Attentional bias and its temporal dynamics among war veterans suffering from chronic pain

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Abstract

Background: Cognitive models propose that attentional dysregulation, including an attentional bias towards threat, is one of the factors through which chronic pain and post-traumatic stress symptoms (PTSS) maintain and exacerbate one another. The current investigation assessed the attentional bias for painful facial expressions and its relationship with PTSS, using both traditional and variability-based attentional bias measures, among veterans with chronic pain and PTSS and controls. Method: Fifty-four veterans with chronic pain and 30 age/education-matched controls participated in this investigation. Participants completed a self-report measure of PTSS and a modified version of the dot-probe task with painful, happy, and neutral facial expressions. Attention was assessed using both traditional and variability-based reaction time measures of attentional bias. Results: Veterans directed attention away from painful facial expressions (i.e., avoidance) relative to both the control group (between-subject effect) and relative to neutral faces (within-subject effect). Veterans also showed significantly elevated attentional bias variability for both happy and painful facial expressions compared to controls. Attentional bias variability for happy and painful facial expressions was correlated with PTSS among all participants. Conclusion: Veterans with chronic pain and PTSS avoided pain-related stimuli and displayed an overall attentional dysregulation for emotional facial expressions. Avoidance of pain cues may be a coping strategy that these individuals develop under stressful conditions. Implications, limitations, and directions for future research are discussed.

Keywords	Attentional bias; trial-level bias score; post-traumatic stress disorder; chronic pain; veterans; dot-probe task
Taxonomy	Cognitive Assessment, Behavioral Assessment

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Submission Files Included in this PDF

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PTSD_CP_MMazidi_Reviewers comments-R3_Final.docx [Response to Reviewers]

Highlights-Mazidi_PTSD_J_Anx_R1.docx [Highlights]

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Thank you for submitting your revised manuscript to Journal of Anxiety Disorders. We have now received detailed reviews from an expert in the field who did not review earlier versions of your manuscript. The manuscript has also been reviewed by our editorial team. As you will see in the comments attached below, the reviewer had a generally favorable reactions to your revised manuscript; however, as might be expected from a new reviewer, there were a number of additional issues that warrant your careful attention.

We would also like to emphasize that the manuscript continued to have a number of presentation issues that, if addressed, would improve overall flow, presentation, and impact. It is critical that these issues are identified and addressed through careful proof reading and attention to English language conventions.

We once again invite you to further revise your manuscript with particular attention to the questions raised by the reviewer and the presentation issues we highlight above. It is important to note that this invitation to revise and resubmit does not carry any guarantee of eventual acceptance and, given the nature of changes requested, a new round of reviews may be sought before reaching a decision.

When resubmitting your manuscript, please carefully consider all issues mentioned in the reviewers' comments, outline every change made point by point, and provide suitable rebuttals for any comments not addressed.

Sincerely,

Michelle Newman, PhD
Associate Editor

Gordon Asmundson, PhD
Editor-in-Chief
Journal of Anxiety Disorders

Thank you for the opportunity to respond to the third reviewer's comments and re-submit our manuscript for further consideration in the Journal of Anxiety Disorders. We have addressed the concerns below. Our comments in response to the reviewer's comments can be found in blue, and any new text added to the manuscript can be found in red. A native speaker has proofread the final version of the manuscript.

Comments from the editors and reviewers:
-Reviewer 3

-

As someone entering this process *in medias res,* I have read the correspondence between reviewers and authors as well as the latest version of the manuscript. The authors have conscientiously attended to concerns raised during the previous rounds of reviews. My comments appear below, keyed to pages in the manuscript.

1. (p. 7) Classic experiments by MacLeod, Mathews, and others on attentional bias for threat were theoretically grounded. The authors' prediction about an attentional bias toward facial depictions of pain fits into this framework. Yet it is unclear why the authors predict that variability in responding to cues of positive as well as negative valence should characterize patients suffering PTSS symptoms and chronic pain. It is not evident why variability is a feature of psychopathology. Indeed, the lack of variability in heart rate (for example) characterizes people with GAD, for example.

   Response: Many thanks to the reviewer for the insightful comment. We would like to start our reply from the point mentioned about the Heart Rate Variability (HRV). Reduced HRV has been suggested to be a result of over functioning sympathetic system's activation, which can lead to increased stress-related hormonal release that can cause a contraction in heart muscles which would result in reduced variability. However, the underlying mechanism that plays a role in the variability of attentional bias might be beyond first-order interaction between sympathetic and parasympathetic systems. An increase in the AB variability can be the result of a more general impairment in top-down control like attentional control (however the exact mechanisms are needed to be examined through carefully designed studies for that purpose). Most studies in the literature examined the variability in negatively valenced stimuli and showed its relationship with psychopathology in patients, but there are also studies like the one by Carlson et al., 2018 suggesting that there is greater variability in attention for both negatively and positively valenced stimuli. We tried to clarify this when we describe our hypothesis (page 7, lines 11-13) and also in the discussion (pages 19, line 23; page 20, lines 1-6):

   Moreover, other studies have shown that positively-salient images can disrupt attention in anxious (Chen, Clarke, Watson, MacLeod, & Guastella, 2014; Taylor, Bomyea, & Amir, 2010) and traumatized populations (Blair et al., 2013; Fani et al., 2019).

