Journal of Traumatic Stress
April 2014, *27*, 232–239

ISTSS International Society for Traumatic Stress Studies

Attention Bias Variability and Symptoms of Posttraumatic Stress Disorder

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Cognitive theories implicate information-processing biases in the etiology of anxiety disorders. Results of attention-bias studies in posttraumatic stress disorder (PTSD) have been inconsistent, suggesting biases towards and away from threat. Within-subject variability of attention biases in posttraumatic patients may be a useful marker for attentional control impairment and the development of posttrauma symptoms. This study reports 2 experiments investigating threat-related attention biases, mood and anxiety symptoms, and attention-bias variability following trauma. Experiment 1 included 3 groups in a cross-sectional design: (a) PTSD, (b) trauma-exposed without PTSD, and (c) healthy controls with no trauma or Axis I diagnoses. Greater attention-bias variability was found in the PTSD group compared to the other 2 groups ($\eta_p^2 = .23$); attention-bias variability was significantly and positively correlated ($r = .37$) with PTSD symptoms. Experiment 2 evaluated combat-exposed and nonexposed soldiers before and during deployment. Attention-bias variability did not differentiate groups before deployment, but did differentiate groups during deployment ($\eta_p^2 = .16$); increased variability was observed in groups with acute posttraumatic stress symptoms and acute depression symptoms only. Attention-bias variability could be a useful marker for attentional impairment related to threat cues associated with mood and anxiety symptoms after trauma exposure.

Posttraumatic stress disorder (PTSD) is an anxiety disorder that follows exposure to a traumatic event. Cognitive theories suggest that early, automatic information-processing biases, particularly for threat, play a central role in the etiology and maintenance of anxiety disorders (Bar-Haim, 2010). Consistent with these theories, hypervigilance often occurs after trauma. Some studies, using cognitive paradigms, have found signs of hypervigilance manifest as attention biased toward threat cues (e.g., Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Dalgleish, Moradi, Taghavi, Neshat-Doost, & Yule, 2001) or greater interference of negative emotional stimuli on attention (e.g., Pineles, Shipherd, Welch, & Yovel, 2007; Vythilingam et al., 2007). Avoidance of threat-related stimuli, however, is also a hallmark of PTSD, and some studies associate suppression of attentional biases, or attention biased away from threat, with PTSD symptoms (e.g., Bar-Haim et al., 2010; Wald, Lubin, et al. 2011; Wald, Shechner, et al. 2011). Studies of other anxiety disorders have demonstrated robust and immediate attention biases toward threat (see Bar-Haim et al., 2007), whereas in PTSD, biased attention toward and away from threat has been demonstrated, and it has been shown that attention biases toward threat-related stimuli become inhibited under threat of exposure to a mildly threatening event (i.e., watching a combat video; Constans, McCloskey, Vasterling, Brailey, & Mathews, 2004). Thus, questions remain concerning the degree, direction, and stability of attention biases for threat associated with PTSD.

Impaired attentional or cognitive control for emotionally salient information could explain instability of attention biases in PTSD. A recent review of executive function in PTSD determined that attention regulation and response inhibition are

The first three authors contributed equally to the study and preparation of this article.

This work was supported in part by The Leo and Julia Forchheimer Foundation in collaboration with the Mount Sinai School of Medicine.

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DOI: 10.1002/jts.21899

among the most robust deficits and are associated with symptom severity (Aupperle, Melrose, Stein, & Paulus, 2012), although this did not include review of all cognitive domains. Ode, Robinson, and Hanson (2011) showed reaction time (RT) variability on attention tasks was associated with less effective cognitive control and proneness to negative emotional states. Across various diagnostic groups, attention variability is a marker for the efficiency of top-down attentional control (Epstein et al., 2011; Kaiser, Roth, Rentrop, Friederich, Bender, & Weisbrod, 2008; Vaurio, Simmonds, & Mostofsky, 2009). Therefore, attention-bias variability, or within-subject variability of attention biases toward and away from threat during an attention-bias assessment, might explain the seemingly conflicting findings of studies reporting biases toward, and others reporting biases away from, threat-cues in PTSD. Attention bias variability could also represent a robust indicator of attentional impairment in PTSD, compared to attention-bias scores.

