A Longitudinal Examination of the Role of Attentional Control in the Relationship Between Posttraumatic Stress and Threat-related Attentional Bias: An Eye-tracking Study

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Abstract

The purpose of the present study was to use eye-tracking technology to (a) show that attentional control can be used to reduce attentional bias to threat (ABT) among those with higher levels of posttraumatic stress (PTS) symptoms, (b) identify the specific attentional control (AC) processes (i.e., inhibition, shifting, working memory updating) that account for this effect, and (c) determine the short- (sympathetic nervous system reactivity) and long-term effects (PTS symptoms) of using attentional control in this manner. At Time 1 (T1), participants ($N = 116$ trauma exposed) completed self-report measures, an eye-tracking task assessing ABT, and behavioral measures assessing cognitive processes. A subsample ($n = 49$) completed an online follow-up assessment (T2). AC at T1 moderated the PTS-ABT relationship. Inhibitory ability appears to be driving this effect. Those with higher PTS symptoms and higher AC at T1, who spent less time attending to threat stimuli and had the lowest sympathetic response, had the highest levels of PTS symptoms at T2. Findings suggest that the habitual use of AC (especially inhibition) to shift attention from threat to neutral stimuli may alleviate distress in the short-term for those with higher PTS symptoms, but maintain, and perhaps exacerbate, PTS symptoms over longer periods.

Keywords: eye tracking, attentional bias, attentional control, inhibition, longitudinal, arousal
1. Introduction

Approximately 6.8% of the American population (Kessler, Chiu, Demler, & Walters, 2005), and 5-20% of returning military personnel (Ramchand et al., 2010) will develop posttraumatic stress (PTS) disorder (PTSD). PTSD is associated with severe dysfunction, high rates of co-occurring psychiatric disorders, and substantial societal, economic, and personal costs (Amaya-Jackson et al., 1999; Brady, Killeen, Brewerton, & Lucerini, 2000). Because of the severe human suffering and substantial economic burden associated with PTSD, researchers have expended considerable effort toward identifying risk and resilience factors for the development and maintenance of PTSD in hopes of ameliorating these negative outcomes.

A bias for attending to threat information (i.e., attentional bias to threat [ABT]) is one factor that has been implicated in the maintenance and exacerbation of PTSD. An extensive body of research has examined ABT in PTSD from a bottom-up (i.e., more automatic, sensory-driven) perspective, while paying relatively little attention to the role of top-down (i.e., more controlled, effortful, and goal-directed) attentional processes in understanding the relation between PTS symptoms and ABT. Findings regarding the degree to which individuals with PTSD exhibit ABT have been mixed, with some suggesting that PTSD-related ABT is a robust phenomenon (e.g., Buckley, Galovski, Blanchard, & Hickling, 2003; Constans, 2005), and other work suggesting that effects used to support PTSD-related ABT are weak at best (e.g., Kimble, Frueh, & Marks, 2009). Mixed findings may be the result of failing to consider that differences in top-down attention may influence the nature and magnitude of the relation between ABT and PTS symptoms.

More specifically, both theory (e.g., goal driven/stimulus driven theory: Corbetta & Shulman, 2002; attentional control theory: Eysenck, Derakshan, Santos, & Calvo, 2007) and
preliminary evidence suggest that attentional control (i.e., the effortful allocation of attention toward goal relevant behavior [top-down] in the face of conflicting prepotent attentional demands that draw on more automatic [bottom-up], habitual, responses tendencies; Sarapas, Weinberg, Langenecker, & Shankman, 2017) may be used to modulate ABT (Bardeen & Orcutt, 2011; Bardeen, Tull, Daniel, Evenden, & Stevens, 2016). Bardeen and Read (2010) found that participants with higher (versus lower) attentional control exhibited quicker affective recovery after providing a first person account of their most traumatic event. Longitudinal findings have similarly suggested the distress-buffering effects of attentional control. In a longitudinal study by Bardeen, Fergus, and Orcutt (2015), attentional control assessed at baseline was inversely associated with PTS symptoms assessed 4-12 weeks later, but only among participants who experienced a potentially traumatic event between the time points. Together, these findings suggest attentional control as trauma-related self-regulatory mechanism.

In considering the distress-buffering effects of attentional control at a more proximal level (i.e., information processing), Bardeen and Orcutt (2011) had participants complete a modified dot-probe task to assess ABT and a battery of self-report measures. Among participants with relatively higher PTS symptoms, those with higher attentional control disengaged and shifted attention from threat to neutral stimuli, whereas those with lower attentional control maintained attention on threat stimuli. This moderation effect remained significant even after accounting for state levels of anxious arousal. Bardeen and Orcutt (2011) hypothesized that the use of attentional control to disengage and shift attention from threat stimuli among those with higher PTS symptoms may help to down-regulate sympathetic nervous system arousal and emotional distress in the short-term. They also suggested the possibility that this form of regulation would allow one to avoid the use of less adaptive strategies that are known to maintain
and exacerbate PTS symptoms (e.g., physical escape) and increase treatment compliance and the likelihood of fear extinction.

Of note, some evidence suggests that the moderating effect of attentional control may apply broadly to the relations between threat related attentional bias and anxiety-related distress. Using a spatial cuing task, Derryberry and Reed (2002) found that individuals high in trait anxiety and high in AC showed significantly faster disengagement from threat cues in comparison to participants high in trait anxiety and low in AC. Studies in which modified dot-probe tasks were used have shown similar effects in relation to dispositional trait anxiety (Ho, Yueng, & Mak, 2016) and social anxiety (Taylor, Cross, & Amir, 2015).

However, one of the significant limitations in this line of research has been an overreliance on self-report to assess attentional control. Evidence suggests that attentional control processes can influence bottom-up reactivity as early as 100-150 ms (Bardeen & Orcutt, 2011; Peers & Lawrence, 2009). Thus, it may be particularly difficult to provide an accurate self-report on processes that occur so quickly. This hypothesis has been supported by recent preliminary research in which self-reported attentional control failed to correlate with behavioral measures of working memory and inhibitory ability (Quigley, Wright, Dobson, & Sears, in press). To address this limitation, as well as others (i.e., lack of a clinical sample, use of attentional bias scores that typically have poor reliability), Bardeen et al. (2016) used a behavioral measure of attentional control that assesses the use of the three top-down cognitive processes that are thought to make up the primary components of the construct (i.e., inhibitory ability, set shifting, and working memory updating; Eysenck et al., 2007; Miyake, Friedman, Emerson, Witzki, & Howarter, 2000). Bardeen et al. (2016) found that attentional control (measured via a behavioral task) moderated the association between PTSD status and ABT, such
that among those with PTSD, those with relatively worse attentional control exhibited significantly greater ABT (assessed via trial-level bias scores; Naim et al., 2015; Zvielli et al., 2015). This effect remained significant even after accounting for variability on trials with only neutral content, thus ensuring that the observed effect was specific to the presence of threat stimuli and not merely a function of general variability in response times.