   Besides, we now made it clear in the manuscript that an empirically supported explanation has not yet been put forward to

delineate the mechanism by which elevated ABV is associated with (and might lead to) psychopathology. We also extended the discussion to highlight the need for future research to test theoretical positions and proposed theoretical possibilities that future researchers may address. It should be noted though that despite the mentioned limitation, previous findings that showed elevated ABV as a marker of PTSD are important as the identification of markers can have theoretical and practical implications (Grant et al., 2003). Please also see the response to the last comment.

In the introduction (page 6, line 23; page 7, line 1):

Elevated ABV has been shown to be associated with higher levels of emotion dysregulation (Bardeen et al., 2017) and also impairments in cognitive control (Swick & Ashley, 2017).

In the discussion (page 20, lines 7-20 and 25-29):

Findings from previous studies that have shown that elevated temporal dynamics of AB are associated with higher levels of PTSS are consistent with the possibility that elevated TL-BSs are a marker for PTSS. Identifying markers of psychopathology has theoretical and practical implications (Grant et al., 2003); however, the potential contributions of increased temporal variability in AB as a marker for PTSS are limited by the current state of the literature. The theoretical aspects of the association between variability in AB and PTSS have not been systematically examined. Clearly articulated and theory-driven models that explain the mechanisms by which greater variability in AB is associated with PTSS are needed to advance research in the field. One potential mechanism that may underlie differences in the temporal dynamics of AB is impaired top-down control processes (e.g., attentional control; (Badura-Brack et al., 2015; Swick & Ashley, 2017). As such, impaired top-down control processes serve as a potential target for interventions designed to reduce PTSS. Attentional control training is an approach to attention modification that is believed to exert effects upon temporal dynamics of AB by enhancing attentional control (Badura-Brack et al., 2015). This training method, which is similar to control conditions in most attention bias modification studies, was more effective at decreasing PTSS compared to the usual look-away threat ABM (Badura-Brack et al., 2015) and bias-contingent ABM (Lazarov et al., 2018).

2. (p. 14) The Benjamini-Hochberg method of correcting for multiple comparisons is a better method than the Bonferroni method. The former lowers the risk of Type II errors.

Response: We thank the reviewer for their careful attention to the statistical approaches used. We changed the correction method and updated the methods and results sections accordingly. The new method

resulted in a few more significant correlations. Among all participants significant correlations found between mean TL-BS scores for pain faces and PTSS, TL-BS variability for happy faces and anxiety and stress. More importantly, among veterans, TL-BS parameters for happy faces significantly correlated with PTSS and depression.

Page 13, lines 21-23:

Benjamini-Hochberg correction for controlling the false discovery rate (Benjamini & Hochberg, 1995). The Benjamini-Hochberg method of controlling for multiple comparisons has been shown to be more powerful than comparable procedures that control the traditional familywise error rate (Benjamini & Yekutieli, 2001).

Page 16, lines 13-21:

Correlational analyses for self-report measures and attentional indices were performed for all participants and each group separately using a Benjamini-Hochberg correction. Detailed results of these analyses are provided as supplementary material; here, we provide only a brief summary. Among all participants, TL-BS parameters from trials with happy facial expressions were significantly correlated with PTSS and symptoms of depression, anxiety, and stress. For trials with painful facial expressions, TL-BS parameters were significantly correlated with PTSS and TL-BS variability was significantly correlated with depression and stress. Among veterans, TL-BS parameters for happy facial expressions were significantly correlated with PTSS and symptoms of depression.

3. (p. 15) Miller and Chapman (2000, *Journal of Abnormal Psychology*) have convincingly argued that the use of ANCOVA to "control for" variables (e.g., M-PTSD scores) is mistaken when subjects have not been randomly assigned to groups (e.g., as in the present study).

Response: We appreciate the reviewer for introducing this highly relevant and interesting paper. We have explored this issue and are in agreement with the reviewer. We removed the ANCOVA analysis and two footnotes related to using ANCOVA for controlling for covariates.
To provide some context for the currently analytic approach, we would like to note that the first reviewer asked us to present analyses considering the role of PTSD symptomatology and suggested using median split or examining correlations between PTSD symptoms and attentional bias measures. We used a median split on PTSD level nested on the group design and provided correlation analyses; however, the second reviewer rightly noted that using a median split with this design is arbitrary and that our median split used different cut-off numbers between groups. The second reviewer subsequently suggested we treat PTSD levels as a continuous variable in an ANCOVA.

We made two other significant changes in the current revision in an attempt to address comments we have received from all three reviewers. Firstly, we modified correlation results based on the Benjamini-Hochberg method for all participants and for the two groups separately. We added a sentence about the correlations between pain-related measures and attentional measures in the discussion. One previous study that examined attentional bias variability among PTSD patients (Swick & Ashley, 2017) also provided correlations instead of using ANCOVA and trying to "control for covariate effects". Secondly, we used multiple regression as a supplementary analysis to the ANOVAs to examine the role of PTSS more specifically and to determine whether the significant effects were driven by PTSS level or chronic pain group status. These analyses are included as supplementary material to decrease the length of the manuscript and thus burden on the readers.

