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Attention to threat images in individuals with clinical and subthreshold symptoms of post-traumatic stress disorder

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ABSTRACT

Attention to general and trauma-relevant threat was examined in individuals with clinical and subthreshold symptoms of post-traumatic stress disorder (PTSD). Participants' eye gaze was tracked and recorded while they viewed sets of four images over a 6-s presentation (one negative, positive, and neutral image, and either a general threat image or a trauma-relevant threat image). Two trauma-exposed groups (a clinical and a subthreshold PTSD symptom group) were compared to a non-trauma-exposed group. Both the clinical and subthreshold PTSD symptom groups attended to trauma-relevant threat images more than the no-trauma-exposure group, whereas there were no group differences for general threat images. A time course analysis of attention to trauma-relevant threat images revealed different attentional profiles for the trauma-exposed groups. Participants with clinical PTSD symptoms exhibited immediate heightened attention to the images relative to participants with no-trauma-exposure, whereas participants with subthreshold PTSD symptoms did not. In addition, participants with subthreshold PTSD symptoms attended to trauma-relevant threat images throughout the 6-s presentation, whereas participants with clinical symptoms of PTSD exhibited evidence of avoidance. The theoretical and clinical implications of these distinct attentional profiles are discussed.

1. Introduction

Post-traumatic stress disorder (PTSD) is a complex clinical syndrome that can develop in response to experiencing, witnessing, or being confronted with actual or threatened death or serious injury. Recent estimates of PTSD in the general population indicate that approximately 3.6% of men and 9.7% of women are affected (Kessler, Berglund, Demler, Jin, & Walters, 2005). The magnitude of distress, functional impairment, comorbidity, and economic costs associated with PTSD is well established (e.g. Keane, Marshall Am, & Taft, 2006). Researchers have also documented the prevalence and disability experienced by those who meet some, but not all criteria for this disorder. Rates of subthreshold PTSD have been cited to range from 3.4% in a community sample (Stein, Walker, Hazen, & Forde, 1997) and 4.6% in a large epidemiological study of veterans (Grubach et al., 2005), to as high as 44% in trauma-specific samples (e.g. Blanchard, Hickling, Taylor, Loos, & Gerardi, 1994). The associated impairments are significant and pervasive, and include increased rates of suicidal ideation, substance use, impaired occupational and social functioning, and other Axis I disorders (e.g. Cukor, Wyka, Jayasinghe, & Difede, 2010; Marshall et al., 2001; Mylle & Mae, 2004; Zlotnick, Franklin, & Zimmerman, 2002).

In addition to the impairments associated with clinical and subthreshold PTSD, researchers have found that this disorder affects how people attend to the world around them. Many studies have shown that PTSD is associated with a heightened vigilance for threat-related stimuli and increased attention to threat-related information, collectively referred to as a threat-related attentional bias (e.g. Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van Ijzendoorn, 2007; Buckley, Blanchard, & Neill, 2000; Cisler & Koster, 2009). Researchers have identified three possible manifestations of biased attention in PTSD: facilitated attention to threat (attending first to threat stimuli more frequently than to other types of stimuli), delayed disengagement from threat (difficulty moving one's attention away from threat stimuli once detected), and attentional avoidance of threat (avoiding threat stimuli once detected). Understanding the attentional profile of PTSD has become a major focus of research due to its clinical and theoretical implications. For example, the vigilance-avoidance model proposes that facilitated attention (vigilance) to threat stimuli, followed by its subsequent avoidance, are two key processes driving attentional biases in anxiety disorders. Applied to PTSD, this model suggests that people with PTSD are primed to detect threat more quickly in order to facilitate its subsequent avoidance (Mogg, Bradley, Miles, & Dixon, 2004;

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Rinck & Becker, 2006). Threat avoidance then enables individuals to evade attentional engagement with reminders of the traumatic event, to avert the emotional distress that trauma-related memories evoke. Confirmation of this attentional profile would have clinical relevance: habituation to trauma-related stimuli is thought to be a key factor in the reduction of PTSD symptoms, but in order to habituate, one must attentionally engage with, rather than avoid, trauma-related stimuli (e.g. Foa & Kozak, 1986; Wells & Mathews, 1994).

Delineating the attentional profile of those with symptoms of PTSD has been difficult due to the limitations of response latency-based measures of attention. Most studies have used the dot probe or the emotional Stroop task (for a review, see Bar-Haim et al., 2007) to evaluate attentional processing in PTSD. These tasks measure the focus of attention only at a single moment in time, however, making it difficult to assess temporal changes in the allocation of attention. This is a crucial limitation given that attention to threat in PTSD and other anxiety disorders is likely a complex, dynamic process that changes over time (Bar-Haim et al., 2007). Another limitation is that response latency-based tasks use facilitation and interference effects to infer attentional engagement; they do not measure attentional engagement directly. Moreover, a variety of factors such as emotional arousal, motivation, and slowed motor response due to comorbid disorders (e.g. depression) can affect participants' verbal and manual responses to threat-related stimuli and complicate the interpretation of response latency data (e.g. Bar-Haim et al., 2007; De Ruiter & Brosschot, 1994; Markela-Lerenc, Kaiser, Fiedler, Weisbrod, & Mundt, 2006).

