed for threat-related attentional bias is specific to threat stimuli.

The reader will recall that Booth and colleagues (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 this 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 and colleagues (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 biproduct of poor psychometric properties. Additionally, Booth and colleagues used a 100*ms* presentation duration, whereas the present study assessed threat-related attention bias variability at 500*ms*. 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 the dot-probe measure of threat-related attentional bias, the expected interaction did not emerge using the eye tracking outcome. The dot probe task and the free viewing task were combined in the present study in order to obtain estimates of threat-related attentional bias at both earlier (500*ms*) and later (3000*ms*) 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 task used by Bardeen and Daniel (2017) did not include a cognitive load manipulation, nor did it require button press during each trial. Thus, it is possible that this methodological approach negatively impacted the 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 by Bardeen and Daniel (2017) 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 & Orcutt, 2011; Bardeen & Daniel, 2017), 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 or avoidance 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, 2017). Failing to account for different patterns of threat-related attentional biases (i.e., maintenance versus avoidance) might contribute to null and inconsistent findings in the ABM literature. By assessing for these differences prior to treatment, and identifying undercontrollers and overcontrollers, treatment providers may be able to provide patient-specific interventions that improve treatment outcomes. Finally, some researchers have begun to explore the use of cognitive load in the delivery of ABM. Booth, Mackintosh, Mobini, Oztop, 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. Findings from the present study are consistent with that perspective. As noted by Booth and colleagues (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, 2017). 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). Study 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 (Beckert & Zayfert, 2001) or Skills Training in Affective and Interpersonal Regulation (STAIR; Hassija & Cloitre, 2015).

This study is not without limitations. Use of the novel threat-related attentional bias task may have prevented the hypothesized effects for the free-viewing portion of the task from being observed. 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 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 trauma relevant to any one participant. Instead, to reduce trauma-specific responding, pre-tested general threat images of a wide variety were used (IAPS; Lang et al., 1999). These images, which have been used in previous examinations of threat-related attentional bias (Bardeen & Daniel, 2017), have been shown to induce negative affective states (Bardeen, 2015).

Although empirical evidence supports a dimensional, rather than categorical conceptualization of PTS (e.g., Broman-Fulks et al., 2006; Forbes, Haslam, Williams, & Creamer, 2005; Ruscio, Ruscio, & Keane, 2002), replicating study findings in a more symptomatic clinical sample will be important to ensure that these findings are generalizable to individuals who meet *DSM-5* criteria for PTSD (APA, 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 versus being broadly relevant to anxiety- and fear-related pathology (Derryberry & Reed, 2002; Ho, Yueng, & Mak, 2017; Taylor, Cross, & Amir, 2016). Finally, although stimulus-response 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).

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 attentional bias 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 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 attentional bias to improve the predictive utility of these models.

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Table 1. Hierarchical linear regressions examining the three-way interaction between PCL-5, attentional cueing incongruent, and load condition on threat-related attentional bias.

Predictor	Threat-related TL-BS		Positive-related TL-BS		Fake TL-BS		Proportion of Dwell on Threat		Proportion of Dwell on Positive	
		S3		S3		S3		S3		S3
	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β
Step 1 (S1)	**.16**		**.17**		**.13**		.06		.03	
LEC Total		**.19**		-.00		.02		-.01		-.08
Stimulant Use		**-.18**		**-.21**		-.10		-.15		-.07
Task Accuracy		-.03		-.21		-.18		.12		-.06
Cueing Congruent		**.38**		-.08		.14		.27		-.07
PCL-5		-.13		-.02		-.08		-.03		-.10
Cueing Incongruent		-.03		**.33**		.17		-.23		.02
Condition		.21		.09		.13		.04		-.02
Step 2 (S2)	.01		.02		.03		.02		.03	
PCL-5 X Cueing Incongruent		.05		-.02		-.08		.09		.10
PCL-5 X Condition		.07		-.09		-.04		.09		.17
Cueing Incongruent X Condition		.03		.11		.17		.05		-.09
Step 3 (S3)	**.04**		.02		.00		.00		.01	
PCL-5 X Cueing Incongruent X Condition		**-.23**		-.14		-.06		-.02		.11

Note. $N = 125$. Bolded values are 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; Cueing Congruent = RTs from congruent trials of the Attentional Cueing Task; PCL-5 = PTSD Checklist; Cueing Incongruent = RTs from incongruent trials of the Attentional Cueing Task; Condition = load condition.