General Method

Overview

Two experiments were conducted to investigate attention-bias variability, using the dot-probe paradigm (MacLeod, Mathews, & Tata, 1986), in different cultural contexts and in samples with different symptom chronicity. Experiment 1 was conducted in the United States and involved a cross-sectional study of the associations between attention-bias variability and PTSD symptoms in three groups: (a) a medication-free PTSD sample, (b) a trauma-exposed but non-PTSD sample, and (c) a healthy comparison sample. In Experiment 2, attention-bias variability was evaluated before and during deployment in Israeli Defense Forces (IDF) male combat soldiers to investigate whether attention-bias variability predated acute posttraumatic stress symptoms or if increased attention-bias variability occurred following trauma exposure and in association with acute symptoms. Participants were selected for three groups, analogous to Experiment 1: (a) those who experienced combat trauma and evidenced high acute posttraumatic stress symptoms; (b) those who experienced combat trauma, but did not evidence acute posttraumatic stress symptoms; and (c) those who did not experience combat trauma and did not evidence acute symptoms. In addition, the specificity of attention-bias variability to posttraumatic stress symptoms was investigated by analyzing an additional group that developed depression, but not posttraumatic stress symptoms.

Procedure

The dot-probe task (Bar-Haim et al., 2007; MacLeod et al., 1986) measures attention biases toward or away from threatening stimuli. The task comprises 160 trials beginning with a fixation cross ("+") presented in the center of the screen for 500 milliseconds (ms), after which two words in size 12 Arial font immediately appeared for 500 ms, one above and one below the location of the fixation cross, separated by 1.5 centimeters. Following the words, a target probe (letter E or F) appeared in the location occupied by one of the words, and remained until participants responded. Participants were instructed to identify the probe using a designated mouse button as quickly as possible. There were 128 trials that included one threat and one neutral word; 32 trials included two neutral words. Stimuli were 32 trauma-related and 64 neutral words, selected from a list developed by MacLeod, Rutherford, Campbell, Ebsworthy, and Holker (2002) for salience to traumatic life events (e.g., "harm," "suffer"). Word pairs were matched for first letter, number of letters, and frequency of usage in the English language (MacLeod et al., 2002) and presented in random order using E-Prime 2.0 software (Psychology Software Tools, Inc., 2012).

To calculate attention bias, RTs from the threat-neutral trials were analyzed. Keeping with standard practice for maintaining data integrity for this task, trials with an incorrect response or in which the RT was extremely short ($<$150 ms) or long ($>$2000 ms) were excluded, as were trials in which RT was outside $\pm$ 2 *SD*s of the participant's mean for each of the two conditions (probes behind threat words or neutral words; O'Toole & Dennis, 2012; Roy et al., 2008). Attention bias was calculated as the difference between mean RT to probes behind neutral words and threat words. Attention bias toward threat is indicated when the mean RT to threat words is shorter than to neutral words, the opposite reflects attention bias away from threat.

To calculate attention-bias variability, dot-probe trials were split into eight sequential bins, and attention-bias scores were calculated for each bin. The *SD* of attention-bias scores across bins was calculated and divided by mean RT to correct for variance in RTs (Epstein et al., 2011; Ode et al., 2011). The resulting attention-bias variability score provides an index of within-session stability of attention biases.

Experiment 1

Experiment 1 involved a cross-sectional study of participants in the United States to elucidate associations between trauma exposure, attention-bias variability, and PTSD symptoms. We hypothesized that participants with a PTSD diagnosis would demonstrate greater attention-bias variability for threat cues compared to participants in the other groups, and that attention-bias variability would positively correlate with mood and anxiety symptoms.

