Motivation and Emotion
https://doi.org/10.1007/s11031-018-9674-6

ORIGINAL PAPER

Dynamic measures of anxiety-related threat bias: Links to stress reactivity

Laura J. Egan[1] **· Tracy A. Dennis-Tiwary**[2,3]

Abstract

Exaggerated attention to threatening information, or the threat bias, has been implicated in the development and maintenance of anxiety disorders. Recent research has highlighted methodological limitations in threat bias measures, such as temporal insensitivity, leading to the development of novel metrics that capture change and variability in threat bias over time. These metrics, however, have rarely been examined in non-clinical samples. The present study aimed to explore the utility of these trial-level metrics in predicting anxiety-related stress reactivity (stress-induced negative mood state) in trait anxious adults ($N=52$). Following a stressor, participants completed the dot probe task to generate threat bias scores. Stress reactivity was measured via stress-induced changes in subjective mood state. More variability in trial-level bias scores (TL-BSs) and greater bias away from threat (both mean and peak negative TL-BSs) predicted increased stress reactivity. The temporal characteristics of threat bias and implications for clinically-relevant measurement are discussed.

Keywords Anxiety · Threat bias · Trial-level bias score · Stress reactivity

Introduction

Nearly three decades of research have provided compelling evidence that both clinical and non-clinical anxiety are associated with an attentional threat bias, or selective and exaggerated attention to threatening stimuli such as threat-relevant words (MacLeod et al. 1986), emotional human faces (Bradley et al. 2000), and complex emotional images (Yiend and Mathews 2001). Although facilitated attention to threat holds clear adaptive value (LeDoux 1996), an excessive and inflexible threat bias is thought to play a prominent role in the development and maintenance of anxiety (Eysenck 1992; Hofmann 2007; Williams et al. 1997). That is, preferential attending to threat, at the expense of attending to pleasant cues or cues for safety, is thought to spark a vicious cycle in which anxiety is heightened, processing of threat is facilitated, and opportunities for disconfirmation of fear beliefs are minimized. There is considerable debate, however, regarding the heterogeneity of the threat bias and the attentional mechanisms underlying it (Cisler et al. 2009; Cisler and Koster 2010; Roy et al. 2015).

This debate hinges on methodological limitations of one of the most widely used behavioral assays of the threat bias, the dot probe task (MacLeod et al. 1986). In the dot probe, two stimuli, one threat-related and one non-threat, are presented simultaneously. After their offset, participants are required to respond as quickly and accurately as possible to a target probe that appears with equal probability in the location of one of the stimuli. Faster response latencies to probes appearing in the location of the threatening stimulus suggest that attention was "captured" by threat. Threat bias is inferred when participants respond faster to probes replacing threat versus non-threat stimuli. However, there are several factors, such as the presence of stressors and temporal dynamics of attention, that introduce variability into findings derived from this dot probe task.

Diathesis-stress models of anxiety-related vulnerability factors, such as threat bias, propose that observable effects of these factors may not be evident in the absence of a stressor (Beck 1987; MacLeod et al. 2004). Recent evidence suggests that threat bias represents a latent vulnerability that emerges

✉ Tracy A. Dennis-Tiwary
tracy.dennis@hunter.cuny.edu

1 St. Francis College, Brooklyn, NY, USA

2 Department of Psychology, Hunter College, The City University of New York, 695 Park Avenue, New York, NY 10065, USA

3 The Graduate School and University Center, The City University of New York, New York, NY, USA

Published online: 02 March 2018

under conditions of stress (e.g., Bar-Haim et al. 2010; Sipos et al. 2013), which is consistent with the proposal that the sensitivity to threat increases as anxiety increases (Mathews and Mackintosh 1998; Mathews et al. 1997; Williams et al. 1997). Further, several studies document that inducing a bias towards threat leads to elevations in stress reactivity in non-clinical samples (i.e., greater anxious mood in response to a stressful task or challenge), strengthening the plausibility of a causal link between the threat bias and the development of anxiety (Clarke et al. 2008; Eldar et al. 2008; MacLeod et al. 2002). It is therefore crucial to clarify the nature of the threat bias in sub-clinically anxious individuals, given the potential for such biases to contribute to the development of clinical anxiety disorders (Eysenck 1992; Hofmann 2007; Williams et al. 1997).