Table 2. Hierarchical linear regressions examining the three-way interaction between PCL-5 arousal, attentional cueing incongruent, and load condition on threat-related attentional bias.

Predictor	Threat-related TL-BS		Positive-related TL-BS		Fake TL-BS		Proportion of Dwell on Threat		Proportion of Dwell on Positive	
		S3		S3		S3		S3		S3
	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β
Step 1 (S1)	**.16**		**.15**		**.14**		.07		.03	
LEC Total		.16		-.02		.02		-.03		-.08
Stimulant Use		-.15		**-.22**		-.09		-.16		-.06
Task Accuracy		-.05		-.09		-.19		.14		-.03
Cueing Congruent		**.38**		-.11		.15		.25		-.03
PCL-5 Arousal		-.13		.05		-.13		.07		-.08
Cueing Incongruent		-.08		**.34**		.15		-.20		.02
Condition		**.21**		.15		.14		.03		.00
Step 2 (S2)	.01		.02		.03		.01		.02	
PCL-5 Arousal X Cueing Incongruent		.03		-.06		-.02		.01		.13
PCL-5 Arousal X Condition		.05		.00		-.04		.07		.10
Cueing Incongruent X Condition		.02		.12		.16		.05		-.07
Step 3 (S3)	**.07**		.01		.01		.00		.01	
PCL-5 Arousal X Cueing Incongruent X Condition		**-.31**		-.13		-.13		.04		.14

Note. $N = 125$. Bolded values are 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; Cueing Congruent = RTs from congruent trials of the Attentional Cueing Task; PCL-5 = PTSD Checklist; Cueing Incongruent = RTs from incongruent trials of the Attentional Cueing Task; Condition = load condition.

Table 3. Hierarchical linear regressions examining the three-way interaction between PCL-5 avoidance, attentional cueing incongruent, and load condition on threat-related attentional bias.

Predictor	Threat-related TL-BS		Positive-related TL-BS		Fake TL-BS		Proportion of Dwell on Threat		Proportion of Dwell on Positive	
		S3		S3		S3		S3		S3
	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β
Step 1 (S1)	**.16**		**.15**		**.12**		.07		.03	
LEC Total		**.20**		-.01		.00		.03		-.12
Stimulant Use		**-.18**		**-.20**		-.12		-.13		-.11
Task Accuracy		-.03		-.09		-.17		.09		-.01
Cueing Congruent		**.31**		-.13		.09		.28		-.01
PCL-5 Avoid		-.09		-.05		-.03		-.11		.08
Cueing Incongruent		.04		**.40**		.20		-.22		-.06
Condition		**.22**		.19		.11		.03		-.02
Step 2 (S2)	.02		.02		.02		.05		.01	
PCL-5 Avoid X Cueing Incongruent		.05		**-.19**		.03		.17		.07
PCL-5 Avoid X Condition		.05		-.00		.00		-.12		.07
Cueing Incongruent X Condition		.02		.13		.16		.08		-.09
Step 3 (S3)	**.03**		**.03**		.00		.00		.00	
PCL-5 Avoid X Cueing Incongruent X Condition		**-.21**		**-.20**		.06		.05		.02

Note. $N = 125$. Bolded values are 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; Cueing Congruent = RTs from congruent trials of the Attentional Cueing Task; PCL-5 Avoid = PTSD Checklist Avoidance; Cueing Incongruent = RTs from incongruent trials of the Attentional Cueing Task; Condition = load condition.

Table 4. Hierarchical linear regressions examining the three-way interaction between PCL-5 cognitions, attentional cueing incongruent, and load condition on threat-related attentional bias.