Method

Participants. Participants were recruited through flyers, online advertisement, and the outpatient Mood and Anxiety Disorders Program at Icahn School of Medicine at Mount Sinai, New York. Participants aged 18–60 years were eligible if they spoke English as their first language, had no substance abuse or dependence within 6 months, no current psychotherapy or psychiatric medication treatment, and met appropriate criteria

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following a psychiatric diagnostic interview. The criteria included (a) for the healthy control group, no history of traumatic life events or Axis I diagnosis; (b) for the trauma control group, at least one traumatic life event qualifying as Criterion A for a PTSD diagnosis according to the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed. Text Revision *DSM-IV-TR*; American Psychiatric Association, 2000), but no history of PTSD diagnosis and no other Axis I diagnosis; and (c) for the PTSD group, current diagnosis of PTSD, with other Axis I diagnoses were permitted if PTSD was the primary Axis I diagnosis. The sample included the first 33 healthy controls, 10 trauma controls, and 30 PTSD participants who met enrollment criteria.

Measures. Diagnostic interviews were conducted using the Structured Clinical Interview for DSM-IV Axis I Disorders (SCID- I/P; First, Spitzer, Gibbon, & Williams, 2002). Clinician-rated measures of anxiety and depression symptoms included the Hamilton Anxiety Rating Scale (HAM-A; Hamilton, 1959) and Hamilton Depression Rating Scale (HAM-D-17; Hamilton, 1960). The HAM-A is a 14-item assessment of the severity of anxiety symptoms over the past week on a 0 = *not present* to 4 = *very severe* scale; total scores range from 0 to 56. Cronbach's α for this assessment in this sample was .92. The HAM-D-17 is a 17-item assessment of the severity of depression symptoms over the past week on a 0 = *not present* to 4 = *very severe* scale; total scores range from 0 to 68. Cronbach's α for this assessment in this sample was .95. The Clinician Administered PTSD Scale (CAPS; Blake et al., 1995) was also administered to rate the severity of PTSD symptoms. The CAPS is a 17-item structured interview corresponding to the *DSM-IV-TR* criteria for PTSD. Frequency and intensity scores, ranging from 0 = *not present* to 4 = *very severe* are given for each symptom; total scores range from 0 to 136. A cutoff score > 40 was required for participation in the PTSD group to ensure at least moderate severity of PTSD symptoms. Cronbach's α for this assessment in this sample was .93. Raters for all assessments were primarily medical doctor- and doctoral-level, and occasionally masters- and bachelors-level trained clinical raters working in the same mood and anxiety disorders program. Raters all received extensive training on the assessments until the team of raters demonstrated a two-way mixed, absolute-agreement, single-measures intraclass correlation coefficient > .80 on each assessment. Urine toxicology tests were conducted to ensure participants were free of substances that may influence cognitive functioning. Tests utilized Reditest RediCups® (Redwood Toxicology Laboratory, Santa Rosa, CA) to screen for methamphetamine, cocaine, marijuana, opiates, and benzodiazepines.

Procedure. All study procedures were preapproved by the Program for the Protection of Human Subjects at Mount Sinai School of Medicine. After providing written consent to participate, participants underwent a diagnostic interview (SCID) and urine drug test, and were administered clinician-rated measures (HAM-A, HAM-D, CAPS). Participants then completed the dot-probe attention-bias assessment. Participants were compensated $40 for travel expenses and their time.

Data analysis. Attention-bias variability was compared across groups using a one-way ANOVA. Fisher's least significant difference (LSD) tests were planned to explicate between-group differences. To investigate associations between attention-bias variability and mood or anxiety symptoms, Pearson's correlations were calculated. All tests were two-sided with $\alpha = .05$. Considering the relatively small and unequal sample sizes, power to detect significant differences was a concern, so effect sizes were calculated in addition to *p* values. Corrections for multiple comparisons were not made for the follow-up tests, as Fisher's LSD with three groups following an omnibus ANOVA maintains the family-wise error rate at $\alpha = .05$.