Although such a bias is often present in individuals with anxiety (Bar-Haim et al. 2007; Puliafico and Kendall 2006), there are also studies documenting an anxiety-related attentional bias away from threat (Monk et al. 2006; Salum et al. 2013). Moreover, reaction time-based measures of threat bias derived from tasks such as the dot probe have methodological limitations that make it difficult to identify stable individual differences, which may emerge in a temporally-dynamic fashion and thus are obscured by calculating an aggregate score across the entirety of the threat bias assessment (Brown et al. 2014; Price et al. 2015; Rodebaugh et al. 2016; Roy et al. 2015; Schmukle 2005; Weierich et al. 2008; Zvielli et al. 2014a, b).

A recent measurement innovation has addressed this neglect of the temporal dynamics of threat bias. Trial-level bias score (TL-BS) computation generates metrics of threat bias over the course of the assessment (Zvielli et al. 2014b). Whereas the traditional bias score is derived from average reaction times to trials where probes replace the non-threatening stimulus (incongruent trials) versus the threat stimulus (congruent trials), the TL-BS variability metric, in contrast, is calculated as the absolute value of the sum of the mathematical differences between successive temporally contiguous pairs of trials. This approach is intended to capture the degree to which the bias changes on a trial-by-trial basis over the course of the task. The TL-BS variability metric has been shown to predict, above and beyond the traditional bias measure, clinical diagnosis of specific phobia (Zvielli et al. 2014b), posttraumatic stress symptoms in soldiers (Iacoviello et al. 2014), and is directly reduced by cognitive behavioral therapy in individuals with social anxiety disorder (Davis et al. 2016). Additionally, greater emotion dysregulation predicts the TL-BS variability metric in the presence of threatening stimuli (Bardeen et al. 2017). These promising early findings suggest that continued work is warranted to explore the clinical relevance of TL-BS variability metric as an additional measure of threat bias beyond the traditional threat bias scoring approach.

In addition to capturing within-subject variability, the TL-BS reflects the phasic directionality of threat bias towards and *away* from threat by calculating the mean and peak positive and negative bias score across the duration of the task, respectively. Several studies suggest that a bias *away* from threat may be associated with distress-related anxiety symptoms (Bar-Haim et al. 2010; Lee et al. 2010; Sipos et al. 2013) and prolonged exposure to threat in non-clinical anxiety (Koster et al. 2005, 2006; Mogg et al. 2004). The TL-BS metrics offer a fine-grained tool for tracking the heterogeneity in presentation of biases towards and away from threat in subclinical anxiety.

The present study examined whether threat bias measured via TL-BS metrics predicted anxiety-related stress reactivity in an undiagnosed group of adults reporting mild to moderate symptoms of anxiety. Threat bias was measured after a stressor in order to increase expression of threat bias in this non-clinical group.

Method

Participants

Participants were 57 non-diagnosed adults recruited through the psychology participant research pool at Hunter College, The City University of New York. Three participants discontinued participation in the study due to noncompliance with task procedures and two participants were excluded due to excessive errors during the dot probe task (> 60% errors). The final sample consisted of 52 adults (9 males, 43 females) aged 18–38 ($M = 20.33$, $SD = 4.40$). Self-reported race/ethnicity was as follows: 17 White, 8 Hispanic, 19 Asian or Pacific Islander, 6 African American, and 2 "other." At the beginning of each semester, students in the psychology participant research pool can respond to a series of questionnaires via the recruiting webpage to determine eligibility for a variety of studies offered.