Predictor	Threat-related TL-BS		Positive-related TL-BS		Fake TL-BS		Proportion of Dwell on Threat		Proportion of Dwell on Positive	
		S3		S3		S3		S3		S3
	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β
Step 1 (S1)	**.17**		**.15**		**.14**		.06		.03	
LEC Total		**.18**		-.00		.02		-.02		-.08
Stimulant Use		**-.19**		**-.21**		-.10		-.15		-.06
Task Accuracy		-.01		-.08		-.17		.13		-.06
Cueing Congruent		**.37**		-.07		.17		.27		-.11
PCL-5 Cog		-.09		-.04		-.11		-.01		-.15
Cueing Incongruent		-.01		**.37**		.16		-.23		.01
Condition		**.20**		.17		.14		.03		-.03
Step 2 (S2)	.00		.03		.04		.01		.04	
PCL-5 Cog X Cueing Incongruent		.06		-.08		-.01		.08		.16
PCL-5 Cog X Condition		.06		-.01		-.09		.08		.07
Cueing Incongruent X Condition		.06		.16		**.19**		.05		-.11
Step 3 (S3)	**.04**		.01		.00		.00		.01	
PCL-5 Cog X Cueing Incongruent X Condition		**-.22**		-.11		-.07		-.05		.14

Note. $N = 125$. Bolded values are 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; Cueing Congruent = RTs from congruent trials of the Attentional Cueing Task; PCL-5 Cog = PTSD Checklist Cognitions; Cueing Incongruent = RTs from incongruent trials of the Attentional Cueing Task; Condition = load condition.

Table 5. Hierarchical linear regressions examining the three-way interaction between PCL-5 intrusion, attentional cueing incongruent, and load condition on threat-related attentional bias.

Predictor	Threat-related TL-BS		Positive-related TL-BS		Fake TL-BS		Proportion of Dwell on Threat		Proportion of Dwell on Positive	
		S3		S3		S3		S3		S3
	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β
Step 1 (S1)	**.17**		**.14**		**.12**		.07		.04	
LEC Total		**.18**		-.01		.00		.00		-.08
Stimulant Use		**-.19**		**-.21**		-.11		-.16		-.09
Task Accuracy		-.03		-.10		-.17		.14		-.03
Cueing Congruent		.24		-.14		.09		.23		-.02
PCL-5 Intrusion		-.07		.01		.02		-.04		-.13
Cueing Incongruent		.10		**.38**		.22		-.17		-.01
Condition		.18		.14		.12		.06		-.01
Step 2 (S2)	.01		.02		.03		.04		.02	
PCL-5 Intrusions X Cueing Incongruent		.12		-.01		-.01		.13		.10
PCL-5 Intrusion X Condition		.07		.01		-.03		.18		.07
Cueing Incongruent X Condition		.04		.12		.17		.08		-.06
Step 3 (S3)	.00		.00		.00		.00		.00	
PCL-5 Intrusion X Cueing Incongruent X Condition		.02		-.02		.06		-.01		.01

Note. $N = 125$. Bolded values are 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; Cueing Congruent = RTs from congruent trials of the Attentional Cueing Task; PCL-5 = PTSD Checklist Cognitions; Cueing Incongruent = RTs from incongruent trials of the Attentional Cueing Task; Condition = load condition.