Results

Table 1 presents the demographic and clinical characteristics of the sample. There were no significant differences between groups in age, gender, or ethnicity (*p*s > .439). The degree of trauma exposure was similar between trauma control and PTSD groups. No significant difference in time since the index trauma was found between groups, $t(37) = -0.21$, $p = .839$. Chi-square analysis of category of trauma (physical assault—sexual assault, domestic violence, and other noncombat trauma; accident—motor vehicle accident, building fire, and near drowning; and witnessing death or serious violence to another) revealed no significant difference between the trauma control and PTSD groups, χ^2 (2, $N = 40$) = 1.82, $p = .401$. Twenty percent of participants in the trauma control and PTSD groups experienced recurrent traumatic events. The groups differed in regard to psychiatric comorbidities. No Axis I diagnoses were allowed for the healthy control or trauma control groups, but the PTSD group could have lifetime comorbidities, which included major depressive disorder (63.3%), social phobia (16.7%), specific phobia (6.7%), eating disorder (6.7%), obsessive–compulsive disorder (3.3%), and past history of substance dependence (20.0%).

Results from the symptom and attention measures are also reported in Table 1. The trauma control group demonstrated statistically significantly higher scores on all symptom measures compared to the healthy control group, and the PTSD group demonstrated significantly higher scores on all symptom measures compared to trauma control and healthy control groups. Task RTs in threat trials and neutral trials, attention-bias scores, and attention-bias variability scores did not differ from the normal distribution (Shapiro-Wilk test, *p*s > .201). There were no significant differences in RT between the groups. In calculating attention bias, on average 3.3% of trials were excluded per participant for falling outside 2 *SD*s of the mean; there were no significant differences between groups in the number of trials excluded, $F(2, 70) = 0.48$, $p = .624$. ANOVA of attention bias indicated no significant differences between groups,

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Table 1
Experiment 1: Demographic, Clinical, and Attention Characteristics

	Healthy control ($n = 33$)		Trauma control ($n = 10$)		PTSD ($n = 30$)	
Variable	*M* or *n*	*SD* or %	*M* or *n*	*SD* or %	*M* or *n*	*SD* or %
Age (years)	36.76	8.67	36.60	9.51	34.93	11.13
Gender (female)	19	42.4	7	70.0	14	46.7
Ethnicity						
White	11	33.3	2	20.0	8	26.7
Black	16	48.5	4	40.0	17	56.7
Asian	4	12.1	0	0.0	2	6.7
Other	2	6.1	4	40.0	3	10.0
Time since trauma[a] (years)	–		14.90	11.06	13.60	12.50
Type of trauma						
Accident	–		2	20.0	3	10.0
Physical assault	–		7	70.0	18	60.0
See death or violence	–		1	10.0	9	30.0
Anxiety	0.55	1.35	3.60	4.25	17.37	5.95
Depression	0.48	1.20	2.30	2.45	15.62	5.88
PTSD	–		5.40	6.35	71.87	18.29
Attention bias score (ms)	−3.70	18.61	−0.45	9.39	−1.99	25.29
Attention bias variability	0.08	0.03	0.09	0.03	0.11	0.03

Note. PTSD = posttraumatic stress disorder.
[a]*DSM-IV-TR* Criterion A traumatic event for PTSD diagnosis.