As described by Bardeen et al. (2016), individuals with PTSD and relatively worse attentional control appear to exhibit a pattern of monitoring that may allow for the constant updating of threat potential, thus resulting in greater attentional engagement with the threat stimulus over time. In contrast, those with PTSD and relatively better attentional control appear to exhibit a more consistent attentional pattern in the presence of threat stimuli. Although it is important to monitor the environment to accurately identify threat, difficulty disengaging from objectively safe stimuli (e.g., images on a computer monitor) may increase the likelihood of functional impairment and serve to maintain emotional distress. On the other hand, using attentional control to habitually disengage and shift attention from threat may also be seen as a maladaptive avoidance strategy that may maintain PTS symptoms over time. Longitudinal research, including the assessment of top-down attentional processes, will be important for understanding the complex nature of the PTS-ABT relationship.

In the few studies that have examined temporal relations between PTSD and ABT, findings have been mixed, with evidence in favor of both avoidance of threat (Beevers, Lee, Wells, Ellis, & Telch, 2011; Wald et al., 2013) and dysregulation both toward and away from threat (Schafer et al., 2016) prospectively predicting higher PTS symptoms, as well as evidence that ABT may develop in response to a traumatic event, but pre-trauma ABT does not necessarily confer risk for post-trauma distress (Iacoviello et al., 2014). Equivocal findings may
be the result of a number of methodological limitations, including the use of methods of assessing ABT that have poor reliability (Schmukle, 2005), the use of word stimuli which require greater semantic processing (Iacoviello et al., 2014; Wald et al., 2013), or the use of aggregate scores with stimulus presentations as long as 30,000 ms (Beever et al., 2011). However, as has been described, discrepancies in the extant literature may be the result of failing to account for the impact of top-down attentional processes on the PTS-ABT relationship. As described by some (Cisler & Koster, 2010; Mogg & Bradley, 2016), failure to move beyond basic bottom-up examinations of ABT may lead to spurious conclusions regarding the nature of threat-related information processing and related maladaptive outcomes. Empirical research has failed to keep pace with recent dual-process models of ABT that assert that two systems (bottom-up and top-down) interact to differentially impact the expression of threat biases (Corbetta & Shulman, 2002; Eysenck et al., 2007). Thus, accounting for the interactive effect of bottom-up and top-down processes may greatly advance our understanding of the complex nature of attentional biases as they relate to PTSD, provide more accurate predictions of vulnerability for experiencing prolonged PTSD symptoms, and have important treatment implications.

1.1. Present Study

As recommended (Bardeen et al., 2016; Wald et al., 2013), eye-tracking technology was used in the present study to provide a more precise, overt measure of attention allocation. This method is less vulnerable to alternate explanations than measures of covert attention that are susceptible to poor reliability (Schmukle, 2005). We first sought to replicate previous research by examining self-reported attentional control as a moderator of the relationship between PTS symptoms and ABT. We hypothesized that, among participants with higher PTS symptoms, those with higher (versus lower) attentional control would spend significantly more time
attending to neutral stimuli than threat stimuli (Bardeen & Orcutt, 2011). Based on the hypothesis that using attentional control to disengage and shift attention from threat to neutral stimuli would down-regulate sympathetic nervous system arousal, we hypothesized that a similar moderation effect would be observed when pupillary response was substituted for ABT as the outcome variable. That is, we expected to observe attenuated pupillary response among those with higher PTS symptoms and higher attentional control compared to those with higher PTS symptoms and lower attentional control.

Even though pupillary response has been widely used as an indicator of emotional arousal (e.g., Bradley, Miccoli, Escrig, & Lang, 2008; Partala, & Surakka, 2003), some evidence suggests that it may also reflect increased cognitive demand (Granholm, Asarnow, Sarkin, & Dykes, 1996). However, it is important to consider the nature of the task when determining what pupillary response is measuring (e.g., task demands and type of stimuli; Holmqvist, Nyström, Andersson, Dewhurst, Jarodzka, & Van de Weijer, 2011). Participants in the present study were not required to use a specific emotion regulation strategy or perform some other demanding task (e.g., making calculations) while pupil diameter was being measured. Instead, changes in pupil diameter were measured in response to viewing images for which a large database of normative ratings exist for the dimensions of arousal and valence (IAPS images; Lang, Bradley, & Cuthbert, 1999). The images have been used across a wide variety of studies to induce negative affective states (e.g., Erk et al., 2003; Pretz, Totz, & Kaufman, 2010). Importantly, Bradley et al. (2008) found that pupillary response covaried with skin conductance in response to viewing IAPS images, and thus concluded that pupillary response to arousing IAPS images reflects emotional arousal. Given that our free-viewing task is relatively low in cognitive demand, and the discussed findings are specific to the same standardized image database that was used in the
present study, pupillary response was considered an indicator of sympathetic nervous system arousal in the context of the current study.

We also included a cognitive battery of behavioral measures assessing top-down cognitive processes to (a) ensure that the noted modulatory effects are due to actual cognitive abilities rather than one's perception of these abilities, and (b) help delineate the specific top-down process(es) involved in the PTS-ABT relationship. We included measures of the three top-down cognitive processes that are thought to make up the attentional control construct (i.e., inhibitory ability, set shifting, and working memory updating), as well as a general measure of problem solving to ensure that the noted modulatory effect is specific to at least one of the components of attentional control rather than simply being a function of cognitive ability. Although evidence is scarce that would allow us to strongly support any one of the cognitive processes related to attentional control over others, we tentatively hypothesized that inhibitory ability would stand out as the driver of the noted modulatory effect based on recent evidence that inhibitory ability moderates the association between threat processing and anxiety (Gorlin & Teachman, 2015).

Finally, we sought to determine whether disengaging from threat stimuli, through the use of attentional control, is adaptive or maladaptive over a prolonged period of time by incorporating a second assessment session into our study design. As described, there are two hypotheses that seem plausible. First, disengaging from threat may help to down-regulate sympathetic nervous arousal and emotional distress, thus allowing one to avoid the use of less adaptive strategies that are known to maintain and exacerbate PTS symptoms (e.g., physical escape) and increase behaviors that favor fear extinction (e.g., treatment compliance, approaching trauma-related contexts). Second, although using attentional control to shift and
maintain attention on neutral stimuli may alleviate physiological and emotional distress in the short-term, it may maintain trauma-related fear and related PTS symptoms over a prolonged period by failing to provide the opportunity for new learning. Because cumulative trauma can be a powerful predictor of PTS symptom severity (Cloitre et al., 2009; Schumm, Briggs-Phillips, & Hobfoll, 2006; Smith, Summers, Dillon, & Cougle, 2016), we will account for it in our analyses.

2. Method

2.1. Participants and Procedure

For the present study, undergraduate students were recruited from a mass testing pool at a mid-sized Southeastern U.S. university. To be eligible, participants were required to be between the ages of 18-64, fluent in English, and have no visual impairments. Additionally, participants had to endorse having experienced a traumatic event, strictly defined as per Criterion A of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association [APA], 2013). The eye-tracker failed to capture eye movements for five participants and responses to our cognitive test battery went unrecorded due to technical difficulties for an additional seven participants, resulting in a sample of 169 participants who completed the eye-tracking task, our cognitive measures, and a measure assessing lifetime trauma history. Of this sample, 69% reported experiencing at least one Criterion A traumatic event, resulting in a final Time 1 (T1) sample of 116 participants (87 [75%] females). The average age of the T1 sample was 20.7 years ($SD = 4.1$) and 90% self-identified as White, 6% as Black, 2% as Asian, 1% as American Indian or Alaska Native, and 2% endorsed “other”. Additionally, 4% of the T1 sample reported being of Hispanic ethnicity.

