Threat-Related Attention Bias Variability and Posttraumatic Stress

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Objective: Threat monitoring facilitates survival by allowing one to efficiently and accurately detect potential threats. Traumatic events can disrupt healthy threat monitoring, inducing biased and unstable threat-related attention deployment. Recent research suggests that greater attention bias variability, that is, attention fluctuations alternating toward and away from threat, occurs in participants with PTSD relative to healthy comparison subjects who were either exposed or not exposed to traumatic events. The current study extends findings on attention bias variability in PTSD.

Method: Previous measurement of attention bias variability was refined by employing a moving average technique. Analyses were conducted across seven independent data sets; in each, data on attention bias variability were collected by using variants of the dot-probe task. Trauma-related and anxiety symptoms were evaluated across samples by using structured psychiatric interviews and widely used self-report questionnaires, as specified for each sample.

Results: Analyses revealed consistent evidence of greater attention bias variability in patients with PTSD following various types of traumatic events than in healthy participants, participants with social anxiety disorder, and participants with acute stress disorder. Moreover, threat-related, and not positive, attention bias variability was correlated with PTSD severity.

Conclusions: These findings carry possibilities for using attention bias variability as a specific cognitive marker of PTSD and for tailoring protocols for attention bias modification for this disorder.

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Threat monitoring facilitates survival by allowing one to efficiently and accurately detect and respond to potential threats in the environment. Threat monitoring involves continuous balancing of various cognitive resources and response patterns (1–5). Healthy adaptation requires people to allocate attention to genuine threats in the environment while ignoring other, similar but nonthreatening stimuli. Traumatic events can offset this delicate balance and induce cognitive biases that give rise to threat avoidance and threat-related hypervigilance, among other clinical symptoms (6, 7).

Threat-related attention bias is one of the most consistently demonstrated cognitive correlates of anxiety disorders (8, 9). Nevertheless, research in posttraumatic stress disorder (PTSD) has yielded rather mixed results, with some studies indicating attention bias toward threat (10–14) and others showing attention bias away from threat (12, 15–19). Importantly, attention bias both toward and away from threat is congruent with two primary symptom clusters of PTSD, namely hypervigilance and avoidance/dissociation (20, 21), respectively. These inconsistencies in threat-related attention deployment can be viewed as reflecting "instability" in threat monitoring in PTSD patients.

Considering this apparent instability, Iacoviello and colleagues (22) used a novel approach to quantify threat-related attention biases in PTSD. This approach, termed "attention bias variability," indexes the degree to which attention fluctuates between vigilance and avoidance and is based on reaction time data derived from variants of the classic dot-probe task (23). In this task, pairs of threat and neutral stimuli are simultaneously presented across repeated trials. Each stimulus pair is followed by a target probe appearing at the location of either the threat stimulus (congruent trials) or the neutral stimulus (incongruent trials). An attention bias score is calculated as the difference between the mean reaction times of these two types of trials. Typically, a single bias score is calculated by averaging across all the trials presented throughout the measurement session. In contrast, Iacoviello et al. (22) derived attention bias variability by grouping, or "binning," consecutive 20-trial sequences on the dot-probe task and calculating a bias score for each bin. The standard deviation of the bias scores across bins was then divided by the participant's mean reaction time to generate the measure of attention bias variability for each subject throughout the

session. Results of this study revealed greater attention bias variability in participants with PTSD than in trauma-exposed participants without PTSD and nonexposed healthy participants. Attention bias variability was also positively correlated with PTSD symptom severity. These results suggest that the magnitude of attention bias variability can index the severity of perturbed threat monitoring in PTSD (22, 24, 25).

The current report extends this initial study in two ways. First, we refined the measure of attention bias variability by employing a moving average technique, rather than the previously employed binning method, to generate a more stable index that is influenced less by the number of trials in any particular study. Second, through reanalysis of extant data in seven studies that did not previously measure attention bias variability, we probed four questions regarding the relations between attention bias variability and PTSD:

1. Does high attention bias variability occur exclusively in PTSD, or does it also occur in other forms of anxiety? To test this we compared attention bias variability in patients with PTSD, patients with social anxiety disorder, undergraduates with high levels of trait anxiety, and healthy comparison participants. We also tested whether attention bias variability is uniquely correlated with PTSD symptoms or whether it also correlated with social anxiety symptoms and trait anxiety scores.
2. Are different types of traumatic events associated with disrupted attention bias variability? To address this question, we compared attention bias variability in patients with combat-related PTSD and patients with PTSD related to motor vehicle accidents.
3. Is attention bias variability greater in chronic PTSD than in acute stress disorder following combat exposure?
4. Is the association between attention bias variability and posttraumatic symptoms specific to threat-related stimuli or is it evident for emotional stimuli in general (e.g., positive stimuli).