$F(2, 70) = 0.16$, $p = .852$, $\eta_p^2 = .01$, and no significant correlations were found between attention bias and symptom measures. ANOVA of attention-bias variability revealed a significant difference between groups (healthy control: $M = 0.08$, $SD = 0.03$; trauma control: $M = 0.09$, $SD = 0.03$; PTSD: $M = 0.11$, $SD = 0.03$), $F(2, 70) = 10.69$, $p < .001$, $\eta_p^2 = .23$. Fisher's LSD analyses revealed significantly greater attention-bias variability in the PTSD group compared to healthy control ($p < .001$, $d = 1.13$) and trauma control ($p = .033$, $d = 0.83$), but no significant difference between healthy control and trauma control ($p = .320$, $d = 0.35$). Attention-bias variability was significantly and positively correlated with anxiety ($r = .43$, $p < .001$), depression ($r = .43$, $p < .001$), and PTSD symptoms ($r = .37$, $p = .029$).

Experiment 2

Experiment 2 analyzed data from a longitudinal study of combat stress in Israeli Defense Force (IDF) soldiers to investigate the emergence of attention-bias variability in response to combat-related trauma and to investigate associations between attention-bias variability and acute posttraumatic stress symptoms. We hypothesized that soldiers who developed significant, acute posttraumatic stress symptoms in response to combat trauma would demonstrate greater attention-bias variability for threat cues, and explored a group × time (predeployment, in deployment) interaction. In addition, we investigated the specificity of increased attention-bias variability to posttraumatic stress symptoms by including a fourth group with posttrauma depression symptoms, but not posttraumatic stress symptoms.

Method

Participants. Fifty-one IDF infantry male soldiers ($M_{age} = 18.41$ years, $SD = 0.61$) were selected from 1,084 soldiers who participated in a longitudinal study on the effects of combat exposure (Wald et al., 2013). Participants were selected if complete data were available for both time points and based on combat experiences and trauma-related symptoms measured during deployment to reflect three groups: (a) combat exposure and acute posttraumatic stress symptoms ($n = 14$), (b) no combat exposure and no posttraumatic stress symptoms (healthy control; $n = 20$), and (c) exposure and no significant posttraumatic stress symptoms (trauma control; $n = 17$). Participants were matched across groups by age and education level, and by the military company they belonged to (i.e., participants shared the same commander, training experience, and deployment environment). Participants in the posttraumatic stress symptoms and trauma control groups were further matched by number and type of combat events experienced.

In this sample, all participants with clinically significant posttraumatic stress symptoms also exhibited elevated depression symptoms. To further explore whether combat-related depression symptoms are associated with attention-bias variability in the absence of significant posttraumatic stress symptoms, an

additional group showing high depression symptoms, but not high posttraumatic stress symptoms (depression; $n = 15$) and similar combat exposure as the other groups were selected for post hoc comparison of attention-bias variability.

Measures. Attention bias was evaluated with a version of the dot-probe task similar to Experiment 1, except this version included 152 threat-neutral trials using trauma-related Hebrew words (Bar-Haim et al., 2010; Wald, Lubin et al., 2011). Posttraumatic stress symptoms were evaluated with the PTSD Checklist (PCL, specific stressor version; Blanchard, Jones-Alexander, Buckley, & Forneris, 1996; Weathers, Litz, Herman, Huska, & Keane, 1993), comprising 17 self-rated items indicating the degree to which the participant had been bothered by symptoms over the past month, from 1 = *not at all* to 5 = *extremely*. Total scores range from 17 to 85. Inclusion among the posttraumatic stress symptoms group required at least one intrusion symptom, three avoidance symptoms, two hyperarousal symptoms, and a total score ≥ 50, indicative of acute stress symptoms in response to ongoing combat. Total score below 25, indicative of minimal acute stress symptoms, was required for the healthy control, trauma control and depression groups. Cronbach's α for this questionnaire in the sample was .93.

Depression symptoms were evaluated with the Patient Health Questionnaire (PHQ-9; Kroenke, Spitzer, & Williams, 2001), comprising nine self-rated items for frequency of depression symptoms in the last 2 weeks, from 0 = *not at all* to 3 = *nearly every day*. Total scores range from 0 to 27. Scores ≥ 10 indicate clinically significant depression symptoms and were required for the depression group. Cronbach's α for this questionnaire in the sample was .83.