Eighty-three percent ($n = 96$) of participants with a trauma history at T1 consented to follow-up contact, and thus, received an invitation (i.e., via e-mail, postal mail, and telephone
depending on whether or not a timely response was received) to complete an online battery of questionnaires six months after completing T1. Of the 96 participants who received this invitation, 53 (55.2%) completed the Time 2 (T2) assessment battery. Four participants reported experiencing an intervening trauma (i.e., Criterion A of the DSM-5 for PTSD) between T1 and T2, and thus, were excluded from the final T2 sample ($n = 49$). At the time of the assessment, the average age of the T2 sample was 21.2 years ($SD = 3.6$) and 84% self-identified as White, 10% as Black, 2% as Asian, 2% as American Indian or Alaska Native, and 2% endorsed “other”. Additionally, 4% of the T2 sample reported being of Hispanic ethnicity.

2.2. Self-report Measures

**Attentional Control Scale (ACS).** The ACS is a 20-item self-report measure that assesses one’s ability to flexibly control attention. ACS items are rated on a 4-point scale (1 = *Almost never* to 4 = *Always*), with higher scores indicating relatively better attentional control abilities. Participants were asked to rate how often, or how much, each statement applies to them in general (e.g., “I can quickly switch from one task to another”). The ACS has exhibited adequate psychometric properties, including good internal consistency and concurrent validity (Derryberry & Reed, 2002). In the present sample, internal consistency for the ACS total score ($M = 51.56$, $SD = 9.12$, Range = 29-74) at T1 was adequate ($\alpha = .87$).

**Life Events Checklist for DSM-5 (LEC-5).** The LEC-5 (Weathers, Blake et al., 2013) assesses lifetime trauma exposure. Participants are provided with a list of 17 potentially traumatic events (e.g., sexual assault, motor vehicle accident, physical assault). For each event, respondents are asked to indicate whether the event happened to them, they witnessed it, they learned about it, it was part of their job, they are unsure, or the event did not apply to them. Consistent with Bovin et al. (2016), an extended version of the LEC-5 that provides the
additional information required to ensure an event meets Criterion A (e.g., exposure to actual or threatened death, serious injury, or sexual violence; APA, 2013) was used in the present study. From the events reported, participants are asked to identify the one event that currently bothers them the most and reference this event when completing the PTSD Checklist-5-Civilian Version (Weathers, Litz et al., 2013). The event types that were endorsed at T1 were summed to serve as an index of cumulative trauma in study analyses (Smith et al., 2016). Participants completed this measure at both assessment sessions.

**PTSD Checklist-5-Civilian Version (PCL-5).** The PCL-5 (Weathers, Litz et al., 2013) is a 20-item self-report measure designed to assess DSM-5 PTSD criteria B, C, D, and E (APA, 2013). Participants rate (0 = not at all to 4 = extremely) how much they have been bothered by each symptom in the past month in relation to the potentially traumatic event that they identified as most distressing on the LEC-5. Higher scores indicate greater PTS symptoms. Consistent with evidence suggesting that PTSD is not a discrete clinical syndrome, but rather a dimensional construct (e.g., Broman-Fulks et al., 2006; Forbes, Haslam, Williams, & Creamer, 2005; Ruscio, Ruscio, & Keane, 2002), PCL-5 items were summed to create an overall total score for use as continuous variable at both sessions. In the present sample, internal consistency for the PCL Total score was adequate at T1 (α = .93, M = 11.47, SD = 12.68, Range = 0-52) and T2 (α = .95, M = 13.80, SD = 15.44, Range = 0-56). The following PTS symptom cluster averages were observed at T1 (intrusion = 3.31 [SD = 3.89], avoidance = 1.91 [SD = 2.39], cognition = 3.32 [SD = 4.49], and arousal = 2.95 [SD = 3.91]) and T2 (intrusion = 3.13 [SD = 4.01], avoidance = 2.23 [SD = 2.53], cognition = 3.40 [SD = 4.64], and arousal = 4.35 [SD = 5.17]). Cut scores of 30 to 35 have been recommended for identifying probable cases of PTSD in general population samples (Weathers et al. 2013). Between 5-11% of the T1 sample and 9-11% of the T2 sample
met or exceeded these cut scores, thus suggesting levels of symptom severity comparable to general population estimates.

2.3. Cognitive Test Battery

A battery of computer-administered cognitive assessment tasks was customized for use in the present study by Lumos Labs, Inc. Each of these tasks was modeled after commonly used stimulus-response or paper-pencil neuropsychological assessment measures. There is extensive psychometric evidence in support of these assessment measures in their original forms, and importantly, recent evidence suggests adequate psychometric properties of the computerized versions, including retest reliability and convergent and discriminant validity (see Morrison, Simone, Ng, & Hardy, 2015).

**Digit Symbol Coding.** This task is based on Digit Symbol Substitution (Royer, 1971), a measure of memory. During the task, a legend of digit-symbol pairs (e.g., 1/$∞$, 2/$\perp$ ... 7/$\Lambda$, 8/$X$, 9/$=$) appears at the top of the screen. During each trial, one of the symbols, selected randomly, appears at the bottom of the screen. The participant is instructed to use the computer keyboard to enter the number that corresponds with the symbol as quickly and accurately as possible. This task lasts 90 seconds and the outcome variable is calculated as the number of correct trials minus incorrect trials.

**Attentional Cuing.** This task is based on Posner’s (1980) cuing task. During each of 100 trials, an arrow appears in the center of the screen, pointing either right or left, for approximately 500ms. Next, a star appears on either the left or the right side of the screen. Participants are required to use the arrow keys on the keyboard to indicate the star’s position on the screen. The star appears on the side of the screen that is indicated by the arrow (congruent trials) on 80% of the trials, and for 20% of the trials the star appears opposite the arrow’s direction (incongruent...
trials). The difference between reaction times on congruent and incongruent trials serves as an indicator of attentional inhibition. Those with better attentional inhibition are able to inhibit predominant tendencies in favor of attending to task-relevant stimuli (Bishop, 2008).

**Trail Making.** The Trail Making Test is one of the most commonly used neuropsychological assessments measures (Army Individual Test Battery [AITB], 1944). This task consists of two parts (A and B). During part A, an array of circles containing numbers (1 to 24) appears on the screen and the participant has to use the computer mouse to connect the numbers, in order, as fast as possible. During part B, an array of circles containing both numbers (1 to 12) and letters (A to L) appears on the screen and the participant has to connect the numbers and letters, in order (i.e., 1 to A, 2 to B, and so on), as fast as possible. While success on the Trail Making Test is thought to rely on a variety of cognitive processes, evidence suggests that the ability that most accurately differentiates performance on part A from part B is task-switching (i.e., switch cost; Sanchez-Cubillo et al., 2009). Following the recommendation of Salthouse (2011), a residualized change score was computed for use in the present study.

**Grammatical Reasoning.** This task is based on Baddeley’s Grammatical Reasoning Test (Baddeley, 1968) and broadly assesses problem solving ability (i.e., ability to use mental operations involving logical reasoning). During the task, two shapes appear side-by-side on the computer screen with a logical statement written below. The participant uses the computer keyboard to respond to as many true/false logic questions as they can in 90 seconds (e.g., "The square is not to the right of the triangle"). The outcome variable is calculated as the number of correct trials minus incorrect trials.