A few studies have used eye gaze tracking paradigms to avoid these limitations and to provide a more complete picture of attentional processing in PTSD (Bryant, Harvey, Gordon, & Barry, 1995; Felminghman, Rennie, Manor, & Bryant, 2011; Kimble, Fleming, Bandy, Kim, & Zambetti, 2010). A major advantage of eye gaze tracking is that it can provide a direct and continuous record of the focus of attention over extended intervals, because the direction of an individual's gaze and the focus of their attention are tightly coupled (Wright & Ward, 2008). Bryant et al. (1995) looked for evidence of enhanced threat detection in PTSD by determining if trauma-relevant words were attended to before neutral words. The participants were motor vehicle accident (MVA) survivors with PTSD and control participants without PTSD. Each word set consisted of three filler words and either one MVA-relevant threat word or one neutral word. Bryant et al. found that, unlike control participants, PTSD participants were more likely to initially fixate on MVA-relevant threat words than neutral words, which was interpreted as evidence of enhanced threat detection in PTSD. In a similar study, Felminghman et al. (2011) compared physical assault survivors with and without a diagnosis of PTSD (there were no non-trauma exposed participants). Participants were presented with sets of four words for 1 s. Each word set consisted of three filler words and either one physical assault-relevant threat word or one neutral word. Felmingham et al. found that physical assault survivors with PTSD had significantly more initial fixations to assault-relevant threat words than neutral words, unlike the trauma-exposed participants without PTSD. Thus, like Bryant et al., Felmingham et al. found evidence of enhanced threat detection in individuals with PTSD. Felmingham et al. also analyzed participants' subsequent fixations to assault-relevant threat words following initial fixation and found no between-group differences. Taken together, their results suggest that individuals with PTSD are more likely to first attend to threat-relevant stimuli than trauma-exposed individuals without PTSD, but are no more likely to subsequently avoid threat.

Kimble et al. (2010) used eye gaze tracking to examine attention to threat-relevant images in a group of veterans of the Iraq war. Participants were assigned to either a high PTSD symptom group or a low PTSD symptom group (2 of the 19 participants met diagnostic criteria for PTSD; there were no non-trauma exposed participants). On each trial, participants were presented with a pair of images for 10 s: either a neutral image paired with a combat-themed image (i.e., a trauma-relevant threat image) or a neutral image paired with a motor vehicle accident-themed image (i.e., a general threat image). Three of Kimble et al.'s findings are especially relevant to the present research. First, unlike Bryant et al. (1995) and Felminghman et al. (2011), Kimble et al. did not find clear evidence of enhanced threat detection in PTSD: their results indicated that the participants in the high PTSD group were no more attentionally vigilant to general threat or trauma-relevant threat images than participants in the low PTSD symptom group. Second, Kimble et al. found a large difference between the high and low PTSD symptom groups in their total fixation time to general threat and trauma-relevant threat images: the high PTSD symptom participants had significantly longer total fixation times to both types of threat images relative to neutral images. This result indicates that the attentional bias for threat was not specific to trauma-relevant images. Finally, to look for evidence of threat avoidance, Kimble et al. compared the total amount of time an image was fixated the first time compared to the second time it was viewed during the same trial. Avoidance was defined as shorter total fixation times to an image the second time it was viewed relative to the first time it was viewed. The two groups did not differ in this respect, which indicated that participants with more severe symptoms of PTSD were no more likely to avoid threat images after they had been initially attended than were participants in the low PTSD symptom group.

2. The present research

Taken together, previous eye tracking research suggests that the attentional profile of individuals with PTSD is characterized by increased attention to general threat and trauma-relevant threat stimuli but no avoidance of these stimuli once attended. While there is some evidence of enhanced threat detection in PTSD (Bryant et al., 1995; Felminghman et al., 2011), the research to date is equivocal on this question (Kimble et al., 2010). Of course, the small number of eye tracking studies in the literature makes it difficult to reach any firm conclusions. In the present study, our goal was to build and expand on previous research by examining attention to threat-related stimuli in individuals with clinical and subthreshold levels of PTSD symptoms (hereafter referred to as the clinical PTSD symptom group and the subthreshold PTSD symptom group, respectively). Eye gaze tracking was used to measure participants' attention while they viewed sets of four images (a negative image, a positive image, a neutral image, and a general threat or trauma-relevant threat image) over a 6-s presentation time. Our study differed from previous eye tracking studies in several important respects. First, presenting multiple images with different valences on each trial allowed us to examine group differences in attention to both positive and negative images when multiple stimuli compete for attention. In addition, presenting four images gave participants more opportunity to avoid general threat and trauma-relevant threat images, an important consideration given that attentional avoidance is hypothesized to be important in PTSD. Second, by using both general threat and trauma-relevant threat images, we were able to examine whether attention to both trauma-relevant and general threat stimuli is affected in individuals with clinical and subthreshold levels of PTSD symptoms. Finally, unlike most studies on attention in PTSD, we included a control group of individuals never exposed to trauma (the no-trauma-exposure group). Assessing the attentional profile of individuals with no trauma exposure provided a baseline that allowed us to determine whether the attentional bias associated with clinical PTSD extends to those with subthreshold symptoms of the disorder,

Table 1
Participant characteristics for the clinical PTSD symptom group, subthreshold PTSD symptom group, and no-trauma-exposure group.

	PTSD ($n = 18$)		Subthreshold PTSD ($n = 13$)		No trauma exposure ($n = 24$)	
	M	SD	*M*	SD	*M*	SD
Age	21.2[a]	5.1	20.8[a]	1.5	22.4[a]	6.5
PCL	55.8[a]	8.0	41.9[b]	7.7	24.5[c]	5.2
BDI	22.5[a]	11.8	14.8[b]	6.4	4.7[c]	3.7

Note. PCL, Post-traumatic Stress Disorder Checklist; BDI, Beck Depression Inventory; PTSD, clinical PTSD symptom group; subthreshold PTSD, subthreshold PTSD symptom group. No trauma exposure, no-trauma-exposure group. Means in the same row with the same subscript are not significantly different at $p < .05$.

and facilitated a better understanding of the similarities and differences between these groups.