Combat exposure was measured by soldiers' reports on the Combat Experiences Scale (CES; Hoge, Castro, Messer, McGurk, Cotting, & Koffman, 2004). The original scale consisted of 18 yes/no questions describing different combat events. Two additional event types specifically relevant to IDF deployment were added. Exposure to ≥ 1 combat event was required for the posttraumatic stress symptoms, trauma control, and depression groups. Cronbach's α for this questionnaire in the sample was .75.

Procedure. Written informed consent was obtained from participants at each time point. The study was approved by the Tel Aviv University Institutional Review Board, the IDF Medical Corps Ethics Committee, and the Israeli Ministry of Health High Ethics Committee. Measures were collected at predeployment (in basic training upon IDF recruitment) and 1 year later, following 6 months of combat deployment. Only data from participants who took part in both assessments were used. All questionnaires were administered in Hebrew following translation from English to Hebrew and back, and are widely used in research with Israeli populations (e.g., Wald, Lubin, et al., 2011).

Data analysis. Attention bias variability was compared across groups and time points with a 2-by-3 repeated-measures ANOVA, with time as a within-subject factor and group as a between-subjects variable. Follow-up one-way ANOVAs and Fisher's LSD were planned to explicate differences between groups. A one-way ANOVA was also conducted to compare in-deployment attention-bias variability scores across the three study groups plus the depression only group, with Fisher's LSD planned to explicate between-groups differences. All tests were two-sided with $\alpha = .05$, and effect sizes were calculated in addition to p values. Corrections for multiple comparisons were not made for follow-up tests, consistent with the rationale for Experiment 1.

Results

Table 2 presents the demographic and clinical characteristics of the sample. Participants in the three study groups were matched by and did not differ in age and education (ps > .105), or military unit. Trauma control and posttraumatic stress symptoms groups were matched for combat experiences but by definition reported more combat events than the healthy control group (ps < .001). In-deployment PCL scores differed between groups, $F(2, 49) = 389.70$, $p < .001$, with the posttraumatic stress symptoms group demonstrating higher PCL scores than the other groups, ps < .001.

Results of the attention measures are also presented in Table 2. Task RTs in threat trials and neutral trials, attention-bias scores, and attention-bias variability scores did not differ from the normal distribution at either time point (Kolmogorov-Smirnov test; ps > .150). Exclusion of trials from analysis that differed by > 2 *SD* from the mean resulted in 4.5% of trials, on average, excluded per participant with no significant difference between groups, $F(2, 48) = 1.31$, $p = .283$. Repeated measures ANOVA of bias scores yielded nonsignificant effects of time, $F(1, 47) = 1.78$, $p = .189$, group, $F(2, 47) = 0.44$, $p = .645$, and time × group interaction, $F(2, 47) = 0.44$, $p = .645$. Analysis of attention-bias variability revealed a significant time × group interaction, $F(2, 48) = 4.03$, $p = .020$, $\eta_p^2 = .14$. One-way ANOVA revealed that at predeployment, groups did not differ in mean attention-bias variability (healthy control: $M = 0.06$, $SD = 0.02$; trauma control: $M = 0.06$, $SD = 0.02$; posttraumatic stress symptoms: $M = 0.06$, $SD = 0.02$), $F(2, 48) = 0.26$, $p = .767$, whereas in deployment (healthy control: $M = 0.06$, $SD = 0.02$; trauma control: $M = 0.05$, $SD = 0.01$; posttraumatic stress symptoms: $M = 0.07$, $SD = 0.02$) a significant between-groups difference was observed, $F(2, 48) = 4.67$, $p = .011$, $\eta_p^2 = .16$. Follow-up analyses revealed that in deployment the posttraumatic stress symptoms group demonstrated greater attention-bias variability than the trauma control group ($p = .004$, $d = 1.10$), but not significantly greater attention-bias variability than healthy control ($p = .079$, $d = 0.55$); trauma control and healthy control groups did not differ ($p = .155$, $d = 0.58$).