We examined these issues through secondary analyses of samples of Israel Defense Forces combat veterans diagnosed with chronic PTSD, civilian survivors of motor vehicle accidents who were diagnosed with PTSD, deployed Israel Defense Forces soldiers with acute stress disorder following combat exposure, U.S. Army soldiers following deployment to Afghanistan, patients diagnosed with social anxiety disorder, and two samples of undergraduate students. The samples were compared in terms of attention bias variability as calculated by using data from variants of the dot-probe task (described in the Method section).

METHOD

Samples

Combat PTSD. These participants were 37 male outpatients recruited from the Israel Defense Forces posttrauma treatment unit; their mean age was 36.1 years (SD=12.1, range=22–65). Participants were included if they were diagnosed with PTSD according to a structured clinical interview based on the Clinician-Administered PTSD Scale (CAPS) (26). For all participants, PTSD resulted from traumatic events that occurred in combat at least 3 years prior to assessment; the time from traumatic events ranged from 3 to 40 years (mean=14.1 years, SD=10.1). Trauma-related symptoms were also assessed by using a self-report questionnaire, the PTSD Checklist (27). Participants completed a word-based dot-probe task with 160 trials, similar to the one used by Wald et al. (18, 19). General threat words were used, paired with neutral words with the same number of letters and same frequency of usage in the Hebrew language. Word pairs were presented for 500 ms.

PTSD related to motor vehicle accidents. These participants were 28 motor vehicle accident survivors with PTSD; 12 were men, and the mean age was 34.8 years (SD=11.5, range 19–62). Participants were diagnosed 3 months after the traumatic event by using the CAPS interview (see 28) and completed a word-based dot-probe task with 100 trials. General threat words were used, paired with neutral words with the same number of letters and same frequency of usage in the Hebrew language. Word pairs were presented for 1,000 ms. Self-reported PTSD symptoms were also assessed by using the PTSD Checklist (27).

Combat acute stress disorder. This sample consisted of 41 Israel Defense Forces male infantry soldiers who were exposed to combat and had PTSD Checklist scores above 50 on surveys collected during deployment (see 29); their mean age was 18.4 years (SD=0.6, range 18–20). A PTSD Checklist score above 50 is considered a strict clinical cutoff for PTSD symptoms (27). PTSD Checklist scores and threat-related attention bias were measured during combat deployment in the field and thus reflect acute stress disorder rather than chronic PTSD. These participants completed a word-based dot-probe task with 152 trials. General threat words were used, paired with neutral words with the same number of letters and same frequency of usage in the Hebrew language. Word pairs were presented for 1000 ms.

U.S. Army soldiers. These participants were 83 U.S. Army soldiers (65 men) from a U.S. Army National Guard transportation company who took part in the study following their deployment to Afghanistan. The sample varied widely in age (18–24 years: 32.5%; 25–29 years: 36.3%; ≥30 years: 31.3%). It comprised primarily enlisted soldiers (E1–E4: 56.9%; E5–E9: 36.9%) with a mean of 8.0 years in service (SD=6.2). Trauma-related symptoms were assessed 6 months after combat deployment, by means of the PTSD Checklist (27). These soldiers were not diagnosed with PTSD or with acute stress disorder but had been exposed to potentially traumatic events during their deployment. Participants completed a face-based dot-probe task with 120 trials (see 30) using stimuli from the NimStim stimulus set (31). The dot-probe variant

used included both neutral-angry and neutral-happy trials, which were intermixed in presentation. Separate indices of attention bias variability were calculated for the two trial types. Face pairs were presented for 500 ms.

Social anxiety disorder. These participants were 91 patients with social anxiety disorder diagnosed according to the Mini-International Neuropsychiatric Interview (MINI) (32) and the semistructured Liebowitz Social Anxiety Scale Interview (33). Their mean age was 31.7 years (SD=8.1, range=18–57), and the group contained 53 men. These participants completed a face-based dot-probe task with 120 trials, similar to the one used by Bechor et al. (34), using stimuli from the NimStim stimulus set (31). Face pairs were presented for 500 ms.

Normative and highly anxious undergraduates. The normative sample consisted of 70 Tel Aviv University undergraduate students; 51 were women, and their mean age was 22.9 years (SD=2.0, range=19–28). Their mean trait anxiety score was 37.4 (SD=6.1, range=29–50) on the Spielberger State-Trait Anxiety Inventory (35). The sample with high trait anxiety consisted of 21 undergraduate students with high trait anxiety scores (mean=56.1, SD=3.9, range=50–64); the group contained 14 women and had a mean age of 23.3 years (SD=2.1, range=19–27). The participants completed two sessions of a face-based dot-probe task, exactly 1 week apart. The dot-probe task consisted of 120 face stimuli trials and use of stimuli from the NimStim stimulus set (31); it was similar to the task used by Bechor et al. (34). Face pairs were presented for 500 ms.

General Method

For all the seven samples, attention bias variability was calculated according to the same procedure (described in the following) with data collected by using variants of the dot-probe task. Trauma-related and anxiety symptoms were evaluated across samples by using structured psychiatric interviews and widely used self-report questionnaires, as specified in the descriptions of each study sample.