### 2.4. Equipment
Participants completed self-report measures, the cognitive test battery, and the eye-tracking task on a Hewlett Packard Z230 desktop computer with a 24-inch BenQ XL2430 monitor. A computer keyboard and mouse were used to respond to questionnaires and cognitive tasks. Self-report measures were presented via Qualtrics (http://www.qualtrics.com/). A Tobii X2-60 Eye Tracker was used to record eye movements and pupil diameter. Recording and stimulus presentation were controlled by Tobii Pro Studio, E-prime 2.0 software, and E-Prime Extensions for Tobii (Psychology Software Tools, Pittsburgh, PA). During tracking, the X2-60 uses infrared diodes to generate reflection patterns on the corneas of the participant's eyes. The X2-60 provides measures of gaze points coordinates, distance from the tracker, and pupil diameter every 16.7 ms (60 HZ). Algorithm filters are available from Tobii Pro Studio that take into account factors (e.g., distance of eye from the tracker) that can distort data if not corrected. The I-VT fixation filter was used in the present study, as this filter provides highly accurate fixation classifications for free-viewing tasks. We also enabled the gap fill-in function to reduce data loss through the use of linear interpolation to fill gaps in gaze points that are less than 75ms in length. Longer gaps (e.g., 100ms and greater) that are more typical of blinking or looking away are not filled, but instead, are recorded as missing data. Tobii Studios software also uses an algorithm to compensate for corneal magnification effects and gaze angle changes as well as for distance of the eye from the tracker to ensure accurate measurement of pupil diameter.

2.5. Eye-Tracking Task

Word stimuli require greater semantic processing than pictoral stimuli (Pineles, Shipherd, Mostoufi, Abramovitz, & Yovel, 2009) and are resistant to familiarity related to frequency of use (Bradley et al., 1997). As such, pictorial stimuli were used in the present study (International Affective Picture System [IAPS]; Lang et al., 1999). The set of images used in the present study
included 40 threat (e.g., vicious dog, car accident) and 80 neutral images (e.g., broom, busy pedestrian sidewalk) and has been used in previous research (Bardeen, 2015; Bardeen et al., 2016). General threat images had negative valence ($M = 2.17$) and high arousal ($M = 6.52$). Neutral images had neither negative nor positive valence ($M = 5.12$) and low arousal ($M = 2.96$; Lang et al., 1999).

To calibrate the eye tracker, each participant was required to follow a dot, with their eyes, as it was presented at nine locations on the screen. Next, the initial instructions appeared on the screen telling participants to view task images freely, as “the purpose of this experiment is to measure parts of your eye, such as your pupil, while you view different pictures on the computer screen” (Buckner, Maner, & Schmidt, 2010). Participants were also instructed to identify a fixation target at the beginning of each trial (either an “O” or an “X”) using the computer keyboard to ensure central fixation (Armstrong, Olatunji, Sarawgi, & Simmons, 2010). Next, two images appeared side-by-side on the screen (i.e., neutral-neutral or threat-neutral) for 3,000 ms (Armstrong, Blisky, Zhao, & Olatunji, 2013). Neutral-neutral image pairings were presented to reduce threat expectancy. After completing five practice trials, corrective feedback was provided by a research assistant (RA) as necessary. The RA retired to an adjacent room and communicated with the participant though the use of an intercom for the rest of the study. Finally, participants completed a single block of 60 trials. The order of image type was randomized across participants. IAPS images intersected at a visual angle of 13.3° × 12.4°. The two images were separated by a vertical distance of 14 cm, resulting in a visual angle of separation of 12.4° at a viewing distance of 60 cm.

The proportion of time attending to threat versus neutral stimuli for neutral-threat presentations was calculated as our measure of Dwell Time. Dwell Time was also calculated for
each 500 ms epoch interval (i.e., 0-500 \( M = .59 \) (SD = .08), \( \alpha = .53 \), 501-1,000 \( M = .74 \) (SD = .13), \( \alpha = .87 \), 1,001-1,500 \( M = .69 \) (SD = .14), \( \alpha = .89 \), 1,501-2,000 \( M = .61 \) (SD = .16), \( \alpha = .89 \), 2,001-2,500 \( M = 0.55 \) (SD = .20), \( \alpha = .91 \), 2,501-3,000 \( M = .51 \) (SD = .22), \( \alpha = .91 \) ms) so that we could examine within-trial variability in Dwell Time (e.g., Armstrong et al., 2013; Buckner et al., 2010). Pupil diameter was recorded over the entire 3,000ms trial interval for neutral-threat pairings, as well as during the presentation of the fixation cross. Baseline pupil diameter (i.e., while viewing the pre-trial fixation cross) was subtracted from (a) pupil diameter during fixation on threat stimuli and (b) pupil diameter during fixation on threat stimuli. Pupillary response was calculated by subtracting the first score from the second (pupillary response: \( M = -.01 \) [SD = .07], \( \alpha = .99 \); Duque, Sanchez, & Vazquez, 2014).

2.6. Procedure

At a single laboratory session (T1), participants were led to a private room where they completed informed consent, a battery of self-report questionnaires, a computerized cognitive test battery, and an eye-tracking task. Before leaving, participants were debriefed and given credit for the psychology course of their choosing. At T2, informed consent and self-report measures were administered via a secure online survey program. This session could be completed from any computer with internet access. Twenty dollars compensation was provided for participating in T2. The interval between T1 and T2 was approximately six months (\( M = 192 \) days; SD = 9.6; range 182 to 228 days). All study procedures were approved by the university’s institutional review board.

3. Results

3.1. Attrition Analysis
T2 participants were compared to eligible nonresponders on demographics (i.e., age, race/ethnicity, sex, income) and variables measured at T1 (i.e., PCL Total, ACS Total, Dwell Time, Pupillary Response, Digit Symbol Coding [working memory], Attentional Cuing [inhibition], Trail Making [set-shifting], and Grammatical Reasoning [problem solving]) in order to examine differences due to attrition. Race and ethnicity were collapsed into a single dummy coded variable (coded as Hispanic and/or non-White [12.4%] versus non-Hispanic White [87.6%]). There were no differences between those who attrited and those who did not in race/ethnicity ($\chi^2[1, N = 91] = 2.23, p = .14$), age ($t[89] = 0.12, p = .88$), PCL Total ($t[89] = 0.62, p = .54$), ACS Total ($t[89] = 1.07, p = .29$), Dwell Time ($t[89] = -0.26, p = .80$), Pupillary Response ($t[89] = -1.44, p = .15$), working memory ($t[89] = -1.33, p = .19$), inhibition ($t[89] = 0.59, p = .56$), set-shifting ($t[89] = 0.29, p = .77$), and problem solving ($t[89] = -0.18, p = .97$). There was a marginally significant difference in household income between those who attrited ($M = $87,158.09, $SD = 61,449.52$) and those who did not ($M = $66,169.21, $SD = 52,380.43$; $t[89] = 1.76, p = .08$). In addition, there were significantly more woman than men in the T2 sample, $\chi^2(1, N = 91) = 4.23, p = .04$.