The depression group did not differ from the other groups in age or education (ps > .107) or military unit.

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Table 2
Experiment 2: Demographic, Clinical, and Attention Characteristics

	Healthy control ($n = 20$)		PTSS ($n = 14$)		Trauma control ($n = 17$)		Depression ($n = 15$)	
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Age (years)	18.40	0.60	18.57	0.76	18.29	0.47	18.87	1.35
Education (years)	12.00	0.00	12.07	0.27	11.94	0.24	12.13	0.52
ID PTSS	18.80	2.46	59.64	8.18	18.77	2.36	19.20	2.65
Combat events	0.00	0.00	2.93	2.13	2.06	1.25	2.75	1.70
PD ABS (ms)	4.09	15.44	1.09	10.81	−1.32	15.67	−3.75	25.61
ID ABS (ms)	−1.07	16.38	−3.13	16.77	−2.24	11.97	1.53	16.29
PD ABV	0.06	0.02	0.06	0.02	0.06	0.02	0.06	0.02
ID ABV	0.06	0.02	0.07	0.02	0.05	0.01	0.07	0.02

Note. PTSS = posttraumatic stress symptoms; ID = in-deployment; PD = postdeployment; ABS = attention bias score; ABV = attention-bias variability.

Dependent-samples *t* tests confirmed that depression symptoms significantly increased in this group from predeployment ($M = 6.98$, $SD = 5.11$) to deployment ($M = 11.72$, $SD = 1.10$), $t(14) = 3.24$, $p = .006$. ANOVA on attention-bias variability scores in deployment revealed a main effect of group, $F(3, 62) = 3.68$, $p = .017$, $\eta_p^2 = .15$. Follow-up analysis indicated that attention-bias variability in the depression group ($M = 0.07$, $SD = 0.02$) did not differ from the posttraumatic stress symptoms group ($p = .682$, $d = 0.14$) or the healthy control group ($p = .199$, $d = 0.42$), but was significantly greater than the trauma control group ($p = .012$, $d = 0.99$).

Discussion

Using the dot-probe paradigm, Experiment 1 revealed no significant bias toward or away from threat-cues in the PTSD, trauma control or healthy control groups, and no differences between groups. In contrast, significantly greater attention-bias variability was observed in the PTSD group compared to trauma control and healthy control groups. In Experiment 2, attention-bias scores did not differentiate between the groups at predeployment or during deployment. At predeployment the groups did not differ in attention-bias variability; however, during deployment, increased attention-bias variability was observed in the posttraumatic stress symptoms group.

This study is the first of which we are aware to report increased attention-bias variability in PTSD and acute posttraumatic stress symptoms. Data from both experiments reveal that individuals who develop significant trauma-related symptoms in response to civilian or combat-related trauma display significantly greater variability in attention biases than individuals who did not develop symptoms. Increased attention-bias variability was significantly and positively associated with PTSD symptom severity in the PTSD and trauma control groups, and with anxiety and depression symptoms in the entire sample. Moreover, increased attention-bias variability was not detected predeployment in Experiment 2, but appears to have developed after trauma exposure along with trauma-related symptoms. In Experiment 2, increased attention-bias variability was also associated with depression in response to combat exposure. Depression is a common comorbidity of PTSD, and the contributing role of depression symptoms in attention-bias variability is an important consideration for future studies. Taken together, the results of both experiments suggest that increased attention-bias variability is present in association with the development of trauma-related mood and anxiety symptomatology, and is unlikely to be attributed simply to trauma exposure.