The Dot-Probe Task

The dot-probe task is frequently used to assess attention biases toward or away from threat stimuli (9, 23). All samples used the same basic task. Each trial began with a fixation sign. Fixation was replaced by a pair of cue stimuli (either two words or two faces), one emotion-laden and one neutral. Following presentation of the cue stimuli, a target probe appeared in the location previously occupied by one of the stimuli, and participants had to discriminate the probe type (e.g., "<" or ">"). In all samples the probe remained on the screen until the participant responded, after which the next trial began. Participants were instructed to focus their attention on the fixation sign at the start of each trial and, when the probe appeared, to identify its type as quickly as possible without compromising accuracy. Across studies, stimuli were presented and data were collected by using E-Prime software (Psychology Software Tools, Pittsburgh).

Attention Bias Variability

In accord with common practice for tasks relying on reaction time data, before calculating attention bias variability we removed trials in which participants appeared not to adhere to standard task requirements. Specifically, we first excluded trials with incorrect responses or trials in which reaction time was extremely short (<150 ms, reflecting anticipatory response) or long (>2,000 ms, reflecting possible lapses in task performance). Then, outlier trials in which the reaction time was outside ±2.5 standard deviations of the participant's mean were also excluded.

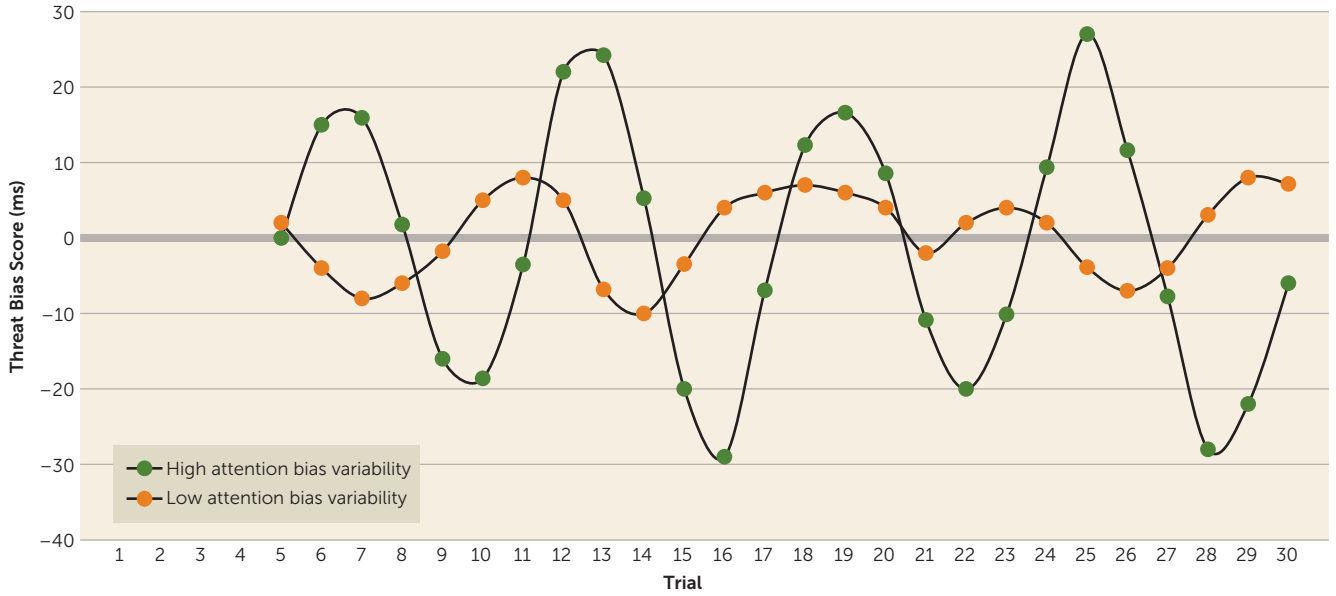
Individual attention bias variability score for the remaining trials was calculated in four steps: 1) a trial-by-trial moving average algorithm computed mean reaction times for all successive 10 neutral trial blocks and all successive 10 threat trial blocks, 2) successive attention bias scores were calculated by subtracting the first threat block average from the first neutral block average, the second threat block average from the second neutral block average, etc., forming a series of consecutive attention bias scores, 3) the standard deviation of these successive bias scores was then calculated, providing an index of variation in attention bias throughout the session, and 4) this standard deviation score was divided by the participant's mean overall reaction time to control for associations between mean and variance. Attention bias variability reflects the within-session variability in threat-related attention bias, normalized to individual task performance (see Figure 1) (22).