Our study was designed to answer several questions: (a) Would participants in the clinical PTSD and subthreshold PTSD symptom groups exhibit hypervigilance for threat-related stimuli, evidenced by initially fixating on threat-related images more frequently than participants with no trauma exposure? (b) Would participants in the clinical PTSD and subthreshold PTSD symptom groups exhibit increased attentional engagement with threat-related stimuli, evidenced by longer total fixation times to threat-related images than participants with no trauma exposure? (c) Would participants in the clinical PTSD and subthreshold PTSD symptom groups attend to trauma-relevant threat images more than general threat images? (d) Would participants in the clinical PTSD and subthreshold PTSD symptom groups avoid threat-related images after they were attended? (e) Would there be differences in the attentional profiles of participants in the clinical PTSD and subthreshold PTSD groups, evidenced by different patterns of attention over the 6-s presentation time?

3. Materials and methods

3.1. Participants

Study participants were 18 individuals with a probable diagnosis of PTSD (based on their scores on the PTSD Checklist-Civilian; Weathers, Litz, Huska, & Keane, 1991, described below), 13 individuals with subthreshold symptoms of PTSD, and 20 individuals with no trauma exposure. The total sample ($N = 55$) consisted of 8 males and 47 females. Participant characteristics are listed in Table 1. Participants who used alcohol, sedatives, or illegal substances within 12 h of the study and those who endorsed significant symptoms of depression (defined below) were excluded from all analyses.

3.2. Measures

3.2.1. Life Stressor Checklist-Revised (LSC-R; Wolfe, Kimerling, Brown, Chrestman, & Levin, 1996)

The LSC-R is a self-report questionnaire that assesses for exposure to 30 potentially traumatic events (e.g. natural disasters, physical or sexual assault, sudden, unexpected death of a loved one). This measure was used to screen for potential study participants.

3.2.2. PTSD Checklist-Civilian (PCL-C; Weathers et al., 1991)

The PCL-C is a 17-item self-report questionnaire that assesses for the presence and severity of PTSD symptoms in a civilian population. This measure has been used extensively in both research and clinical settings with a wide range of populations and has convergent validity with the Clinician-Administered PTSD Scale (e.g. Ruggiero, Del Ben, Scotti, & Rabalais, 2003). Trauma-exposed participants were assigned to either the clinical PTSD symptom group or the subthreshold PTSD symptom group based on their PCL-C score. Trauma-exposed participants were assigned to the clinical PTSD symptom group if they had (a) a total score of 44 or higher on the PCL-C, and (b) a score of 3 ("moderately so") on one intrusion symptom, three avoidance symptoms, and two arousal symptoms. Trauma exposed participants who met only some of these criteria were assigned to the subthreshold PTSD symptom group ($n = 13$). Participants with no trauma history were assigned to the no-trauma-exposure group. Psychometric characteristics of the groups are listed in Table 1.

3.2.3. Beck Depression Inventory, 2nd Edition (BDI-II; Beck, Steer, & Brown, 1996)

The BD-II (Beck et al., 1996) is a 21-item self-report inventory that measures participants' depressive symptoms over the past two weeks. This measure was used to control for effects of depressed mood on attention by excluding participants who exhibited high levels of depressive symptom severity (defined as a BDI score of 30 or higher).

3.3. Stimuli

3.3.1. General threat trials

Stimuli were 60 images, divided equally between four categories: negative, positive, neutral, and general threat. Most of the images were collected from the Internet and the remainder from the International Affective Picture System database (Lang, Bradley, & Cuthbert, 2005). The 60 images were part of a larger set of images that were rated by 102 individuals in a separate study. Each image was rated for category (sad/negative/depressing; positive/happy; threatening/dangerous/scary; and neutral/no emotion) and emotional valence (on a scale from −5: very negative to +5: very positive). For the 60 images used in this study, at least 85% of the raters agreed to its category. The mean valence ratings for the negative, positive, general threat, and neutral images were −3.48, 2.92, −3.62, and 0.08, respectively.

3.3.2. Trauma-relevant threat trials

Stimuli were 60 images, divided equally between four categories: negative, positive, neutral, and trauma-relevant threat. These were different images than those used for the general threat trials described above, but were collected in the same manner. Each trauma-relevant threat image reflected content specific to each participant's self-identified trauma event on the LSC-R. As a consequence, it was necessary to create 30 separate sets of trauma-relevant threat images (with 15 images per set) to correspond to each of the 30 potentially traumatic events assessed for by the LSC-R. For example, one potentially traumatic event listed on the LSC-R is "motor vehicle accident"; for the motor vehicle accident trauma-relevant set, the 15 trauma-relevant threat images contained themes related to motor vehicle accidents (e.g. an image of a car accident with emergency service personnel on site). Similarly, for the trauma-relevant set "experiencing or witnessing adult interpersonal violence", the images depicted scenes of domestic violence.

Table 2
Percentage of first fixations for each image type.

Image type	PTSD	Subthreshold PTSD	No trauma exposure
Trials with a general threat image			
Neutral	11.9% (7.4)	11.2% (4.2)	10.2% (7.6)
Positive	35.1% (13.4)	34.8% (7.7)	31.6% (8.3)
Negative	26.3% (8.8)	31.3% (8.3)	33.0% (9.3)
General threat	26.4% (12.1)	22.5% (10.0)	25.0% (11.3)
Trials with a trauma-relevant threat image			
Neutral	6.3% (7.0)	8.2% (9.0)	5.8% (4.5)
Positive	30.6% (9.2)	30.7% (8.4)	30.5% (10.7)
Negative	33.1% (11.9)	37.4% (12.0)	36.9% (12.7)
Trauma-relevant threat	29.9% (10.9)	23.5% (11.0)	26.6% (12.7)

Note. Standard deviations in parentheses. PTSD, clinical PTSD symptom group; subthreshold PTSD, subthreshold PTSD symptom group; no trauma exposure, no-trauma exposure group.