Attention-bias variability may be a novel marker of attentional control impairment in response to threat cues in trauma-related disorders. This builds on findings that attention-regulation impairment is a robust cognitive phenomenon in PTSD (Aupperle et al., 2012) and is consistent with studies of healthy individuals where attention variability is associated with impaired cognitive control and proneness to negative emotions (Ode et al., 2011). Variability of attention biased toward and away from threat cues is consistent with the hypervigilence and avoidance symptoms of PTSD, and this finding of increased attention-bias variability can reconcile previous inconsistent or null results in studies of attention bias for threat in PTSD, where a strong bias in only one direction or the other was expected. Whether attention-bias variability indicates general attention impairment or is specific to threat cues should be addressed in future studies.

Limitations of the study include the small sample size for the trauma control group in Experiment 1 and the groups in Experiment 2, possibly limiting sufficient statistical power to detect true between-groups differences. This was mitigated to some extent by the within-subject design in Experiment 2, and by the provision of effect sizes to further support the results of both experiments. This factor should be taken into consideration when planning exploratory studies in which the effect or the experimental parameters for revealing it have yet to be firmly established, and in particular when the study involves populations

that may be harder to reach (e.g., PTSD and trauma-control patients, enlisted soldiers). Another limitation concerns psychiatric comorbidity. Some PTSD participants in Experiment 1 demonstrated comorbid Axis I diagnoses that may influence attention patterns (Bar-Haim et al., 2007). In Experiment 2, inclusion of 18-year-olds who may be particularly vulnerable to executive process disruptions needs to be considered, as does the 70% female makeup of the trauma control group in Experiment 1.

Strengths of the study include the size of the PTSD sample in Experiment 1 and that the sample was medication-free, without recent substance use, and representative of the larger urban population in terms of ethnicity and gender. The strict matching of groups in Experiment 2 based on age, gender, and military and combat experiences are strengths of this sample. Both experiments included groups of participants exposed to significant trauma who did not develop psychopathology. Studying trauma-exposed but resilient samples allowed for the investigation of whether attention biases and attention-bias variability were associated with trauma exposure or the development of psychopathology. An additional strength lies in the longitudinal assessments conducted in Experiment 2, which showed that increased attention-bias variability is not a latent vulnerability for the development of trauma-related mood and anxiety symptoms, but appears along with the development of symptoms after trauma exposure, providing a cognitive, quantifiable marker for symptom severity. Moreover, the studies complement each other with regard to trauma-related symptom trajectory, exploring the role of attention-bias variability in both acute (Experiment 2) and longer-standing symptoms (Experiment 1), and with regard to attention-bias variability in diverse types of trauma, cultures, and contexts.

Recently, a modified version of the dot-probe paradigm has been used as an attention-bias modification treatment, targeting the attention biases shown in anxiety disorders (Bar-Haim, 2010; MacLeod, 2012). Although studies of these kinds of treatments have demonstrated reduced anxiety symptoms, few have published data regarding changes in actual attention biases. Considering the apparent variability of attention biases in PTSD, interventions aiming to target a specific attention bias to normalize (either towards or away from threat) may not be the most potent approach. Future studies targeting attention processes in posttrauma symptoms may consider targeting attention-bias variability, perhaps by enhancing executive functioning or cognitive control.

In summary, this study found significantly increased within-session variability of threat-related attention bias associated with posttraumatic stress symptoms compared to trauma-exposed and control groups not exhibiting such symptoms. Attention bias variability was significantly and positively correlated with PTSD symptoms in the trauma-exposed groups. Variability between attending toward and away from threat cues is highly congruent with the symptomatology of PTSD, which involves hypervigilance and avoidance, and attention-bias variability for threat-related information could be a marker for the underlying attentional control impairment in PTSD that gives rise to these symptoms. Furthermore, attention-bias variability may be associated with additional posttrauma symptomatology, such as depression. Further investigations of attention-bias variability in PTSD, its value as a psychopathological marker, and its associations with mood and anxiety symptoms following trauma are warranted.

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