Attention bias variability is a novel measure, and we know of no reports of test-retest reliability. Attention bias variability is conceptualized as reflecting natural plasticity built into the threat-monitoring system that is influenced by different contexts and situations, rather than indexing a stable trait. Therefore, one would expect some, but not robust, stability. Similar expectancies are typically voiced in relation to constructs such as state anxiety (35). We examined test-retest reliability in a normative sample of undergraduate students and in Israel Defense Forces veterans with PTSD. In both samples, two attention bias variability measurements were taken 1 week apart, with the same task and same procedures—the face-based task and the word-based task for the undergraduate students and the Israeli veterans with PTSD, respectively. These analyses revealed significant but modest test-retest reliability in the undergraduate sample (r=0.29, N=70, p=0.02) (Figure 2A) and a slightly higher retest reliability in the PTSD sample (r=0.40, N=26, p=0.04) (Figure 2B).

Data Analysis

To assess differences between samples in terms of attention bias variability, we used one-way analyses of variance (ANOVAs) followed by Tukey post hoc tests or, when contrasting just two samples, independent-sample t tests. Pearson correlation coefficients were calculated to evaluate

FIGURE 1. High and Low Attention Bias Variability As Computed by a Moving Average of Attention Bias Scores Throughout the Dot-Probe Task



associations between attention bias variability and symptom scores. All tests were two-sided with alpha=0.05.

RESULTS

Specificity of High Attention Bias Variability to PTSD

We examined whether high attention bias variability is associated specifically with PTSD by comparing the scores for attention bias variability in the social anxiety disorder sample, the normative and highly anxious undergraduate samples, the healthy combat-exposed U.S. Army soldiers, and the combined pool of clinical PTSD samples (combat PTSD and motor vehicle accident PTSD), as shown in Figure 3A. One-way ANOVA revealed a significant group effect ($F=14.41$, $df=4, 322$, $p<0.0001$). Tukey post hoc tests indicated that the PTSD group had higher attention bias variability (mean=0.09, SD=0.04) than the social anxiety disorder group (mean=0.06, SD=0.03), the sample with high trait anxiety (mean=0.06, SD=0.02), the normative undergraduate sample (mean=0.06, SD=0.02), and the healthy combat-exposed U.S. Army soldiers (mean=0.06, SD=0.03) (in all cases, $p<0.001$). The social anxiety disorder, high trait anxiety, normative undergraduate, and healthy Army samples did not differ in attention bias variability (in all cases, $p>0.27$).

Within the PTSD sample, higher attention bias variability was associated with greater PTSD symptom severity, as rated by either the PTSD Checklist ($r=0.37$, $N=65$, $p=0.002$) or the CAPS ($r=0.45$, $N=65$, $p=0.001$) (see Figures 3B and 3C for respective scatter plots). Nonsignificant correlations were found between attention bias variability and social anxiety symptoms (rated on the Liebowitz Social Anxiety Scale) in the social anxiety disorder sample ($r=0.05$, $N=90$, $p=0.67$). In addition, correlations between attention bias variability and trait anxiety were not significant in the group with high trait anxiety ($r=0.24$, $N=21$, $p=0.28$) and the normative undergraduate sample ($r=0.17$, $N=70$, $p=0.17$).

Do Different Traumatic Events Produce Different Magnitudes of Attention Bias Variability?

We compared attention bias variability in the patients with combat PTSD and the motor vehicle accident survivors with PTSD by using an independent-sample t test. There was no significant difference in attention bias variability ($t=1.68$, $df=63$, $p=0.10$) between the combat group (mean=0.10, SD=0.04) and the accident survivors (mean=0.08, SD=0.03). This suggests that different traumatic events leading to a PTSD diagnosis do not necessarily yield different magnitudes of attention bias variability (Figure 4). This pattern held when we controlled for symptom severity, based on the CAPS total score, as a covariate in the analysis ($F=0.83$, $df=1, 62$, $p=0.37$). Furthermore, both PTSD samples differed from the normative undergraduate sample (combat versus normative: $t=3.97$, $df=96$, $p<0.001$; accident versus normative: $t=6.22$, $df=105$, $p<0.001$).

We also examined correlations between attention bias variability and PTSD symptoms within the two samples separately. In the combat PTSD sample, greater attention bias variability was associated with more severe symptoms on the CAPS ($r=0.45$, $N=37$, $p=0.007$). A nonsignificant trend-level correlation was found in the motor vehicle accident PTSD sample ($r=0.36$, $N=28$, $p=0.06$). The magnitude of the two correlations did not differ significantly (Fisher's r-to-z=0.41, $p=0.68$).

Is Attention Bias Variability Different in Combat-Related PTSD and Combat-Related Acute Stress Disorder?