3.4. Apparatus

Participants' eye movements were tracked and recorded continuously throughout each trial by an Eyelink I eye tracking system (SR Research Ltd., Mississauga, Ontario, Canada). Participants wore a small, lightweight headband equipped with cameras positioned below the eyes that tracked the position of the pupils as they moved. The system has an average gaze error of less than 0.5 degrees of visual angle and a sampling rate of 250 Hz. The eye-tracking system was connected to a Dell Dimension 8300 computer and a ViewSonic G225fb 21-in. flat screen monitor. The computer controlled the visual display and recorded the horizontal and vertical coordinates corresponding to the position of the right eye every 4 ms.

3.5. Procedure

An online survey consisting of a demographics questionnaire and the LSC-R was administered to 1086 undergraduate students. A random sample of participants who endorsed trauma exposure were invited to take part in the eye tracking component of the study. Participants who did not endorse any trauma exposure were also recruited. An appropriate trauma-relevant image set (e.g. domestic violence, motor vehicle accident, animal attack) was identified for each trauma-exposed participant based on his or her self-report on the LSC-R. The trauma events endorsed by individuals who participated in the study included abortion/miscarriage ($n = 1$), adult emotional abuse ($n = 3$), animal attack ($n = 1$), break-in/robbery ($n = 1$), childhood bullying ($n = 1$), childhood emotional abuse ($n = 1$), childhood physical abuse ($n = 7$), sudden unexpected death of a loved one ($n = 8$), experiencing or witnessing adult interpersonal violence ($n = 14$), motor vehicle accident ($n = 6$), sexual assault ($n = 7$), and suicide attempt or significant mental health difficulties ($n = 5$). Participants with no trauma exposure were randomly assigned to one of the trauma-relevant image sets viewed by trauma-exposed participants.

Participants were provided with written and spoken instructions at the beginning of the session and provided informed consent prior to data collection. They were told they would be viewing a "slide show" of images, that they could view the images in any manner they wished, and that their eye gaze would be tracked and recorded while they viewed the images. Participants were then seated in front of a computer display and fitted with the eye tracking head gear. After a brief calibration procedure, they were shown six practice trials to familiarize them with the procedures before data collection began.

At the start of each trial, participants were instructed to fixate on a black dot in the center of the display for three seconds in order to standardize starting gaze position. On each trial, four images were presented for 6 s. One image was placed in each of the four corners of the display (top left, top right, bottom left, bottom right). Images were randomly assigned to these positions and each image type (positive, negative, neutral, and general threat or trauma-relevant threat) was equally likely to appear in each corner. The images were presented at a display resolution of 1024×768 pixels on a white background. Care was taken to match the four images presented on each trial on scene complexity and vibrancy. There were 30 data trials in total: 15 general threat trials containing one negative, one neutral, one positive, and one general threat image, and 15 trauma-relevant threat trials, containing one negative, one neutral, one positive, and one trauma-relevant threat image. The 30 data trials were embedded within a set of 140 four image filler trials of a similar nature, all of which were presented in a random sequence. Two random trial sequences were created to control for order effects and these were alternated across participants.

4. Results

The dependent variables were the first fixation on each trial (the first image fixated) and the total fixation time for each image over the 6-s presentation (the sum of all fixation times). These measures were computed for each trial and then averaged over 15 trials (the 15 trials with a general threat image and the 15 trials with a trauma-relevant threat image). The data were converted to percentages for ease of interpretation (percentage of first fixations for each image type and percentage of total fixation time for each image type). The first fixation data is listed in Table 2 and the total fixation time data is listed in Table 3. The trials with a general threat image and the trials with a trauma-relevant threat image were analyzed separately.

4.1. Percentage of first fixations for each image type

The first fixation on each trial was used as a measure of the initial orienting of attention. If trauma exposed individuals were more likely to attend to general threat or trauma-relevant threat images first then this would be evidence of hypervigilance to threat. These data were analyzed using a 3 (Group: clinical PTSD symptom group, subthreshold PTSD symptom group, no-trauma-exposure group) $\times$ 4 (Image Type: negative, positive, neutral, general threat/trauma-relevant threat) mixed-model analysis of variance (ANOVA). The critical statistical test was the interaction between Group and Image Type; a significant interaction would indicate that the groups oriented to the images differently.

4.1.1. Trials with a general threat image

An analysis of the trials with a general threat image produced an effect of Image Type, $F(3,156) = 42.77$, MSE = 0.012, $p < .001$, partial $\eta^2 = .45$, with the lowest percentage of first fixations for neutral

Table 3
Percentage of total fixation time for each image type.

Image type	PTSD	Subthreshold PTSD	No trauma exposure
Trials with a general threat image			
Neutral	17.7% (6.6)	16.0% (6.0)	18.2% (3.9)
Positive	27.2% (8.9)	22.6% (4.0)	27.8% (9.6)
Negative	24.7% (7.8)	28.5% (5.0)	24.1% (4.5)
General threat	29.9% (10.1)	32.6% (6.5)	29.7% (7.8)
Trials with a trauma-relevant threat image			
Neutral	16.7% (5.3)	14.3% (4.9)	18.8% (4.1)
Positive	28.1% (10.3)	25.6% (7.3)	30.7% (7.0)
Negative	24.5% (6.6)	27.4% (5.8)	25.2% (5.5)
Trauma-relevant threat	30.5% (9.5)	32.6% (5.6)	25.3% (5.2)

Note. Standard deviations in parentheses. PTSD, clinical PTSD symptom group; subthreshold PTSD, subthreshold PTSD symptom group; control, no-trauma-exposure group.

images (11.2% of trials); for negative, positive, and general threat images the percentages were 30.3%, 33.9%, and 24.7%, respectively. There was no interaction between Group and Image Type, $F(6,156) = 1.06$, MSE = .012, $p > .10$.