Inclusion criteria

In order to qualify for the present study, potential participants needed to report at least + 1SD from the college norm for trait anxiety scores (score of 49 or higher; Spielberger 1983). The trait subscale of the State-Trait Anxiety Inventory includes 20 items that measure participants' perceptions of their general (trait) level of nervousness, anxiety, and shyness; scores range from 20 to 80 with higher scores indicating greater anxiety. Trait anxiety scores ranged from 49 to 75, with an average of 55.44 ($SD = 5.81$). This cutoff is consistent with a previous study that recruited undergraduates with elevated, but subclinical, anxiety who fell in the upper quartile of scores from a larger group (Eldar and Bar-Haim 2010).

Procedures

Participants in this study were part of a larger study examining threat bias modification. Following informed consent and a questionnaire period, participants completed the Trier Social Stress Task (TSST; Kirschbaum et al. 1993). The TSST involved a pre- and post-stressor mood questionnaire and video recording. Following the TSST, participants completed the threat bias assessment (using the dot probe). The remainder of the procedures (completion of a threat bias modification task followed by a post-training assessment identical to the procedures for the present study as well as EEG recordings during the dot probe and training tasks) is not reported in this paper. The entire visit lasted approximately 3 h.

Trier Social Stress Task (TSST; Kirschbaum et al. 1993)

The TSST requires participants to undergo a social-evaluative threat, where they give a speech and complete a difficult arithmetic task in front of two judges. Participants were given a 3-min preparation period following the speech instructions then they completed a 3-min speech and a 3-min arithmetic task. There were two versions of each task (i.e., different content for speeches and different starting number for arithmetic) which were counterbalanced across pre- and post-training to avoid order effects. There was no difference in stress reactivity (described below) between the two versions of the task in the data reported in the present study, $t(50) = 1.62$, $p = .11$. For the speeches, participants were asked to either introduce themselves as though they were applying for a job or to defend their stance on the death penalty. For the arithmetic task, participants were asked to count backwards by 13 from either 1022 or 1999; every time they made a mistake they were stopped and asked to begin again from the original number.

Stress reactivity

Self-reported mood was recorded before and after the TSST using the 65-item Profile of Mood States (POMS; McNair et al. 2003). Participants were instructed to indicate on a five-point scale how well each adjective describes their current mood (not at all to extremely). The POMS measures six different mood states (Tension/Anxiety, Depression/Dejection, Anger/Hostility, Vigor/Activity (reverse scored), Fatigue/Inertia, Confusion/Bewilderment). Stress reactivity was indexed as the change in the Tension/Anxiety subscale from before to after the stressor.[1] The sample as a whole showed an increase in Tension/Anxiety from before to after the stressor, $t(51) = 7.46$, $p < .001$.

The dot probe task

Participants were seated 65 cm from the monitor and were instructed to remain still and not blink during each trial. They were instructed to blink between trials when the fixation cross was present and informed of longer breaks that would be available for them to rest their eyes. The dot probe task begins with a fixation cross for 1000 ms, followed by a pair of cue stimuli (complex emotional scenes) for 500 ms. Images subtended 15.5 cm × 11.5 cm and were presented equal distance (2 cm) to the right and left of the fixation cross, for a horizontal visual angle of 13.5° and a vertical visual angle of 11°. Following the cues was a variable interstimulus interval from 100 to 300 ms followed by a probe (arrow) for 200 ms in the location occupied previously by either stimulus. Participants have up to 1300 ms to respond and are required to determine whether the arrow is pointing to the left or the right. Each trial ended with an intertrial interval of 500–1000 ms. See Fig. 1 for sequence of events in a single trial.[2]

Cue pairs were a threatening and a non-threatening image (TN: threat on the left and neutral on the right; NT: neutral on the right and threat on the left), two threatening images (TT), or two non-threatening images (NN). This study included 192 picture stimuli from the International Affective Picture System (IAPS; Lang et al. 2008): 48 TN and NT pairs,[3] 24 NN pairs,[4] and 24 TT pairs.[5] Each image was used in only one pairing and the same two images were always presented together as a pair. Threatening images contain knives, guns,

[1] Analyses were not significant when using the composite "Total Mood" score that comprises all six mood states as the dependent measure.

[2] The inclusion of a jittered interstimulus interval and removal of the probe after 200 ms is consistent with a dot probe study employing EEG measures, in which highly anxious participants showed a behavioral threat bias (Eldar et al. 2010).