To examine this we compared attention bias variability in the Israeli Defense Forces combat-exposed groups with

FIGURE 2. Attention Bias Variability 1-Week Test-Retest Correlations in a Normative Sample of Undergraduate Students and a Group of Veterans With PTSD

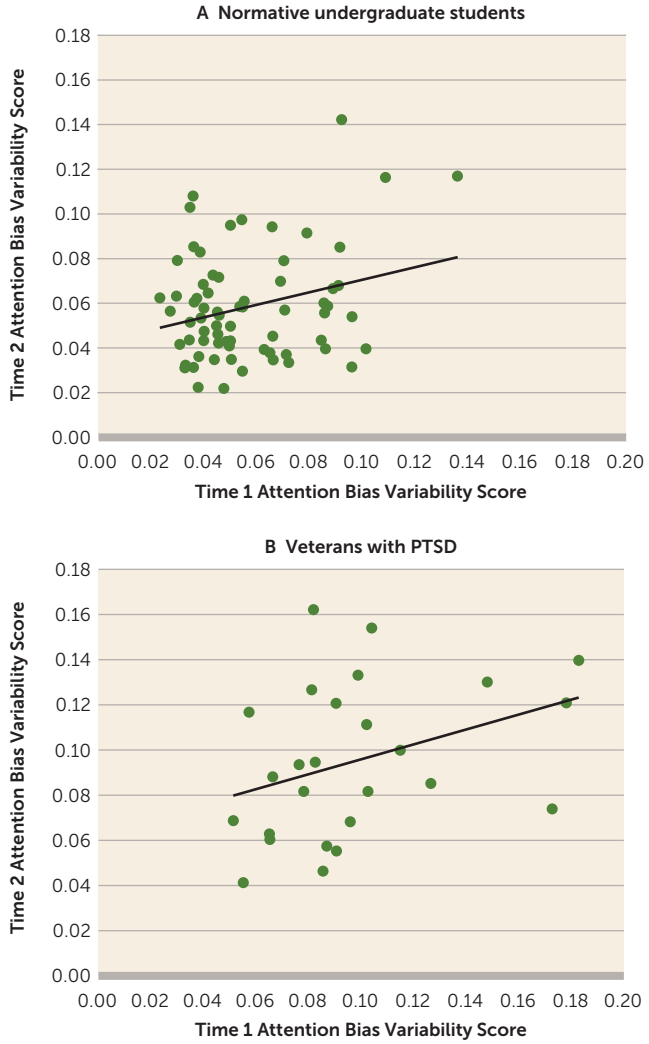
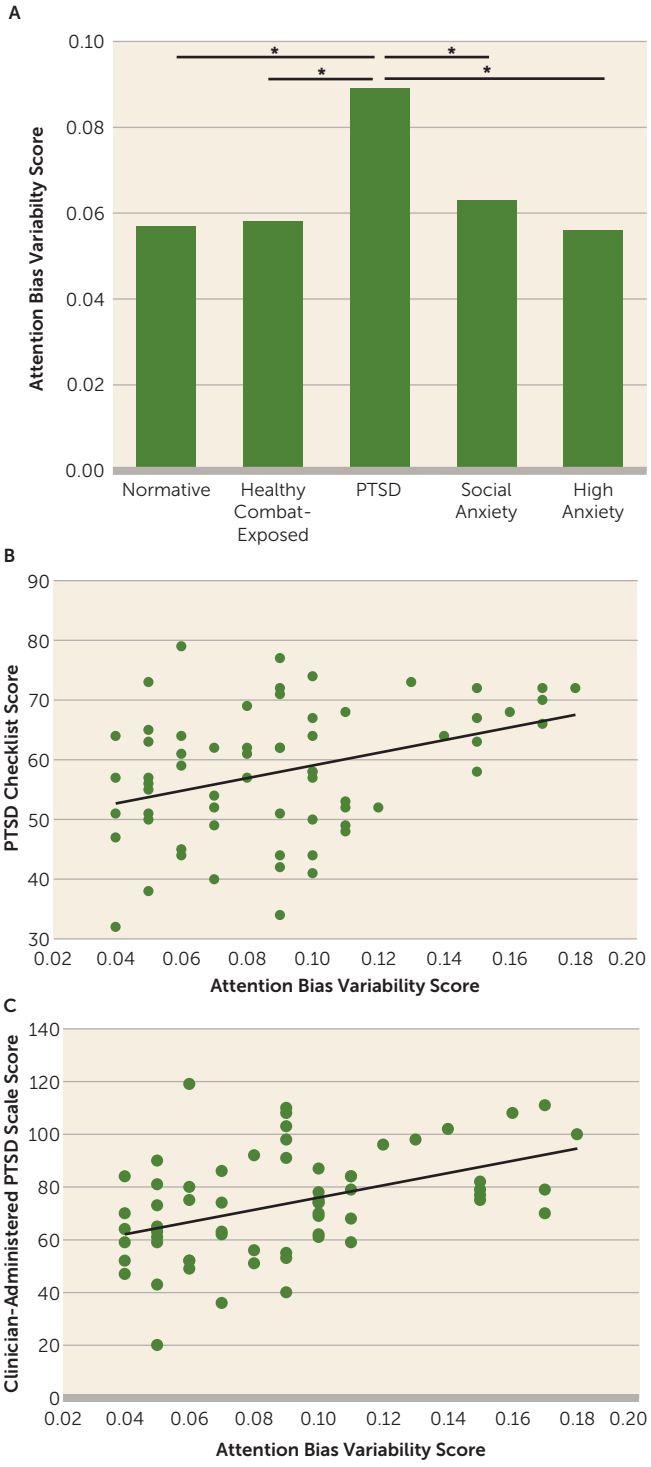