4.1.2. Trials with a trauma-relevant threat image

An analysis of the trials with a trauma-relevant threat image produced equivalent results, with an effect of Image Type, $F(3,156) = 58.11$, MSE = 0.014, $p < .001$, partial $\eta^2 = .53$, again with the lowest percentage of first fixations for neutral images (6.8% of trials). For negative, positive, and trauma-relevant threat images the percentage of first fixations was 35.8%, 30.7%, and 26.7%, respectively. There was no interaction between Group and Image Type ($F < 1$).

Taken together, these two analyses indicate that the participants in the trauma-exposed groups did not fixate first on general threat or trauma-relevant threat images any more frequently than participants with no trauma exposure.

4.2. Percentage of total fixation time for each image type

The percentage of total fixation time for each image type over the 6-s presentation was analyzed using a 3 (Group: clinical PTSD symptom group, subthreshold PTSD symptom group, no-trauma-exposure group) × 4 (Image Type: negative, positive, neutral, general threat/trauma-relevant threat) mixed-model ANOVA.

4.2.1. Trials with a general threat image

The analysis of the trials with a general threat image produced an effect of Image Type, $F(3,156) = 23.30$, MSE = 0.007, $p < .001$, partial $\eta^2 = .31$, but no interaction between Group and Image Type, $F(6,156) = 1.29$, MSE = 0.007, $p > .10$. As can be seen in Table 3, there were large differences between the four image types in the percentage of time they were attended. However, the three groups did not differ significantly in their attention to the different images.

4.2.2. Trials with a trauma-relevant threat image

The analysis of the trials with a trauma-relevant threat image produced a different pattern of results. There was an effect of Image Type, $F(3,156) = 29.28$, MSE = 0.006, $p < .001$, partial $\eta^2 = .36$, and a significant interaction between Group and Image Type, $F(6,156) = 2.85$, MSE = 0.006, $p < .05$, partial $\eta^2 = .10$. The interaction was followed up using simple main effects to compare the three groups for each type of image. These tests revealed statistically significant differences for neutral images, $F(2,52) = 3.87$, MSE = 0.002, $p < .05$, partial $\eta^2 = .13$, and trauma-relevant threat images, $F(2,52) = 5.45$, MSE = 0.005, $p < .01$, partial $\eta^2 = .17$, but not for negative ($F < 1$) or positive images, $F(2,52) = 1.66$, MSE = 0.007, $p > .10$. *T*-tests were used to follow up the significant simple main effects. For neutral images, the only significant difference was between the subthreshold PSTD symptom group and the no-trauma-exposure group: participants in the subthreshold PTSD symptom group attended to the neutral images significantly less than participants in the no-trauma-exposure group (14.3% of total fixation time vs. 18.8%, respectively), $t(35) = 2.75$, $p < .01$. For trauma-relevant threat images, participants in the clinical PTSD symptom group and the subthreshold PTSD symptom group attended to these images significantly more than participants in the no-trauma-exposure group (30.5%, 32.6%, and 25.3% of total fixation time, respectively), $t(40) = 2.36$, $p < .05$, and $t(35) = 3.04$, $p < .001$, respectively. There was no difference between the clinical PTSD symptom group and the subthreshold PTSD symptom group, $t(29) = 0.85$, $p > .10$. Taken together, the total fixation time data indicate that participants in both trauma-exposed groups attended to trauma-relevant threat images more than participants in the no-trauma-exposure group over the course of the 6-s presentation, whereas for general threat images this was not the case.

4.3. Attention to threat images over time: time course analyses

To examine group differences in attention to the images over time, each 6-second trial was divided into three 2-s intervals (0–2 s, 2–4 s, and 4–6 s) and the percentage of fixation time for each image within each 2-s interval was calculated. These data are listed in Table 4 (trials with a general threat image) and Table 5 (trials with a trauma-relevant threat image). These data were analyzed using a 3 (Group: clinical PTSD symptom group, subthreshold PTSD symptom group, no-trauma-exposure group) × 4 (Image Type: negative, positive, neutral, general threat/trauma-relevant threat) × 3 (Time Interval: 0–2 s, 2–4 s, 4–6 s) mixed-model ANOVA. The critical statistical test was the three-way interaction between Group, Image Type, and Time Interval; a significant interaction would indicate that the groups differed in their attention to the images over the course of the 6-s presentation.

4.3.1. Trials with a general threat image

An analysis of the trials with a general threat image revealed an effect of Image Type, $F(3,156) = 26.01$, MSE = 0.019, $p < .001$, partial $\eta^2 = .33$; no effect of Group, $F(2,52) = 2.05$, MSE = 0.006, $p > .10$; no effect of Time Interval, $F < 1$; an interaction between Time Interval and Image Type, $F(6,312) = 14.69$, MSE = 0.009, $p < .001$, partial $\eta^2 = .22$; and no three-way interaction between Group, Time Interval, and Image Type, $F(12,312) = 1.16$, MSE = .009, $p > .10$. These data are listed in Table 4. Because the three-way interaction was not statistically significant no further analyses were necessary.

4.3.2. Trials with a trauma-relevant threat image

Table 5 lists the data from the trials with a trauma-relevant threat image. In this analysis there was an effect of Image Type, $F(3,156) = 32.75$, MSE = 0.016, $p < .001$, partial $\eta^2 = .39$; no effect of Group, $F < 1$; no effect of Time Interval, $F < 1$; an interaction between Group and Image Type, $F(6,156) = 3.67$, MSE = 0.016, $p < .01$,

Table 4
Percentage of fixation time for each image type for each time interval (trials with a general threat image).