[3] Image numbers for TN/NT pairs: 1019–5533; 1030–7170; 1050–5800; 1052–7550; 1070–5750; 1111–5530; 1120–2200; 1300–7006; 1301–2600; 1310–2570; 1930–7061; 1932–2441; 2120–2107; 2683–7240; 2692–7058; 3500–2980; 3530–2396; 5950–7249; 5961–2357; 5972–7039; 6190–2032; 6200–6570.2; 6211–5520; 6213–2487; 6220–2397; 6230–7031; 6231–2575; 6240–2411; 6250–7025; 6263–7062; 6350–7175; 6510–7490; 6520–1935; 6530–7710; 6540–1908; 6550–5661; 6570–2635; 6940–2383; 9600–5390; 9623–7487; 9630–2038; 9635.1–5395; 9800–7130; 9810–7590; 9901–7496; 9902–5250; 9909–5731; 9911–2026.

[4] Image numbers for NN pairs: 1122–2273; 2235–2594; 2579–2595; 2870–6930; 5534–6150; 7000–7010; 7004–7080; 7014–7016; 7018–7021; 7019–7195; 7020–7035; 7032–7040; 7036–7037; 7043–7056; 7045–7059; 7053–7055; 7057–7060; 7077–7150; 7242–7300; 7255–7513; 7497–7495; 7509–8191; 7547–7632; 7950–8117.

[5] Image numbers for TT pairs: 1022–1525; 1026–6561; 1033–1302; 1040–6560; 1051–1304; 1090–6210; 1113–6360; 1114–2811; 1303–