FIGURE 3. Attention Bias Variability in Five Samples and Relation to Scores on Self- and Clinician-Administered PTSD Scales[a]



[a] The groups represented in part A were normative undergraduates, healthy combat-exposed U.S. Army soldiers, PTSD patients, patients with social anxiety disorder, and undergraduates with high levels of trait anxiety.
*p<0.001.

PTSD and with acute stress disorder. An independent-sample t test revealed higher attention bias variability for combat-related PTSD (mean=0.09, SD=0.04) than for combat-related acute stress disorder (mean=0.07, SD=0.03) (t=3.38, df=61, p=0.001) (Figure 5). The two samples differed in age, with older participants in the combat PTSD sample (t=9.02, df=76, p<0.001), and in symptom severity, with higher PTSD Checklist scores in the PTSD sample (t=2.05, df=76, p=0.04). Consequently, we conducted an ANCOVA with age and PTSD Checklist scores as covariates to control for these differences. This analysis yielded the same result: higher attention bias variability for combat PTSD than for combat acute stress disorder (F=7.60, df=1, 74, p=0.007).

We tested the correlation between attention bias variability and PTSD Checklist score for each of the samples separately. A significant correlation was observed in the combat PTSD sample (r=0.40, N=37, p=0.01) but not in the combat acute stress disorder sample (r=0.04, N=41, p=0.80), with a significant difference in the magnitude of the two correlations (Fisher's r-to-z=1.63, p=0.05).

Is the Association Between Attention Bias Variability and Posttraumatic Symptoms Specifically Related to Threat?

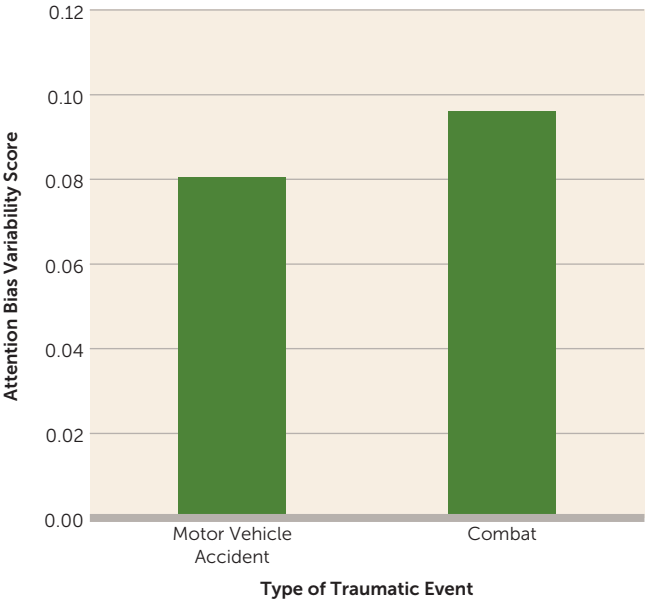
To address this question, we calculated threat-related attention bias variability (angry faces) and positive attention bias variability (happy faces) in the sample of healthy combat-exposed U.S. Army soldiers returning from deployment to Afghanistan. The dot-probe variant used in this sample included both neutral-angry and neutral-happy trials, and attention bias variability was calculated separately for each trial type by using the same methods described above. Paired-sample t tests comparing threat-related attention bias variability (mean=0.06, SD=0.03) and positive attention bias variability (mean=0.06, SD=0.03) indicated no difference in the magnitudes of the two scores (t=0.97, df=79, p=0.33). Threat-related and positive attention bias variability were significantly and modestly correlated (r=0.30, N=80, p=0.006). Importantly, however, greater threat-related attention bias variability was associated with more severe PTSD symptoms as measured with the PTSD Checklist (r=0.32, N=69, p=0.008), whereas positive attention bias variability did not correlate significantly with PTSD symptoms (r=0.07, N=69, p=0.56). A Fisher's r-to-z test indicated a significant difference between the magnitudes of these two correlations (z=2.31, p=0.02).

DISCUSSION

The analyses presented here extend our understanding of attention bias variability and its applicability as a cognitive marker of aberrant attentional processes in PTSD. First, as for the question of whether elevated attention bias variability occurs exclusively in PTSD, analyses revealed elevated attention bias variability in patients with PTSD relative to patients with social anxiety disorder and to undergraduate students with high trait anxiety, with higher attention bias variability associated with greater PTSD symptom severity only in the PTSD samples. Second, similar attention bias variability magnitudes were observed for PTSD caused by different traumatic events. Third, attention bias variability was elevated in veterans with PTSD relative to soldiers with acute stress disorder, with the latter displaying a magnitude of attention bias variability similar to that of the non-PTSD samples. Finally, threat-related attention bias variability, and not positive attention bias variability, was correlated with PTSD severity. These data extend the findings of Iacoviello et al. (22), who first reported an association between attention bias variability and PTSD, in a number of important ways.