Image type	PTSD	Subthreshold PTSD	No trauma exposure
0–2 s interval			
Neutral	11.8% (5.0)	8.5% (4.2)	12.2% (6.2)
Positive	24.0% (6.1)	25.2% (6.1)	24.7% (7.2)
Negative	26.6% (6.2)	29.1% (6.3)	25.0% (5.0)
General threat	37.4% (7.6)	37.1% (9.0)	38.0% (8.7)
2–4 s interval			
Neutral	21.2% (9.4)	17.3% (5.2)	21.6% (7.0)
Positive	24.5% (10.3)	20.4% (7.5)	27.2% (10.9)
Negative	24.2% (9.5)	29.0% (7.4)	25.0% (6.6)
General threat	29.7% (13.4)	33.3% (10.3)	25.9% (8.0)
4–6 s interval			
Neutral	20.1% (11.1)	20.8% (10.6)	21.5% (6.4)
Positive	32.2% (16.9)	22.0% (5.8)	30.0% (15.1)
Negative	24.5% (14.2)	28.5% (10.1)	23.0% (8.7)
General threat	22.9% (13.6)	28.6% (11.6)	25.2% (12.7)

Note. Standard deviations in parentheses. PTSD, clinical PTSD symptom group; subthreshold PTSD, subthreshold PTSD symptom group; no trauma exposure, no-trauma-exposure group.

partial $\eta^2 = .12$; an interaction between Time Interval and Image Type, $F(6,312) = 5.58$, MSE = 0.008, $p < .001$, partial $\eta^2 = .10$; and, most important, a three-way interaction between Group, Image Type, and Time Interval, $F(12,312) = 2.13$, MSE = 0.008, $p < .05$, partial $\eta^2 = .08$. The three-way interaction was followed-up using simple interaction contrasts (Group × Image Type interactions), one for each of the three time intervals (0–2 s, 2–4 s, and 4–6 s), to determine how the groups differed at each interval.

For the 0–2 s interval, the Group × Image Type simple interaction contrast was marginally significant, $F(6,156) = 2.07$, MSE = 0.007, $p = .06$, partial $\eta^2 = .07$. Simple main effects were used to look for differences between the groups for each image type. These analyses revealed a significant difference for trauma-relevant threat images only, $F(2,52) = 4.33$, MSE = 0.006, $p < .05$, partial $\eta^2 = .14$. Follow-up comparisons revealed that participants in the clinical PTSD symptom group attended to trauma-relevant threat images significantly more than participants in the no-trauma-exposure group (33.9% vs. 26.8% of fixation time), $t(40) = 2.89$, $p < .01$. In contrast, participants in the subthreshold PTSD symptom group did not attend to trauma-relevant threat images more than participants in the no-trauma-exposure group (31.1% vs. 26.8% of fixation time), $t(35) = 1.59$, $p > .10$.

For the 2–4 s interval, the Group × Image Type simple interaction contrast was significant, $F(6,156) = 2.37$, MSE = 0.01, $p < .05$, partial $\eta^2 = .08$. Simple main effects revealed significant differences between the groups for trauma-relevant threat images only, $F(2,52) = 4.95$, MSE = 0.01, $p < .05$, partial $\eta^2 = .16$. Follow-up comparisons revealed that participants in the subthreshold PTSD symptom group attended to trauma-relevant threat images more than participants in the no-trauma-exposure group (36.0% vs. 25.9% of fixation time), $t(35) = 3.00$, $p < .01$, whereas the participants in the clinical PTSD symptom group did not (26.8% vs. 25.9% of fixation time), $t(40) = 0.28$, $p > .10$. The participants in the subthreshold PTSD symptom group also attended to trauma-relevant threat images more than participants in the clinical PTSD symptom group (36.0% vs. 26.8% of fixation time), $t(29) = 2.58$, $p < .05$.

Finally, for the 4–6 s interval, the Group × Image Type simple interaction contrast was significant, $F(6,156) = 3.57$, MSE = 0.016, $p < .01$, partial $\eta^2 = .12$. Unlike the patterns observed in the analyses of the 0–2 and 2–4 s intervals, simple main effects revealed significant differences for all four image types: neutral images, $F(2,52) = 3.53$, MSE = 0.006, $p < .05$, partial $\eta^2 = .12$; positive images, $F(2,52) = 3.45$, MSE = 0.017, $p < .05$, partial $\eta^2 = .12$, negative images, $F(2,52) = 3.76$, MSE = 0.013, $p < .05$, partial $\eta^2 = .13$; and trauma-relevant threat images, $F(2,52) = 3.60$, MSE = 0.015, $p < .05$, partial $\eta^2 = .12$. The statistically significant group differences were as follows. For neutral images, participants in both trauma-exposed groups attended to neutral images less than participants in the no-trauma-exposure group (17.5% for the clinical PTSD symptom group, 15.8% for the subthreshold PTSD symptom group,

Table 5
Percentage of fixation time for each image type for each time interval (trials with a trauma-relevant threat image).

Image type	PSTD	Subthreshold PTSD	No trauma exposure
0–2 s interval			
Neutral	11.7% (4.5)	9.5% (4.7)	13.1% (6.3)
Positive	27.2% (7.2)	30.6% (8.3)	31.0% (8.4)
Negative	27.0% (6.4)	28.8% (8.3)	28.7% (6.2)
Trauma-relevant threat	33.9% (7.9)	31.1% (8.7)	26.8% (7.2)
2–4 s interval			
Neutral	20.8% (7.1)	16.2% (9.0)	20.7% (6.5)
Positive	27.3% (9.8)	23.9% (11.1)	29.1% (8.5)
Negative	25.0% (8.3)	23.9% (7.8)	24.1% (5.8)
Trauma-relevant threat	26.8% (12.1)	36.0% (9.9)	25.9% (7.4)
4–6 s interval			
Neutral	17.5% (7.7)	15.8% (7.6)	22.4% (8.3)
Positive	30.5% (18.0)	20.6% (7.1)	32.0% (10.6)
Negative	21.6% (12.3)	30.9% (8.8)	23.0% (8.1)
Trauma-relevant threat	30.1% (15.5)	32.4% (12.3)	22.2% (9.2)

Note. Standard deviations in parentheses. PTSD, clinical PTSD symptom group; subthreshold PTSD, subthreshold PTSD symptom group; no trauma exposure, no-trauma-exposure group.