### 3.2. PTS Symptoms & Self-reported Attentional Control

**Predicting Dwell Time.** Mixed effects linear modeling with autoregressive covariance structures was used to examine self-reported attentional control as a moderator of the relation between PTS symptoms and dwell on threat over time. This approach provides greater flexibility in modeling interactive time effects than repeated measures ANOVA, while also accounting for the within-participant autoregressive effects associated with repeated measures designs. Traumas (i.e., number of potentially traumatic events endorsed on the Life Events Checklist – 5) served as a covariate in the model.\(^1\) Independent variables were treated as fixed.
Of our main effects variables, only epoch interval significantly predicted Dwell Time, $F(5, 517.61) = 84.46, p < .001$, with attention to threat decreasing over the course of the 3,000 ms trial window. Among our interaction terms, only PCL Total x ACS Total significantly predicted Dwell Time, $F(1, 127.35) = 4.38, p = .038$. Because the interaction effect did not vary as a function of time, we removed our time variable (i.e., epoch interval) from the analytic model and further examined the significant interaction in a hierarchical regression analysis. As with the original model, Traumas served as a covariate and PCL Total and ACS Total, as well as the two-way interaction between PCL Total and ACS Total served as predictor variables. Total Dwell Time (over the 3,000 ms trial) served as the outcome variable.

In the first step of the model ($R^2 = .01; p = .80$), none of the main effects variables significantly predicted Dwell Time. In the second step of the model ($R^2 = .04; p = .04$), the interaction term (PCL Total x ACS Total) significantly predicted Dwell Time ($\beta = -.19, p = .04$). Simple slopes analysis was used to explore the significant interaction effect (Aiken & West, 1991). Simple slopes analysis consists of constructing two simple regression equations in which the relationship between the predictor variable and the outcome variable is tested at both high (+1 SD) and low (-1 SD) levels of the moderating variable (i.e., ACS Total). Simple slopes analysis revealed a significant negative association between PCL Total and Dwell Time at high ($\beta = -.29, p = .04$), but not low ($\beta = .10, p = .44$), levels of ACS Total. The nature of the interaction was such that as posttraumatic stress symptoms increased, Dwell Time decreased, but only among those with higher levels of attentional control.

**Predicting Pupillary Response.** Pupillary Response served as the outcome variable in a hierarchical regression model. Predictor variables were consistent with those above (i.e., Traumas, PCL Total, ACS Total, PCL Total x ACS Total). In the first step of the model ($R^2 = ...
.13, \( p = .002 \), Traumas (\( \beta = .28, \ p = .003 \)) and PCL Total (\( \beta = -.32, \ p < .001 \)) significantly predicted Pupillary Response, while ACS Total did not (\( \beta = .05, \ p = .54 \)). In the second step of the model (\( \Delta R^2 = .03, \ p = .048 \)), the interaction term (PCL Total x ACS Total) shared a significant association with Pupillary Response (\( \beta = -.18, \ p = .048 \)). Simple slopes analysis (Aiken & West, 1991) revealed a significant negative association between PCL Total and Pupillary Response at high (\( \beta = -.53, \ p < .001 \)), but not low (\( \beta = -.17, \ p = .17 \)), levels of ACS Total. Consistent with the interaction effect described above, as posttraumatic stress symptoms increased, Pupillary Response decreased, but only among those with higher levels of attentional control.

3.3. PTS Symptoms & Behavioral Measures of Cognitive Processes

**Predicting Dwell Time.** Mixed effects linear modeling with autoregressive covariance structures was used to examine our four behaviorally measured cognitive processes as moderators of the relationship between PTS symptoms and dwell on threat over time (i.e., epoch interval; see Table 1). As above, Traumas served as a covariate in the model and independent variables were treated as fixed. Of our main effects variables, only epoch interval significantly predicted Dwell Time (\( p < .001 \)). Among our two-way interaction terms, PCL Total x epoch interval and Trail Making x epoch interval significantly predicted Dwell Time (\( ps = .03 \) and < .01, respectively). Additionally, both PCL Total x Digit Symbol Coding and PCL Total x Attentional Cuing shared marginally significant associations with Dwell Time (\( ps = .05 \) and .07, respectively). Interactions between PCL Total x Attentional Cuing and PCL Total x epoch interval were qualified by a significant three-way interaction (PCL Total x Attentional Cuing x epoch interval, \( p = .03 \)).
The significant three-way interaction effect was examined via conditional mixed linear modeling. Specifically, the relationship between epoch interval and Dwell Time was tested at both high (+1 SD) and low (-1 SD) levels of PCL Total and Attentional Cuing. As noted above, lower scores on Attentional Cuing are indicative of relatively better inhibition. A significant positive relation between epoch interval and Dwell Time was observed at all combinations of PCL Total and Attentional Cuing (High PCL Total x High Attentional Cuing, \(F[5, 418.67] = 25.64, p < .001\); High PCL Total x Low Attentional Cuing, \(F[5, 420.01] = 13.48, p < .001\); Low PCL Total x High Attentional Cuing, \(F[5, 417.78] = 26.16, p < .001\); Low PCL Total x Low Attentional Cuing, \(F[5, 417.54] = 7.84, p < .001\)). Conditional means of Dwell Time were plotted for each epoch interval by levels of PCL Total and Attentional Cuing (i.e., ± 1 SD) and 95% confidence intervals were examined at each epoch interval to explore mean differences in Dwell Time (see Figure 1). A clear pattern of effects appear in Figure 1, with individuals with higher PTS symptoms and relatively lower (better) attentional cuing scores appearing to spend substantially less time than all others attending to threat versus neutral images over the course of the 3,000 ms trial window; this effect appears to increase over time (i.e., faster shifting from threat to neutral stimuli). However, an examination of 95% confidence intervals suggests significant differences in Dwell Time at only three of the six epoch intervals (i.e., 1,500-2,000, 2,000-2,500, 2,500-3,000 ms). Specifically, non-overlapping confidence intervals were observed between High PCL Total x Low (better) Attentional Cuing and both Low PCL Total x Low (better) Attentional Cuing and Low PCL Total x High (worse) Attentional Cuing at epoch intervals five and six (i.e., 2,000-2,500, 2,500-3,000 ms). At the fourth epoch interval (i.e., 1,500-2,000 ms), non-overlapping confidence intervals were observed between means plotted at
Conditional mixed linear modeling was also used to further examine the significant interaction between Trail Making x epoch interval. The relationship between epoch interval and Dwell Time was tested at both high (+1 SD) and low (-1 SD) levels of Trail Making. As noted above, lower residualized Trail Making scores are indicative of relatively better set-shifting. A positive relation between epoch interval and Dwell Time was significant at both high ($F[5, 408.07] = 7.91, p < .001$) and low ($F[5, 408.03] = 29.15, p < .001$) levels of Trail Making.

However, an examination of conditional means of Dwell Time and 95% confidence intervals at each epoch interval by level of Trail Making (i.e., ± 1 SD) revealed that the mean difference in Dwell Time, based on Trail Making, was not significant at any of the epoch intervals. These findings suggest a significance difference in the linear slope of dwell over time (i.e., a steeper slope for better, versus worse, Trail Making scores), but a nonsignificant difference in Dwell Time means at each epoch interval.