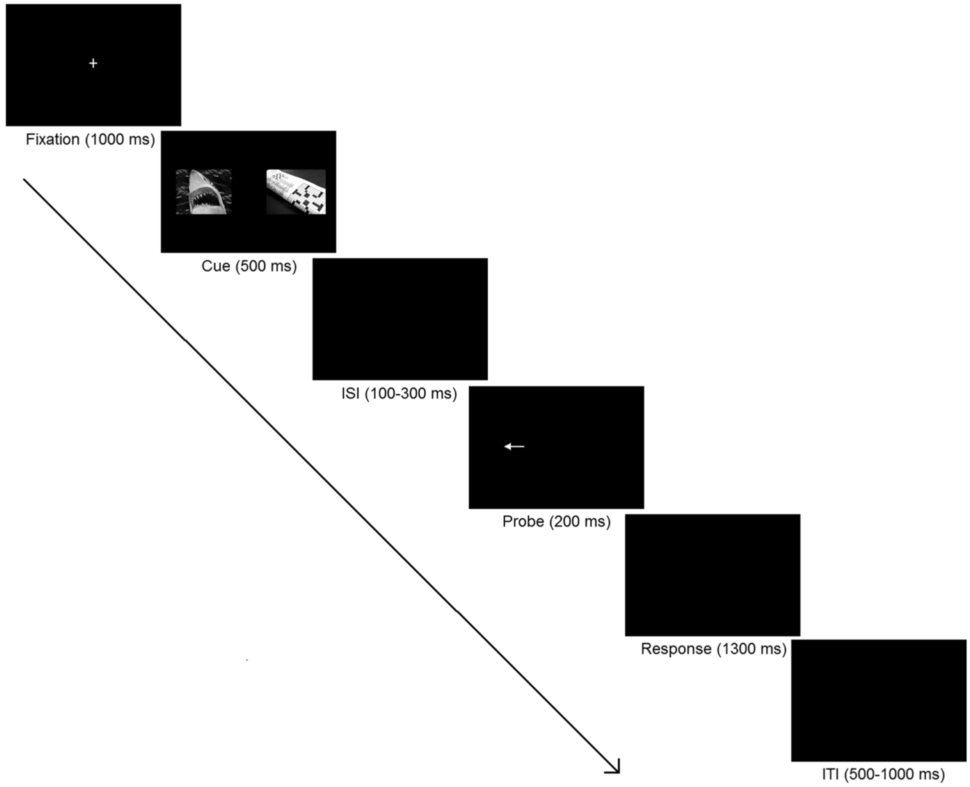

Fig. 1 Sequence of events in a single trial of the dot probe task

and aggressive animals and non-threatening images contain tools, shoes, and household objects. Images were chosen based on the IAPS classification and normative valence and arousal ratings, with image pairs matched for visual complexity based on subjective judgments by several research assistants to ensure that one image in a pair was not more likely to draw attention based on its visual characteristics as opposed to its threatening or non-threatening nature. Probes can appear in the location of the threatening stimulus from TN/NT pairs (threat cue), the non-threatening stimulus from TN pairs (non-threat cue), either stimulus from TT pairs (only threat cue), or either stimulus from NN pairs (only non-threat cue). Participants received an equal number of threat, non-threat, only threat, and only non-threat cue trials, for a total of 192 trials (48 trials per cue type). Before calculating the traditional and trial-level threat bias scores, trials with RT outliers (RTs faster than 150 ms or slower than 2000 ms or RTs > ± 3 SD from the participants mean RT) and errors were identified and discarded. There were no differences between RTs for the four types of trials, $F(3, 153) = 1.07$, $p = .36$.

Footnote 5 (continued)

6243; 1321–6244; 1726–6212; 2100–2110; 5971–5973; 6241–1931; 6242–6821; 6260–6300; 6370–5970; 6410–9620; 6571–6312; 6313–5920; 6315–2682; 9622–5940; 9903–9910; 9904–9908.

Table 1 Descriptive statistics for traditional threat bias and trial-level bias scores (TL-BS)

	M	*SD*
Traditional Bias Score	− 5.83	22.38
TL-BS Mean Positive Score	126.17	48.54
TL-BS Peak Positive Score	433.50	176.56
TL-BS Mean Negative Score	− 131.02	43.84
TL-BS Peak Negative Score	− 467.44	158.68
TL-BS Variability Score	2.62	1.28

Traditional threat bias score calculation The traditional threat bias score was calculated using the average response time for all trials of each cue condition, with RT non-threat cue—RT threat cue. Positive scores indicate a bias towards threat and negative scores indicate a bias away from threat (Table 1).

Trial-level bias score (TL-BS) calculation TL-BS scores were generated by employing the traditional bias score calculations described above on temporally contiguous pairs of trials in the dot probe task following the approach described by Zvielli et al. (2014b). That is, the response time for individual trials rather than average response time across trials in a condition were used for these calculations. First, non-threat trials were paired with the next closest

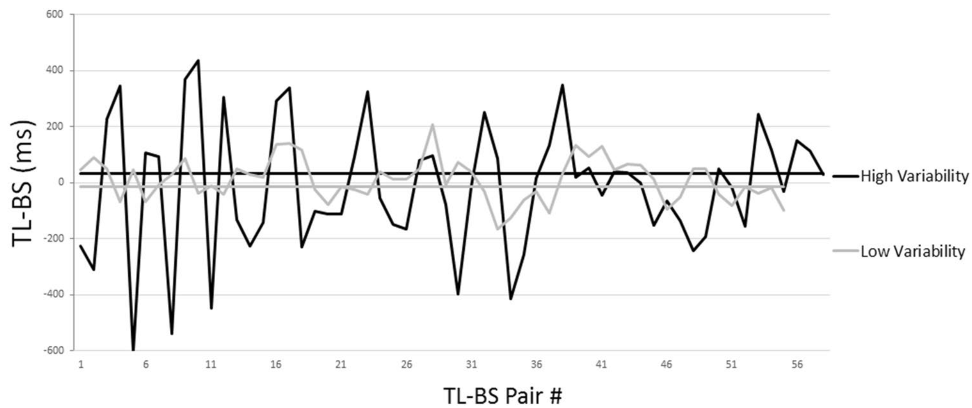

Fig. 2 Trial-level bias scores (TL-BS) plotted in sequential order for a participant high variability (black line) and low variability (grey line). The variability measure indexes the length of the line, with higher scores indicating greater varaibility in threat bias over the course of the assessment. The horizontal lines indicate the traditional bias for each participant