22.4% for the no-trauma-exposure group), $t(40) = 1.99$, $p = .05$, and $t(35) = 2.39$, $p < .05$, respectively. For positive images, participants in the subthreshold PTSD symptom group attended to positive images less than participants in the clinical PTSD symptom group and the no-trauma-exposure group (20.6%, 30.5%, and 32.0% of fixation time, respectively), $t(29) = 2.09$, $p < .05$, and $t(35) = 2.53$, $p < .05$, respectively. Conversely, for negative images, participants in the subthreshold PTSD symptom group attended to negative images more than participants in the clinical PTSD symptom group and participants in the no-trauma-exposure group (30.9%, 21.6%, and 23.0% of fixation time, respectively), $t(29) = 2.58$, $p < .05$, and $t(35) = 2.31$, $p < .05$, respectively. Finally, for trauma-relevant threat images, participants in the clinical PTSD symptom group and the subthreshold PTSD symptom group attended to these images more than participants in the no-trauma-exposure group (30.1%, 32.4%, and 22.2% of fixation time, respectively), $t(40) = 2.05$, $p < .05$, and $t(35) = 2.39$, $p < .05$, respectively. This result indicates that PTSD-associated differences in attention to trauma-relevant threat were present even after the four images had been viewed for 4–6 s.

4.3.3. Trend analyses

To summarize, the time course analyses revealed that participants in the clinical PTSD symptom group attended to trauma-relevant threat images more than participants with no trauma exposure during the first 2 s of each trial (the 0–2 s interval); then, during the next 2 s (the 2–4 s interval) their attention to the trauma-relevant threat images decreased to the equivalent of the participants with no trauma exposure; then, during the last 2 s of the trial (the 4–6 s interval), their attention to these images increased and was greater than that of the participants with no trauma exposure. This pattern is consistent with early engagement with trauma-relevant images, followed by a brief period of avoidance, followed by a return of attention to these images. A trend analysis of this group's data supported this interpretation, with a significant quadratic trend in the pattern of means across the three intervals (33.9%, 26.8%, and 30.1% for the 0–2, 2–4, and 4–6 s intervals, respectively), $F(1,17) = 5.14$, MSE = .007, $p < .05$, partial $\eta^2 = .23$. By contrast, for the participants with no trauma exposure, attention to the trauma-relevant threat images decreased steadily over the 0–2, 2–4, and 4–6 s intervals (26.8%, 25.9%, and 22.2%, respectively), as evidenced by a significant linear trend in their data, $F(1,23) = 4.40$, MSE = .006, $p < .05$, partial $\eta^2 = .16$. A different pattern was observed for the participants in the subthreshold PTSD symptom group: these individuals exhibited heightened and sustained engagement with the trauma-relevant threat images; their attention to these images did not increase or decrease over the course of the 6-s presentation (31.1%, 36.0%, and 32.4% for the 0–2, 2–4, and 4–6 s intervals, respectively), as evidenced by the absence of a significant linear ($p > .10$) or quadratic ($p > .10$) trend in their data.

5. Discussion

The purpose of our study was to examine differences in attention to threat-related images as a function of trauma exposure and PTSD symptom severity, and to compare the attentional profiles of individuals with clinical and subthreshold levels of PTSD symptoms and individuals with no trauma exposure. To do so, we used eye gaze tracking to measure participants' attention while they viewed sets of positive, negative, neutral, and threat-related images over a 6-s presentation.

There are four key findings to consider. First, participants in the clinical and subthreshold PTSD symptom groups were no more likely to fixate first on threatening images (general threat or trauma-relevant threat) than participants with no trauma exposure. Thus, our data do not support an attentional profile defined by hypervigilance for either general or trauma-relevant threat stimuli. In this respect our results are different from those of Bryant et al. (1995) and Felminghman et al. (2011), who reported that participants with PTSD were more likely to initially fixate on threat words, whereas they are consistent with Kimble et al. (2010), who reported that high PTSD symptom participants were no more likely to initially fixate on threat images. One obvious difference between the four studies in question is the type of stimuli used (images versus words). It is possible that images, due to their greater visual saliency and complexity, are more likely to capture attention automatically regardless of whether the images are threat-related; if so, this would make it more difficult to detect differences in the initial fixations to threat images and other types of images. Another possibility is that our test for hypervigilance was less sensitive than those in previous eye tracking studies because we presented four types of images (positive, negative, neutral, and threat-related), whereas in previous studies threat-related words or images were always paired with neutral words or images. As a consequence, threat-related information may have been more salient in the displays used in previous studies. At the same time, our study may have provided a more naturalistic test for hypervigilance because we presented multiple images of different valences simultaneously. Finally, it is worth noting that although there was no evidence of hypervigilance in the first fixation data, the fixation time data indicated that participants in the clinical PTSD symptom group attended to trauma-relevant threat images more than participants in the no-trauma-exposure group during the first 2 s of each trial (the 0–2 s interval). Thus, perhaps defining "hypervigilance" as the first fixation is too restrictive and our data for the 0–2 s interval should also be considered evidence of hypervigilance. If so, then the fact that participants in the subthreshold PTSD group did not attend to these images more than participants in the no-trauma-exposure group during first 2 s is an important result, because it suggests that only clinical levels of PTSD are associated with hypervigilance.