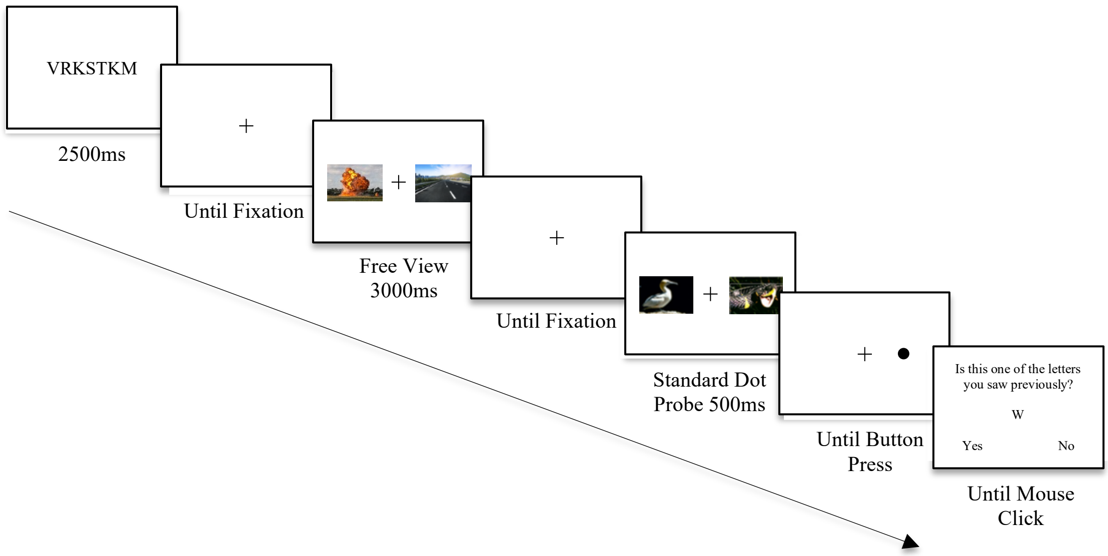

Figure 1. Attentional Bias Task in High Load Condition

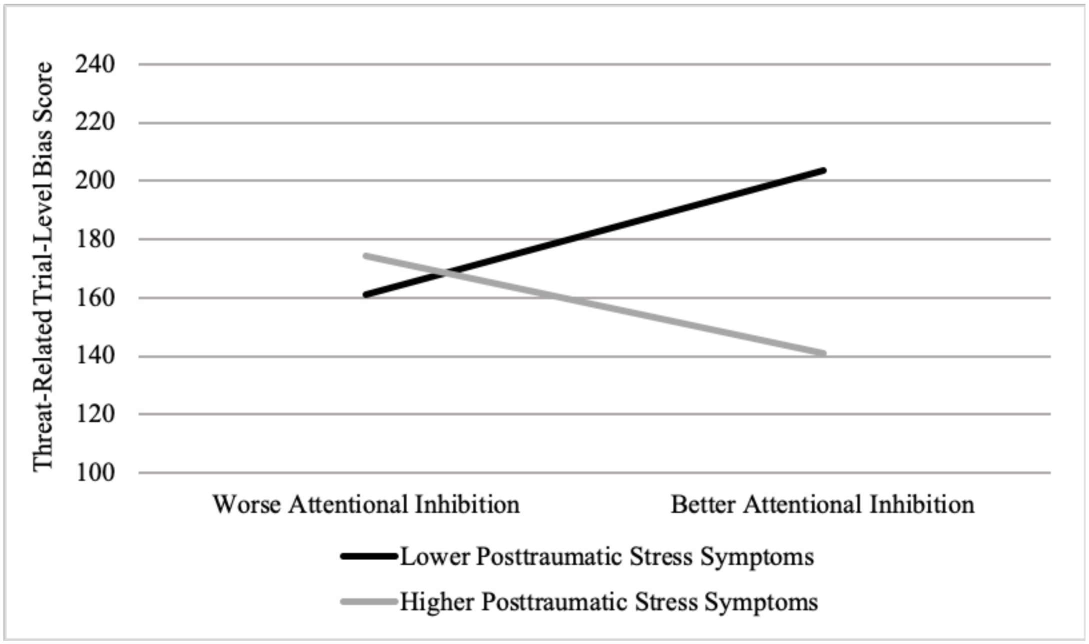

Figure 2. Interactive effect of PTS symptoms and attentional inhibition on threat-related trial-level bias scores in the low cognitive load condition. Attentional inhibition = attentional cueing scores +1 (worse) and -1*SD* (better) above the mean; Threat-related trial level bias scores = RTs from dot-probe task.