Because the marginally significant ($p = .05$) interaction between PCL Total x Digit Symbol Coding did not vary as a function of time, we removed our time variable (i.e., epoch interval) from the analytic model and further examined the significant interaction in a hierarchical regression analysis. Total Dwell Time (over the 3,000 ms trial) served as the outcome variable. After removing the time variable and the three-way interaction terms from the model, the relationship between PCL Total x Digit Symbol Coding and Dwell Time was not significant ($\beta = -.08, p = .49$), and thus, was precluded from further analysis.

**Predicting Pupillary Response.** Pupillary Response served as the outcome variable in a hierarchical regression model. The predictor variables were consistent with those in the mixed
model described above (i.e., Traumas, PCL Total, Digit Symbol Coding, Attentional Cuing, Trail Making, Grammatical Reasoning). In the first step of the model ($R^2 = .15, p = .007$), Traumas ($\beta = .23, p = .03$) and PCL Total ($\beta = -.32, p < .001$) were the only significant predictors of Pupillary Response. In the second step of the model ($\Delta R^2 = .09, p = .02$), PCL Total x Attentional Cuing was the only interaction term that significantly predicted Pupillary Response ($\beta = .29, p = .002$). Simple slopes analysis (Aiken & West, 1991) revealed a significant association between PCL Total and Pupillary Response at low (i.e., better; $\beta = -.61, p < .001$), but not high (i.e., worse; $\beta = -.03, p = .83$), levels of Attentional Cuing. Specifically, as posttraumatic stress symptoms increased, Pupillary Response decreased, but only among those with relatively better inhibitory ability (lower Attentional Cuing scores).

### 3.4. Predicting Time 2 Posttraumatic Stress Symptoms

Given our relatively small T2 sample ($n = 49$), with its limited power, we were unable to simultaneously model our behavioral measures of cognitive processes and the interactive effects of interest. As such, self-reported attentional control at T1 was used in the following models to examine interactions of interest (T1 attentional control x T1 PTS symptoms x T1 eye tracking indices [Dwell Time or Pupillary Response]) predicting T2 PTS symptoms. One case exhibited undue influence on the overall regression estimates of both of the models (i.e., defined as $> 1$ Cook’s $D_i$; Cohen et al., 2003), and thus, was removed from the longitudinal analysis ($n = 48$).

T2 PTS symptoms (i.e., T2 PCL Total) served as the outcome variable in both regression models and Traumas served as a covariate. In our first model, T1 PCL Total, T1 ACS Total, and T1 Dwell Time, as well as the two- and three-way interactions between these variables served as predictor variables (see Table 2). The only difference between the first and second model is that Pupillary Response replaced Dwell Time. In the first model, a marginally significant association,
with a medium-large magnitude effect, was observed between the three-way interaction term (T1 PCL Total x T1 ACS Total x T1 Dwell Time) and T2 PTS symptoms ($\beta = .37, p = .065$). This three-way interaction was examined using the PROCESS macro for SPSS (Hayes, 2013). PROCESS generates simple slopes between the predictor (i.e., T1 PTS) and outcome variable (T2 PTS) at high and low levels ($\pm$ 1 SD) of both moderators (i.e., T1 ACS, T1 Dwell Time). The graphical depiction of these results is presented in Figure 2. The association between T1 PTS symptoms and T2 PTS symptoms was only significant at the combination of high T1 ACS + low T1 Dwell Time ($B = 2.71, SE = .83, p = .002$); none of the other simple slopes presented in Figure 2 were significant ($p$s from .10 to .51).

In the second model, a large magnitude effect was observed for the association between the three-way interaction term (T1 PCL Total x T1 ACS Total x T1 Pupillary Response) and T1 PTS symptoms ($\beta = -.59, p = .017$). Consistent with above, conditional effects were examined using the PROCESS macro (Hayes, 2013). The graphical depiction of these results is presented in Figure 3. A strong positive association between T1 PTS symptoms and T2 PTS symptoms was observed at the combination of high T1 ACS + low T1 Pupillary Response ($B = 2.01, SE = .56, p = .001$). Although the magnitude of the effects was significantly smaller, significant positive associations between T1 PTS symptoms and T2 PTS symptoms were observed for the combinations of low T1 ACS + high T1 Pupillary Response ($B = 1.01, SE = .38, p = .011$) and low T1 ACS + low T1 Pupillary Response ($B = 0.51, SE = .23, p = .033$). For those with the combination of high T1 ACS and high T1 Pupillary Response, the relationship between T1 PTS symptoms and T2 PTS symptoms was not significant ($B = -0.11, SE = .42, p = .785$).

4. Discussion

As predicted, and consistent with previous research, self-reported attentional control
moderated the relationship between PTS symptoms and ABT. Among those with higher PTS symptoms, those with higher attentional control spent significantly less time attending to threat stimuli than those with lower attentional control. Importantly, among attentional control processes, inhibition interacted with PTS symptoms to predict alterations in ABT as a function of time. Specifically, those with higher PTS symptoms and relatively better inhibitory ability disengaged attention from threat stimuli and shifted and maintained attention on neutral stimuli. This effect appears to be most pronounced from 1,500 to 3,000 ms. In contrast, evidence of differences in ABT, based on PTS symptoms and attentional control or inhibitory ability, were not observed for epoch intervals indicative of faster orienting toward threat in studies that used similar free-viewing tasks (i.e., 0-500 ms; Garner, Mogg, & Bradley, 2006, Armstrong et al., 2010). Although this finding appears to be partially consistent with the attention-maintenance rather than vigilance-avoidance model of ABT (Weierich, Treat, & Hollingworth, 2008), it may also aid in understanding the apparent discrepancy between these models. While there does not appear to be a difference in initial orienting toward threat as a function of PTS symptom level, among those with higher PTS symptoms, those with relatively worse inhibitory ability may wish to cognitively disengage from threat stimuli, but lack the requisite resources to effectively do so (i.e., attention maintenance). That is, as suggested by Bardeen et al. (2016), even when these individuals are able to disengage and shift overt attention from threat stimuli, they may find it particularly difficult to cognitively disengage from, or inhibit, that threat information. This may result in a pattern of monitoring that allows for the constant updating of threat potential and greater attentional engagement with threat stimuli over time. In contrast, those with higher PTS symptoms and relatively better inhibitory ability appear to disengage faster and are better able to maintain focus on neutral stimuli once disengagement has occurred (i.e., attentional avoidance).
The present findings suggest that this pattern of avoidance allows for the down-regulation of emotional arousal (i.e., sympathetic nervous system arousal), which is commonly induced by viewing IAPS images with high arousal and low valence ratings (e.g., Erk et al., 2003; Pretz et al., 2010). Heightened sympathetic activation is associated with sensory processing and sensorimotor integration decrements (Lacey & Lacy, 1980), as well as general attention regulation deficits (Crowe et al., 2001). As such, those with higher PTS symptoms and lower inhibitory ability, who already have a more difficult time inhibiting threat information, may find it even more difficult to maintain focus on goal-relevant, or distress-alleviating, stimuli when threat stimuli are highly salient or remain present for prolonged periods of time. However, results from the longitudinal portion of this study do not necessarily suggest that this results in negative long-term outcomes.