The second key finding is that both the clinical PTSD symptom group and the subthreshold PTSD symptom group exhibited an attentional bias for trauma-relevant threat – both groups of participants attended to trauma-relevant threat images more than participants with no trauma exposure. Although few studies have examined attention to threat stimuli in individuals with subthreshold PTSD (and relative to individuals with no trauma exposure), the existence of a threat-related attentional bias in this group aligns with a number of findings in the literature. In particular, subthreshold PTSD is associated with significant and distressing impairment in a variety of domains, as previously noted, and threat-related attentional biases have been associated with the maintenance of PTSD symptoms (Chemtob, Roitblat, Hamada, Carlson, & Twentyman, 1988; Ehlers & Clark, 2000; Litz & Keane, 1989) and appear to diminish with symptom amelioration (El Khoury-Malhame et al., 2011). Thus, biased attention to threat-related stimuli in individuals with subthreshold symptoms of PTSD is consistent with researcher's current understanding of the role of attention in PTSD. An important question for future studies is whether biased attention to threat in this group represents a vulnerability factor for the development of future PTSD.

The third key finding is that the attentional biases exhibited by the clinical and subthreshold PTSD symptom groups were specific to trauma-relevant threat images – both groups of participants attended to trauma-relevant threat images more than participants with no trauma exposure, whereas for general threat images there were no group differences. This result is consistent with the recent findings of Fleurkens, Rinck, and van Minnen (2011), who reported that sexual-assault survivors with PTSD displayed increased Stroop interference to sexual assault-relevant threat words, but not to accident-related threat words. On the other hand, Kimble et al.

(2010), who used an eye tracking paradigm similar to our own, did not find that combat veterans attended to combat images significantly more than images of motor vehicle accidents (although the trend in their data was consistent with such a difference). Interestingly, Fleurkens et al. found that while most of their PTSD participants exhibited attentional bias specificity, a subgroup with high levels of arousal symptoms exhibited a generalized attentional bias to threat stimuli unrelated to their traumatic event (i.e., accident-related threat words). This finding suggests that heterogeneity in PTSD symptom presentation could moderate attentional bias specificity.

Finally, the time course and trend analyses revealed differences between the subthreshold and clinical PTSD symptom groups in their patterns of attention to trauma-relevant threat images over the course of the 6-s presentation. Relative to participants in the no-trauma-exposure group, participants in the clinical PTSD symptom group exhibited heightened attention to trauma-relevant threat images early in the trial (the 0–2 s interval), followed by a reduction in attention to these images during the middle of the trial (the 2–4 s interval), followed by an increase in attention to these images during the remainder of the trial (the 4–6 s interval). In contrast, participants in the subthreshold PTSD symptom group exhibited heightened attention to trauma-relevant threat images only later in the trial (the 2–4 s interval), and, unlike participants in the clinical PTSD symptoms group, they maintained this heightened attention throughout the remainder of the 6-s presentation. Thus, whereas the participants in the subthreshold PTSD symptom group sustained their heightened attention to trauma-relevant threat, participants in the clinical PTSD symptom group temporarily reduced their attention to trauma-relevant threat following initial engagement.

This reduction in attention to trauma-relevant threat images likely reflects avoidance of trauma-relevant stimuli, a phenomenon that is manifested behaviorally in individuals with PTSD (e.g. avoidance of places or reminders of a traumatic event; American Psychiatric Association, 1994). Avoidance of trauma-relevant stimuli may impair one's ability to habituate to trauma-relevant cues, which could in turn contribute to the development and/or maintenance of PTSD symptoms. Emotional processing of trauma-relevant cues is thought to be a critical component of successful recovery from PTSD (Foa & Kozak, 1986; Wells & Mathews, 1994) and an attentional bias away from threat could impede this processing. Extending this reasoning to individuals with subthreshold PTSD, it is possible that the pattern of sustained engagement with trauma-relevant threat images observed in this study reflects better processing of a trauma event, which facilitates habituation to trauma stimuli and limits symptom severity. This difference in the patterns of attention to trauma-relevant stimuli may therefore reflect a greater underlying vulnerability in those who are diagnosed with the full PTSD syndrome relative to those with a subthreshold level of symptoms.

6. Limitations and directions for future research

One limitation of the present study was the use of a relatively homogeneous university student sample, and therefore additional research with a community-based clinical sample will be necessary to determine if our results generalize to those with a clinical diagnosis of PTSD. Also note that the female-to-male gender ratio of our sample was 5.9 to 1, which is approximately twice that observed in the general population (2.7 to 1, according to the National Comorbidity Survey, 2005). Finally, our study did not control for time elapsed since trauma exposure, although the relatively young age of our sample restricted the range of this potentially important variable. Nevertheless, it is possible that attentional biases for trauma-relevant threat may generalize to general threat over time, and this possibility should be evaluated in future research.

7. Conclusions

The results of this study suggest that a threat-related attentional bias is present in individuals with subthreshold symptoms of PTSD, in addition to those with the full syndrome. Further, this bias appears to be specific to trauma-relevant stimuli and does not generalize to threat of a general nature. Time course and trend analyses revealed different patterns of attention as a function of PTSD symptom severity – participants with clinical symptoms exhibited immediate heightened attention to threat followed by its avoidance, whereas participants with subthreshold symptoms were slower to exhibit heightened attention to threat but then maintained that heightened attention over time. The attentional avoidance observed in participants with clinical PTSD symptoms may be an important factor in the maintenance of the disorder; avoidance of threat-relevant stimuli may interfere with an individual's ability to habituate to trauma cues (since exposure is a correlate of PTSD recovery). The results of this study highlight the advantages of including individuals with subthreshold symptoms in PTSD attention research and demonstrate the utility of eye tracking methods for understanding how attention to threat stimuli changes over time in individuals with varying symptom severity.

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