threat trial. Second, threat trials were paired with the next closest non-threat trial. Pairs of trials were no further than five trials apart (before or after) and redundant pairings were discarded. This approach is employed to maximize the number of temporally contiguous pairs of trials across the length of the dot probe task. The resulting bias scores were divided into positive and negative values and then the mean and peak score of each direction were calculated. Positive scores indicate a bias towards threat and negative scores indicate a bias away from threat. TL-BS variability was calculated as the sum of the distance between each sequential bias score divided by the number of scores. This score provides a measure of the "length" of the plotted TL-BS line, with higher scores indicating greater variability (see Fig. 2). Thus, six scores were generated using the TL-BS approach—*peak and mean positive* (bias towards threat), *peak and mean negative* (bias away from threat) and *variability* (reflecting the amount of change from trial to trial) (Table 1).

Results

All statistical analyses were conducted in SPSS (Version 20) using general linear model and hierarchical regressions. Data analyses for predictors of stress reactivity followed the approach of Zvielli et al. (2014b): using a regression approach to identify significant TL-BS predictors of stress reactivity followed by additional tests to confirm the specificity of those predictors and to rule out alternative explanations for findings.

First, we conducted six linear regressions to determine whether the threat bias measures predicted stress reactivity (see Table 2 for regression statistics for traditional bias score and all five TL-BS metrics). As predicted, greater bias away from threat (*TL-BS Mean Negative* and *TL-BS Peak Negative* scores) were significantly related to greater stress reactivity [*TL-BS Mean Negative:* $F(1, 50) = 11.89$, $p = .001$, $R^2 = .19$; *TL-BS Peak Negative:* $F(1, 50) = 4.25$, $p = .04$, $R^2 = .08$]. Additionally, greater variability in bias scores (*TL-BS Variability* score) was significantly related to greater stress reactivity [$F(1, 50) = 4.76$, $p = .03$, $R^2 = .09$].

Second, we conducted three follow-up hierarchical regressions to determine whether each of the significant TL-BS predictors explained variance in stress reactivity above and beyond the traditional bias score: traditional bias score was entered in the first step followed by each of the significant TL-BS metrics in the second step. Greater bias away from threat as measured by *TL-BS Mean Negative* scores remained a significant predictor of greater stress reactivity [Full Model: $F(2, 49) = 6.13$, $p = .004$, $R^2 = .20$: Step 2: $F\Delta(1, 49) = 11.78$, $p = .001$, $\Delta R^2 = .19$, $\beta = -.44$, $t = -3.43$, $p = .001$], however *TL-BS Peak Negative* scores did not [Full Model: $F(2, 49) = 2.09$, $p = .13$, $R^2 = .08$: Step 2: $F\Delta(1, 49) = 3.77$, $p = .06$, $\Delta R^2 = .07$, $\beta = -.28$, $t = -1.94$, $p = .06$]. Additionally, greater *TL-BS Variability* scores also continued to predict greater stress reactivity [Full Model:

Table 2 Regressions statistics

	F	p	R^2
Traditional Bias Score	0.39	.54	.008
TL-BS Mean Positive Score	2.19	.15	.04
TL-BS Peak Positive Score	1.28	.26	.03
TL-BS Mean Negative Score[a]	11.89[a]	.001[a]	.19[a]
TL-BS Peak Negative Score[a]	4.25[a]	.04[a]	.08[a]
TL-BS Variability Score[a]	4.76[a]	.03[a]	.09[a]
"Fake" TL-BS Mean Positive Score	0.53	.59	.02
"Fake" TL-BS Peak Positive Score	1.63	.21	.06
"Fake" TL-BS Mean Negative	1.65	.20	.06
"Fake" TL-BS Peak Negative Score	1.33	.28	.05
"Fake" TL-BS Variability Score	1.29	.28	.05

The baseline neutral and baseline threat "fake" scores were entered into the models simultaneously. Separate regression models were also not significant

[a]Significant models

$F(2, 49)=3.13$, $p=.05$, $R^2=.11$: Step 2: $F\Delta(1, 49)=5.84$, $p=.02$, $\Delta R^2=.11$, $\beta=.34$, $t=2.42$, $p=.02$].