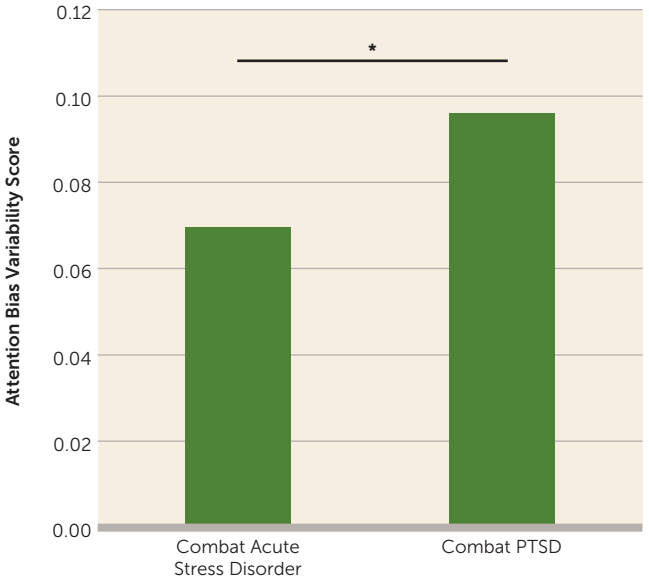
Evidence of greater attention bias variability in individuals with PTSD relative to social anxiety disorder, acute stress disorder, high trait anxiety, and normative samples suggests specificity of elevated attention bias variability in PTSD. Attention bias toward threat occurs in anxiety disorders and among individuals with elevated trait anxiety (9). In contrast, increased variability between bias toward and away from threat (attention bias variability) occurs only in PTSD, not in social anxiety disorder or acute stress disorder or among individuals with elevated trait anxiety. This could reflect a unique pattern of attention allocation among individuals who manifest persistent PTSD symptoms after a life-threatening traumatic event. On the one hand, confronting a traumatic event may evoke extreme allocation of attentional resources toward threat stimuli in a way that hinders the ability to suppress fear responses, even when the individual is already in a safe context (for instance, see references 36 and 37). On the other hand, traumatic events can induce

FIGURE 4. Attention Bias Variability for PTSD Related to Motor Vehicle Accidents and to Combat[a]



[a] The difference was not statistically significant.

FIGURE 5. Attention Bias Variability in Combat-Related Acute Stress Disorder and Combat-Related PTSD



* p=0.001.

attentional avoidance of trauma-related stimuli, providing a momentary relief from overwhelming anxiety (see references 18 and 19). These conflicting response patterns, occurring simultaneously during a traumatic event, might challenge the delicate attentional balance normally kept by the human threat-monitoring system.

Indeed, previous studies show that PTSD may involve malfunction of different attentional processes related to fear inhibition (38, 39) or may involve impaired attention control (24). A review of executive function in PTSD indicated that attention regulation and response inhibition are among the most robust deficits experienced by patients with PTSD (24). From this perspective, attention bias variability may reflect the conflict between threat-related attentional hypervigilance and attention suppression, revealed as attention dysregulation. Such perturbations at the attentional level may then be transformed to chronic avoidance and arousal symptoms, appearing concurrently in PTSD. However, in the case of attention bias variability, it is important to underscore the finding that only threat-related attention bias variability, and not positive attention bias variability, was related to PTSD symptom severity, suggesting specificity rather than a more general executive function deficit. Further work examining relations among valence-specific measures of attention bias variability and measures of response inhibition may clarify the factors that produce perturbed attention bias variability in PTSD.

Iacoviello et al. (22) reported elevated attention bias variability in a combat-related PTSD sample and in an urban civilian population with PTSD not related to combat trauma (e.g., physical assault, accident, witnessing death or violence). The current findings replicated those of elevated attention bias variability in combat-related PTSD in a different sample of soldiers, and they extended the finding of elevated attention bias variability in patients with PTSD after a motor vehicle accident, which is one of the most common events leading to PTSD (40). Taken together, elevated attention bias variability across different PTSD samples emphasizes the potential value of attention bias variability as a general cognitive marker for PTSD acquired through different types of traumatic contexts.