Results from the longitudinal analysis suggest that using attentional control to attend to neutral versus threat stimuli and down-regulate sympathetic nervous system arousal may maintain, and perhaps exacerbate, PTS symptoms over the course of six months, but only among those who have relatively higher PTS symptoms at baseline. The key to understanding this effect may lie at the intersection of ability (i.e., attentional control) and the application of that ability. Specifically, theories of emotion regulation suggest that the ability to flexibly control attention is essential for maintaining psychological well-being (e.g., Gross, 1998). Flexible control suggests a willingness to experience fluctuations in emotional states that rigid attempts at control do not. The pattern of threat-related avoidance observed in the present study by those with high PTS symptoms and high attentional control suggests a rigid fear-based approach to regulating emotional arousal. The chronic use of avoidance to provide immediate relief from experiencing bodily sensations to which one is highly averse is specifically identified in the DSM-5 as a
symptom of PTSD. Consistent with the present results, attempts to avoid aversive internal experiences (i.e., experiential avoidance) associated with a traumatic event may alleviate suffering in the short-term by decreasing the severity of trauma-related distress, which reinforces the likelihood that this behavior will continue, perhaps becoming habitual and more easily enacted with continued use. Over time, the chronic use of avoidance prevents disconfirmation of faulty threat appraisals which results in the maintenance of maladaptive fear responses and posttraumatic stress (Foa & Kozak, 1986).

Based on this conceptualization, it may be particularly important in future research to consider the role that experiential avoidance plays in the already complex web of relations among PTS, ABT, and attentional control. Interestingly, the combination of high Pupillary Response and high attentional control appears to have buffered the effect of T1 PTS symptoms on T2 PTS symptoms. This finding might further suggest that both ability (i.e., attentional control) and willingness to experience short-term emotional distress may be protective. This is consistent with evidence that those with outcome-specific vulnerabilities and greater experiential willingness report greater short-term emotional distress in response to negative mood induction procedures, but relatively less long-term negative outcomes (Bardeen, 2015). In contrast, those with outcome-specific vulnerabilities and greater experiential avoidance report less short-term distress and greater negative long-term outcomes.

The bulk of attention modification programs for treating anxiety and related disorders are designed to train attention (implicitly) away from threat and toward neutral or positive stimuli. The basic assumption used to support this approach is that individuals with anxiety and related disorders attend to threat stimuli longer than those without these emotional disorders, and prolonged attentional engagement with threat maintains negative affective states (e.g., chronic
hypervigilance and increased physiological arousal; Kuckertz et al., 2014) and contributes to the
development and maintenance of psychopathology. However, there is considerable evidence that
the assumption that individuals with anxiety and PTSD preferentially process threat information
is flawed (e.g., Kimble et al., 2009). Results from the present study, as well as previous research
(Bardeen & Orcutt, 2011; Bardeen et al., 2016; Derryberry & Reed, 2002; Ho et al., 2017),
suggest that it is important to consider the role of top-down attentional processes to understand
the processing of threat information in both PTS and anxiety disorders. Whereas those with
relatively worse attentional control and greater symptomatology are more likely to exhibit
prolonged attentional engagement with threat, those with relatively better attentional control and
greater symptomatology exhibit avoidance of threat stimuli. As such, it seems problematic to use
a one-size-fits-all treatment technique designed to reduce attentional engagement with threat
stimuli among individuals who already appear to disengage faster and exhibit enhanced ability to
maintain focus on non-threat stimuli once disengagement has occurred. The results of the present
study suggest that this may be particularly problematic because this short-term regulatory
approach, among those with higher PTS symptoms, appears to maintain symptoms over time.

Study findings may help to explain the limited support in favor of attention bias
modification. Although some meta-analytic evidence suggests small- to medium-sized effects for
the use of attention bias modification for treating anxiety and related disorders (e.g., Hakamata et
al., 2010), Cristea, Kok, and Cujpers (2015) found that previously-significant effects became
nonsignificant when (a) accounting for extreme outliers, (b) confining analyses to patient
samples, and (c) adjusting for publication bias. Such evidence might lead one to conclude that
research on the clinical effectiveness of attention bias modification should be abandoned, but this
conclusion may be a bit premature, as we first need to determine if moderator variables, such as
attentional control, influence the treatment-outcome relationship (see Mogg & Bradley, 2016, for a review of the effectiveness of attention bias modification and a discussion of additional factors that likely influence discrepant findings). Standard attention bias modification programs, designed to train attention away from threat, may reduce PTS symptoms among those that lack the ability to maintain threat disengagement (i.e., lower attentional control and higher PTS symptoms). In contrast, those that apparently have the ability to maintain disengagement from perceived threat, but are doing so in a chronic and inflexible manner (i.e., higher attentional control and higher PTS symptoms), may be better served by modification programs designed to train attention toward task success rather than away from threat stimuli (i.e., use of a modified dot-probe task with the probe presented in place of both threat and neutral stimuli; Badura-Brack et al., 2015), thus promoting flexibility of attentional control. Additionally, treatment approaches that have been shown to be effective in increasing psychological flexibility and decreasing experiential avoidance for these individuals (e.g., Acceptance and Commitment Therapy: Hayes, Luoma, Bond, Masuda, & Lillis, 2006; Mindfulness-Based Stress Reduction: Kabat-Zinn, 1990). Thus, it will be important to account for attentional control processes and experiential willingness in future research to clarify conceptual models of ABT in PTSD, as well as studies pursing practical application of such models.

Study limitations must be acknowledged. Although evidence supports a dimensional, rather than categorical (presence versus absence), conceptualization of PTS (e.g., Broman-Fulks et al. 2006; Forbes et al. 2005; Ruscio et al. 2002), replication of the current findings in a clinical sample with a comprehensive assessment of PTSD and commonly co-occurring pathology will help ensure generalizability of findings to individuals who meet diagnostic criteria for PTSD. Moreover, an examination of a broader range of psychopathology will clarify whether results
from the present study are specific to PTSD or are exhibited across anxiety and related disorders. In addition, given our study design (two sessions with assessment of Pupillary Response and attentional control processes at Time 1 only), we cannot determine temporal relations among constructs of interest. Examination of moderated mediation would be of particular interest given our conceptual model in which those with higher PTS symptoms and higher attentional control shift attention from threat to neutral stimuli, which in turn, is thought to reduce sympathetic nervous system arousal. It will be important in future research to use experimental and longitudinal (i.e., at least three time points) methods to clarify the temporal nature of relations among these constructs and to infer causality.

The small T2 sample was a significant limitation in the present study. Although the attrition rate of 45% is not uncommon in longitudinal research (Chandler, & Shapiro, 2016; Marcellus, 2004; McCoy et al., 2009), it is sufficiently large to consider differences between T2 participants and nonresponders. The two groups did not differ on our variables of interest, but did differ in regard to sex and household income. Specifically, females were more likely to complete T2 than males, and T2 participants reported lower household income than those who only completed T1. We believe that the most likely cause of our low T2 retention rate, based on these results, is the relatively high household income of those who only completed T1 (over $87,000). Compensation of $20 may not have been thoroughly motivating for these participants. It will be important for researchers to consider household income, especially in affluent areas, or with undergraduate populations with high median household incomes, when designing studies such as these in the future. It will also be important in future research to ensure follow-up sample sizes large enough to examine the role of behaviorally assessed top-down cognitive processes in a single model to identify the specific process(es) that account for unique variance in predicting
prospective PTS symptoms. Because the risk of Type I error may be higher due to the large number of predictors in our analytic models, findings that are less robust should be considered preliminary until replicated.