Third, we conducted three additional follow-up hierarchical regressions to control for individual differences in RT variability: mean RT from baseline neutral trials and baseline threat trials were entered in the first step followed by each of the significant TL-BS metrics in the second step. Although the model for the first step was significant [$F(2, 49)=3.89$, $p=.03$, $R^2=.14$], the coefficients for mean RT on baseline neutral trials ($\beta=-.28$, $t=-0.54$, $p=.59$) and mean RT for baseline threat trials ($\beta=.63$, $t=1.23$, $p=.22$) were not. However, separate correlations indicate that greater RT in both conditions is related to greater stress reactivity (baseline neutral: $r=.33$, $p=.02$; baseline threat: $r=.36$, $p=.008$). Again, greater bias away from threat as measured by *TL-BS Mean Negative* scores remained a significant predictor of greater stress reactivity [Full Model: $F(3, 48)=4.28$, $p=.009$, $R^2=.21$: Step 2: $F\Delta(1, 48)=4.49$, $p=.04$, $\Delta R^2=.07$, $\beta=-.34$, $t=-2.12$, $p=.04$], however *TL-BS Peak Negative* scores [Full Model: $F(3, 48)=3.24$, $p=.03$, $R^2=.17$: Step 2: $F\Delta(1, 48)=1.80$, $p=.19$, $\Delta R^2=.03$, $\beta=-.19$, $t=-1.34$, $p=.19$] and *TL-BS Variability* scores did not [Full Model: $F(3, 48)=2.59$, $p=.06$, $R^2=.14$: Step 2: $F\Delta(1, 48)=0.12$, $p=.73$, $\Delta R^2=.00$, $\beta=.07$, $t=0.35$, $p=.73$].

Last, we created "fake TL-BS" metrics by relating baseline neutral trials to each other and baseline threat trials to each other as a random sequence of continguous pairs and then computing the TL-BS metrics. These scores did not predict stress reactivity (see Table 2 for regression statistics for "fake" TL-BS metrics in the baseline neutral and baseline threat conditions).

Discussion

The present study demonstrated that bias away from threat of threat, and to a lesser degree variability in the threat bias, are useful metrics in predicting stress reactivity in subclinical anxiety. We found support for our hypothesis that increases in anxiety following a stressor would be predicted greater trial-level variability in threat bias and greater bias away from threat: both mean and peak TL-BS scores and variability of TL-BS scores were significant predictors in a sample of subclinically anxious individuals. Both greater mean TL-BS scores and greater variability in TL-BS scores predicted stress reactivity above and beyond the traditional threat bias, while peak TL-BS scores did not. Further, when controlling for mean reaction time to neutral-only and threat-only only mean TL-BS scores remained significant predictor of stress reactivity.

The stressor task prior to completing the threat bias assessment may have induced a bias away from threat. Such avoidance of threat is potentially counterproductive, as it precludes the opportunity to disconfirm negative beliefs thus exacerbating the effects of threat (Ouimet et al. 2009). Thus, greater bias away from threat following the stressor would be predictive of a heightened stress response. This interpretation is consistent with previous research (Bar-Haim et al. 2010; Koster et al. 2005, 2006; Lee et al. 2010; Mogg et al. 2004; Sipos et al. 2013), however future studies should incorporate dot probe tasks both before and after the stressor to more finely track such changes. The finding that only the mean of negative TL-BS, but not the peak TL-BS, remained a significant predictor through the follow-up comparison is consistent with Zvielli et al. (2014b), who showed that mean but not peak positive scores were predictive of phobia diagnosis. It is not surprising that the peak scores are not strong predictors, given that they are based on a single pair of trials whereas the mean score is comprised of all the negative bias score trials.