The current findings also revealed higher attention bias variability in PTSD relative to acute stress disorder. In addition, elevated attention bias variability was associated with trauma-related symptoms in PTSD, but not in acute stress disorder. These results further highlight the specificity of attention bias variability to PTSD, but they also potentially suggest that increased attention bias variability in PTSD develops over time and is related to greater severity and chronicity of symptoms. Stress symptoms typically reside in most people who are exposed to potentially traumatic events. Yet a PTSD diagnosis is made only after a more prolonged period. In the same manner, so are threat-related attention fluctuations that may become more rooted and accentuated with time in certain individuals. Because the majority, but not all, of individuals with acute stress disorder subsequently develop PTSD (41), more studies are needed to explore the longitudinal trajectory of elevated attention bias variability, possibly by comparing individuals diagnosed with acute stress disorder who eventually develop PTSD to individuals with acute stress disorder who do not develop PTSD by means of a within-between study design. It would also be interesting to test whether attention bias variability is normalized following effective treatment of PTSD.

Finally, the results indicate that the association between attention bias variability and posttraumatic symptoms is specific to threat-related stimuli and is not evident for positive stimuli. These results are in line with theories suggesting increased activation for threat stimuli in PTSD (for example, see reference 42). However, current interpretation of positive attention bias variability findings in PTSD must proceed with caution because of the lack of important comparison groups. There is literature showing that for anxious individuals, attention orienting to positive stimuli is different from that for threat-related stimuli. For threat-related stimuli, only anxious but not healthy individuals show the classic threat bias. For positive stimuli, positive biases seen in healthy individuals are typically attenuated in anxiety (for a review, see reference 43). More studies are needed to further explore the dynamics of positive attention bias variability in PTSD relative to positive attention bias variability in normative and other anxious populations.

The current data also carry implications for recent findings on attention bias modification treatments (44, 45). Attention bias modification treatments systematically manipulate threat-related attention biases in anxious populations, traditionally targeting a specific attentional bias toward threat in anxiety disorders. Considering the apparent variability of attention biases in patients with PTSD and the lack of clear-cut evidence for an attention bias in a specific direction in PTSD, future studies may consider the development of treatments targeting normalization of attention bias variability instead. Indeed, two recent randomized controlled trials in Israeli and U.S. Armed Forces combat veterans with PTSD indicated that computerized attention control treatment designed to normalize fluctuations in threat-related attention was efficacious in reducing PTSD symptoms and that symptom reduction was mediated by reduction in attention bias variability (46).

While the neural substrates of attention bias variability are still unknown, studying its neural networks and their perturbed function in PTSD could further highlight potential targets for intervention. Neuroimaging studies in PTSD reveal consistent hyperactivation within limbic regions (particularly the amygdala and insula) and hypoactivation of prefrontal regions, which are involved in enhanced attention toward triggers associated with traumatic material (e.g., the anterior cingulate), and regions thought to be primarily involved in inhibition of responses to emotional stimuli and decreased attention control (e.g., the ventromedial prefrontal cortex) (for reviews and a meta-analysis, see references 47–49). Perturbations in this neural architecture and the interconnectivity between its different components could

serve as preliminary candidates for investigation of the neural underpinnings of elevated attention bias variability in PTSD.

The current report should also be viewed in light of potential limitations. First, the results presented here are based on secondary analyses of samples from different studies; thus, inherently, the samples were not fully matched, and there were subtle differences among the dot-probe tasks employed for the different samples. However, in-depth analyses suggest that these differences in task characteristics did not affect the reported findings. Thus, the current outcomes appear to reflect repeated and robust evidence of elevated attention bias variability in PTSD under diverse traumatic circumstances and populations and when measured with different variants of the dot-probe task, suggesting robustness and generalizability. However, future studies addressing the association between attention bias variability and PTSD through a priori hypotheses and preplanned studies could better control for experimental and population factors in order to provide a better estimate of the actual effect size of the elevated attention bias variability in PTSD.

Second, in the currently analyzed PTSD samples, the stimuli were not specifically tailored to the traumatic event types experienced by the participants. A recent meta-analysis indicates that threat-related attention bias is stronger in PTSD when specific trauma stimuli are used in measurement (50). Future studies could test whether such content specificity is associated with even more elevated attention bias variability in PTSD patients. Additionally, the current samples differed on stimulus presentation durations. Stimulus presentation times in the dot-probe task could tap into different subcomponents of attention (e.g., capture, disengagement, inhibition of return) and thus could affect the interpretation of the mechanism of attentional fluctuations indexed by attention bias variability. While the current results indicate no differences in attention bias variability and in the pattern of correlation between attention bias variability and PTSD symptoms in two samples whose stimuli were presented for 500 ms (combat PTSD) and 1000 ms (motor vehicle accident PTSD), future studies could manipulate stimulus presentation times and perhaps use alternative paradigms to shed light on this issue.

In conclusion, our findings offer a new perspective on threat-related attention processes in PTSD, suggesting elevated attention bias variability as a marker of this psychopathology. Furthermore, attention bias variability can be easily calculated and offers a new approach to data analysis of attention bias tasks, looking at fluctuations in attention while monitoring threat over time in addition to giving a single read of attention bias directionality. Importantly, attention bias variability could be calculated by using extant dot-probe data in order to address a variety of critical questions related to PTSD as well as other psychopathologies.

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