Also of note, participants did not provide ratings of valence and arousal for the images that were used in the study. As such, the degree to which task stimuli were unrelated to participant-specific traumatic experiences is unknown. It was our goal to use general threat stimuli; and thus, it would have been ideal to identify images completely unrelated to one's most distressing event. However, given that the large majority of participants reported experiencing multiple traumatic events, removing all images that were potentially trauma-related would have been impractical. Moreover, study results would have been confounded had participants viewed stimuli for the purpose of making ratings prior to completing the free-viewing task. Specifically, repeated exposure to the stimuli may have reduced image-related arousal during the task. Therefore, we identified images of a wide variety that were pre-tested elsewhere to identify the affective valence of each and to reduce trauma-specific responding (IAPS; Lang et al., 1999). These specific images have been used in previous examinations of threat-related attentional bias (Bardeen & Orcutt, 2011; Bardeen et al., 2016) and have been used reliably to induce negative affective states (Bardeen, 2015). Although these images were matched on ratings of valence and arousal and image pairings were matched for complexity via basic visual inspection, image pairings were not matched on other features (e.g., luminance, color), which may have influenced the results. However, it may be that certain types of stimuli share specific feature qualities and removal of these qualities may negate the intended purpose of the stimulus set. Removal of these feature qualities in future research (i.e., a stepwise removal and replace approach) may help to clarify which qualities are most important for threat-related responding.
A plethora of research has suggested attentional control as a protective factor against both short- and long-term negative outcomes. The current study suggests that the chronic inflexible use of attentional control processes to avoid threat information may reduce emotional arousal in the short-term, but maintain, and perhaps exacerbate, PTS symptoms over prolonged periods of time. These results are consistent with a functional-contextual perspective in which the rigid avoidance of unwanted internal experiences attenuates short-term distress, but paradoxically exacerbates distress over prolonged periods of time (Hayes et al., 2006). These findings are not only conceptually important, but also may have profound implications for considering the clinical use of attention bias modification programs. These programs, in their present form, may only be helpful in alleviating PTS symptoms among those with ABT and relatively lower attentional control. As such, with replication of the present findings in a clinical sample, it may be important to assess attentional control and ABT among individuals with PTSD to determine whether use of an attention bias modification treatment approach is warranted.
References


Footnote

1The cumulative trauma variable was removed from all analytic models and our analyses were repeated to examine the impact of this variable on the highlighted interaction effects. First, the magnitude of the effect of the interaction between PCL Total and ACS Total on Pupillary response slightly decreased from $\beta = -.18$ ($p = .048$) to $\beta = -.16$ ($p = .072$). Second, the magnitude of the effect of the interaction between PCL Total and Attentional Cuing on Pupillary response slightly increased from $\beta = .29$ ($p = .002$) to $\beta = .31$ ($p < .001$). The remaining results were consistent with our initial analysis; effect sizes were almost identical and statistically significant findings remained significant and nonsignificant findings were unchanged.
### Table 1

*Mixed linear model: Behavioral tasks predicting dwell over time*

<table>
<thead>
<tr>
<th>Model</th>
<th>F</th>
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<th>p</th>
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<tr>
<td>Traumas</td>
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<tr>
<td>PCL Total</td>
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<td>(1, 102.44)</td>
<td>.08</td>
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<tr>
<td>DSC</td>
<td>0.40</td>
<td>(1, 101.91)</td>
<td>.53</td>
</tr>
<tr>
<td>AC</td>
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<td>(1, 101.79)</td>
<td>.37</td>
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<tr>
<td>TM</td>
<td>0.01</td>
<td>(1, 100.71)</td>
<td>.96</td>
</tr>
<tr>
<td>GR</td>
<td>1.43</td>
<td>(1, 104.00)</td>
<td>.24</td>
</tr>
<tr>
<td>Epoch (Time)</td>
<td>68.06</td>
<td>(5, 417.98)</td>
<td>&lt; .001</td>
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<tr>
<td>PCL Total x DSC</td>
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<td>(1, 105.11)</td>
<td>.05</td>
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<tr>
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<td>(1, 102.53)</td>
<td>.07</td>
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<td>.31</td>
</tr>
<tr>
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<tr>
<td>DSC x Epoch (Time)</td>
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<td>(5, 417.18)</td>
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<td>GR x Epoch (Time)</td>
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<td>(5, 417.97)</td>
<td>.03</td>
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<td>PCL Total x TM x Epoch (Time)</td>
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<td>.94</td>
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<td>1.16</td>
<td>(5, 421.67)</td>
<td>.33</td>
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Note. N = 116. Traumas = number of potentially traumatic events endorsed on the Life Events Checklist – 5; PCL = Posttraumatic Stress Disorder Checklist-Civilian Version-5; DSC = digit symbol coding; AC = attentional cuing (difference between congruent and incongruent trials; high scores indicate worse performance); TM = trail making (residual change score; higher scores indicate worse performance on TM part B accounting for TM part A performance); GR = grammatical reasoning; Epoch (Time) = Dwell time on threat stimuli over six intervals (1 = 0-500, 2 = 500-1,000, 3 = 1,000-1,500, 4 = 1,500-2,000, 5 = 2,000-2,500, 6 = 2,500-3,000 ms).
Table 2

**Time 1 variables predicting Time 2 posttraumatic stress symptoms**

<table>
<thead>
<tr>
<th></th>
<th>ET Variable = Total Dwell Time</th>
<th>ET Variable = Pupillary Response</th>
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<td><strong>ΔR²</strong></td>
<td>Step 1 β 2 β 3 β</td>
<td>Step 1 β 2 β 3 β</td>
</tr>
<tr>
<td>Traumas</td>
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<td>.27^ .26^ .25^</td>
</tr>
<tr>
<td>PCL Total</td>
<td>.54*** .64*** .76***</td>
<td>.50*** .49*** .50***</td>
</tr>
<tr>
<td>ACS Total</td>
<td>.06 .10 .22</td>
<td>.02 - .01 - .04</td>
</tr>
<tr>
<td>ET Variable</td>
<td>-.14 -.11 -.16</td>
<td>-.05 -.03 -.17</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>.17**</td>
<td>.01</td>
</tr>
<tr>
<td>PCL x ACS</td>
<td>.00 .25</td>
<td>.13 .08</td>
</tr>
<tr>
<td>PCL x ET Variable</td>
<td>-.25^ -.36*</td>
<td>-.04 -.41^</td>
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<tr>
<td>ACS x ET Variable</td>
<td>.41*** .24</td>
<td>.08 -.03</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>.04^</td>
<td>.08*</td>
</tr>
<tr>
<td>PCL x ACS x ET Variable</td>
<td>-.37^</td>
<td>-.59*</td>
</tr>
</tbody>
</table>

Figure 1. Conditional means of dwell time at each epoch interval plotted at ± 1 SD of PCL Total and Attentional Cuing.
Figure 2. The relationship between T1 PCL Total (posttraumatic stress symptoms) and T2 PCL Total plotted at ± 1 SD of ACS (attentional control) and Dwell (dwell time on threat).
Figure 3. The relationship between T1 PCL Total (posttraumatic stress symptoms) and T2 PCL Total plotted at ± 1 SD of ACS (attentional control) and Pupil (pupillary response to threat).