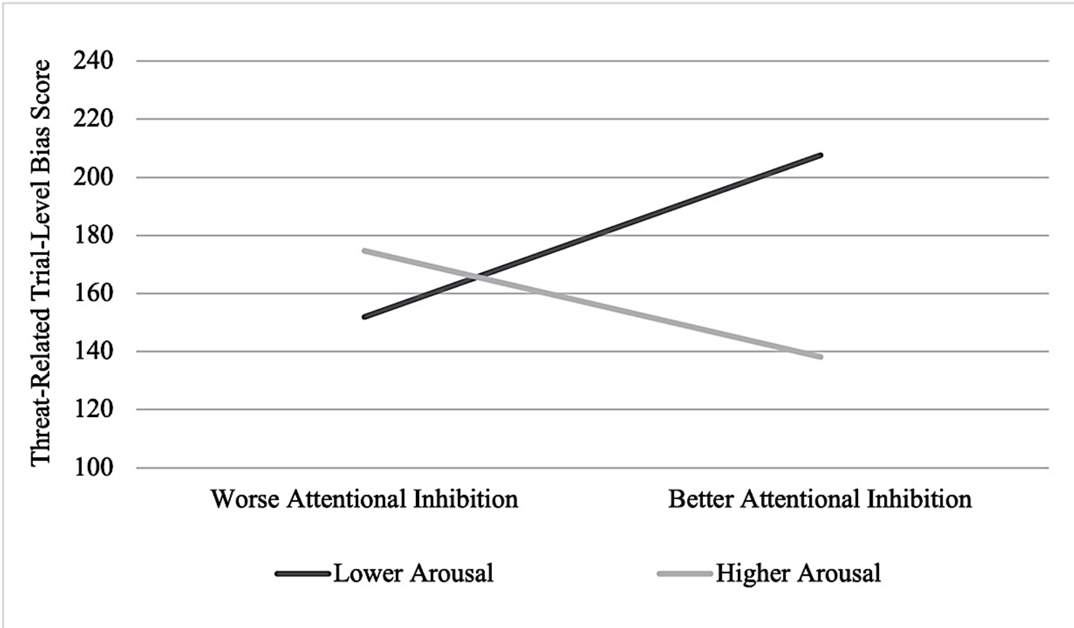

Figure 3. Interactive effect of PTS Arousal symptoms and attentional inhibition on threat-related trial-level bias scores in the low cognitive load condition. Attentional inhibition = attentional cueing scores +1 (worse) and -1*SD* (better) above the mean; Threat-related trial level bias scores = RTs from dot-probe task.

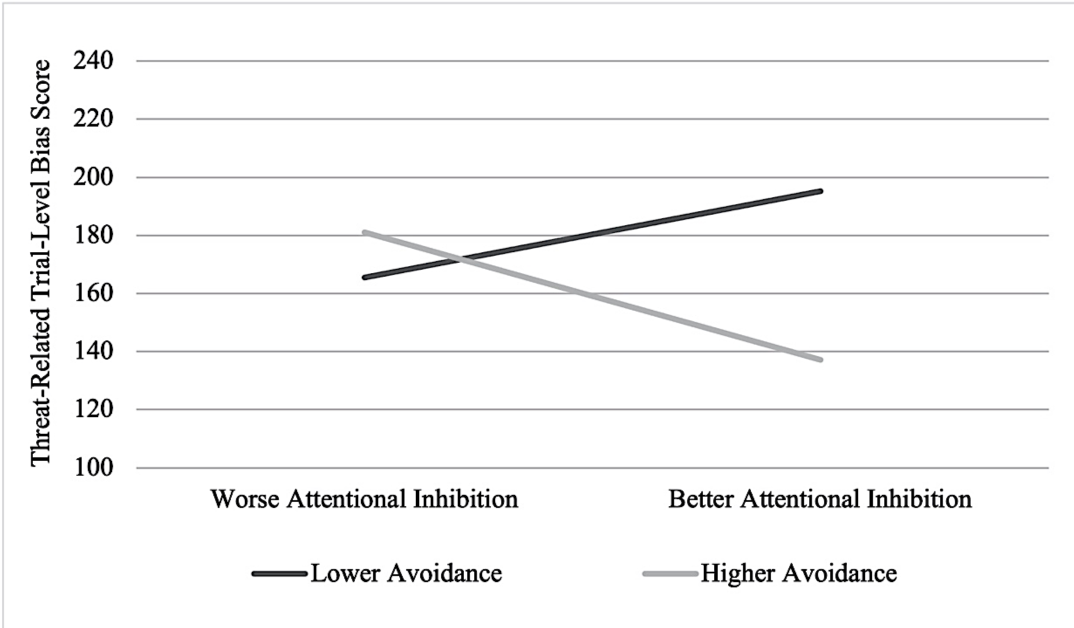

Figure 4. Interactive effect of PTS Avoidance symptoms and attentional inhibition on threat-related trial-level bias scores in the low cognitive load condition. Attentional inhibition = attentional cueing scores +1 (worse) and -1*SD* (better) above the mean; Threat-related trial level bias scores = RTs from dot-probe task.