Findings also add to the growing number of studies documenting the predictive utility of the TL-BS variability metric (Bardeen et al. 2017; Davis et al. 2016; Iacoviello et al. 2014; Zvielli et al. 2014b). The variability metric did not hold up as a significant predictor through all of the follow-up comparisons in the present study. This divergence from previous studies may have occurred due to the induction of a stress response prior to measuring the threat bias: it may be that the stressor "organizes" attention away from threat thus reducing the variability of the threat bias. This could also be tested in future studies by incorporating a pre- and post-stressor dot probe task to track changes in the TL-BS measures following acute stress.

Several models of the anxiety-related threat bias propose that attentional *competition* from threat is a necessary condition to produces a detectable threat bias (Mathews and Mackintosh 1998; Mathews et al. 1997; Williams et al. 1997). The dot probe task has previously been modified to assess the contributions of vigilance (the degree to which attention is captured by threat) and disengagement (the degree to which attention is held by threat) with the inclusion of "baseline" trials where no threatening stimuli are presented. Findings are inconsistent, with some studies indicating that threat bias is driven by difficulty disengaging from threatening stimuli (Koster et al. 2004, 2006; Salemink et al. 2007) and others showing enhanced vigilance for threat (Carlson and Reinke 2008; Klumpp and Amir 2009). Previous studies employing the TL-BS metric have instead controlled for baseline reaction times using neutral-only trials (Bardeen et al. 2017; Iacoviello et al. 2014; Zvielli et al. 2014b). The present study, however, included trials in which threat competed for attention with non-threat (one threatening image and one non-threatening image), trials where threat did not compete for attention (two threatening images), and trials with no threat (two non-threatening images). The inclusion of both types of baseline trials may explain why the variability metric was not as strong a predictor as in previous studies; some of the variability in threat bias scores over the course of the task may have been explained by the response to threat in general. Given that the "fake" TL-BS metrics did not predict stress reactivity, however, it is not likely that individual differences in mean responses, to either neutral or threatening stimuli, explain findings of the current study. By including threat-only trials as a covariate in analyses along with neutral-only trials, the present study further explores the parameters under which dynamic measures of threat bias may serve as clinically-relevant metrics of dysregulated responses to threat.

Limitations of the present study include the severity and size of the images used in the dot probe task and the gender distribution of participants. Although a stressor prior to threat bias assessment was included to trigger a threat bias, research has demonstrated that non-anxious individuals will show facilitated attention towards severely, but not moderately, threatening stimuli while anxious individuals show facilitated attention to both severely and moderately threatening stimuli (Wilson and MacLeod 2003). Given that the images used in the present study were not severely threatening, this may have posed a compounded limitation combined with the subclinical anxiety level of participants. However, there is a critical need to investigate predictors of clinical anxiety, such as the threat bias, in non-clinical samples in order to better understand the mechanisms through which selective processing becomes maladaptively biased towards threat and contributes to the development and maintenance of clinical anxiety disorders (Eysenck 1992; Hofmann 2007; Williams et al. 1997). The size of the stimuli was larger than traditionally employed, which may limit the comparison to previous dot probe studies. Additionally, the large disparity in the gender of the participants (9 males versus 43 females) did not allow us to investigate gender as a potential covariate in analyses and may limit the generalization of the findings to larger populations.

Taken together, results demonstrate that investigating the temporal dynamics of the anxiety-related threat bias holds great promise in identifying additional methods for assessing threat bias and in clarifying the clinical and predictive relevance of this cognitive mechanism in the emergence, maintenance, and treatment of anxiety. Future studies should explore how these trial-level measures may fluctuate in response to stressors and how those changes may be predictive of other clinically-relevant outcomes.

Disclaimer The contents are solely the responsibility of the authors and do not necessarily represent the official views of the NIMHD or the NIH.

Funding This research was made possible by grant SC1MH104907 awarded to TDT from the National Institute of General Medical Sciences and grant R56MH111700 awarded to TDT from the National Institute of Mental Health, both of the National Institutes of Health. This research was also made possible by grant TR000457 of the National Center for Advancing Translational Sciences of the National Institutes of Health.

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