Page 14, lines 2-5:

As an ancillary analysis designed to examine the role of PTSS more specifically and determine whether the significant effects were driven by PTSS or group status, we ran multiple regression analyses for the dependent variables that differed significantly between groups (see supplementary material).

4. (p. 21) It is not obvious to me why clinicians would want to target AB variability or why reducing variability would someone reduce symptoms. Late in the manuscript the authors wonder whether variability in the dot-probe paradigm might signify poor overall executive control. Perhaps. But if so, why not directly attempt to augment attentional control with other procedures? And if these patients had better control over their attention, how would they exercise it to reduce their suffering? The assumption seems to be that poor attentional control explains why chronic pain and PTSS symptoms are chronic, and by diminishing variability (control?) pain and PTSS should diminish. Arguments to support (what seems to be) their claims would be welcome.

Response: So far, a large clinical effect size for attentional control training on PTSS has been evidenced by three independent RCTs: two in military veterans (Badura-Brack et al., 2015) and one in civilians (Lazarov et al., 2018); however, the absence of a theoretical framework represents a major limitation when considering the clinical implications of modifying ABV. The researchers of the aforementioned RCTs suggested that the enhanced symptom reduction in attentional control training compared to attention bias modification is due to its more robust effect on attentional bias variability and improvement of attentional control (Basanovic et al., 2017). There are some evidence that show attentional control can act as a buffering mechanism against prolonged attentional engagement with threat-related stimuli among those with high PTSS (Bardeen & Orcutt, 2011)

and high pain catastrophizing (Heathcote et al., 2015). Also, higher attentional control may increase the stability of information processing by decreasing ABV (as elevated ABV can be considered a deficit in the stability of information processing). But the above-mentioned RCTs did not directly assess attentional control (or other cognitive control factors) and, therefore, cannot provide enough evidence that attentional control training enhances attentional control. Overall, more research on the nature of ABV, the mechanisms underlying ABV, and the role of ABV in psychopathology is needed to refine the current interventions.

We have added a few sentences to the discussion to highlight the need for systematic examination of different strategies for the management of attentional bias (page 20, lines 26-29; page 21. Lines 1-3). Please also see the response to the first comment.

Enhanced symptom reduction in attentional control training over ABM is thought to be due to improved attentional control (Basanovic, Notebaert, Grafton, Hirsch, & Clarke, 2017). The above-mentioned studies did not directly assess attentional control (or other top-down control processes), precluding conclusive determinations of the mechanisms driving the enhanced effects of attentional control training. Further research specifically designed to elucidate the mechanisms underlying associations between psychopathology and the temporal dynamics of AB is needed to optimize the therapeutic benefits of attentional interventions.

Highlights

- Chronic pain is highly comorbid with PTSD symptoms in war veterans
- Attentional bias in pain is suggested to be relevant to anxiety in chronic pain
- Veterans showed a greater attentional bias away from pain-related cues
- Avoidance from pain may indicate suppression of emotion in stressful situations
- Suppression is maladaptive and may result in consequent emotional problems

Attentional bias and its temporal dynamics among war veterans suffering from chronic pain: investigating the contribution of post-traumatic stress symptoms

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Abstract

Background: Cognitive models propose that attentional dysregulation, including an attentional bias towards threat, is one of the factors through which chronic pain and post-traumatic stress symptoms (PTSS) maintain and exacerbate one another. The current investigation assessed the attentional bias for painful facial expressions and its relationship with PTSS, using both traditional and variability-based attentional bias measures, among veterans with chronic pain and PTSS and controls.

Method: Fifty-four veterans with chronic pain and 30 age/education-matched controls participated in this investigation. Participants completed a self-report measure of PTSS and a modified version of the dot-probe task with painful, happy, and neutral facial expressions. Attention was assessed using both traditional and variability-based reaction time measures of attentional bias.

Results: Veterans directed attention away from painful facial expressions (i.e., avoidance) relative to both the control group (between-subject effect) and relative to neutral faces (within-subject effect). Veterans also showed significantly elevated attentional bias variability for both happy and painful facial expressions compared to controls. Attentional bias variability for happy and painful facial expressions was correlated with PTSS among all participants.

Conclusion: Veterans with chronic pain and PTSS avoided pain-related stimuli and displayed an overall attentional dysregulation for emotional facial expressions. Avoidance of pain cues may be a coping strategy that these individuals develop under stressful conditions. Implications, limitations, and directions for future research are discussed.

Keywords: *Attentional bias; trial-level bias score; post-traumatic stress disorder; chronic pain; veterans; dot-probe task*

1. Introduction

Various theoretical models include attentional biases (ABs), or the preferential allocation of attention towards or away from certain types of stimuli (Cisler & Koster, 2010), as important mechanisms influencing the development and maintenance of psychological disorders (Beck & Clark, 1997; Mathews & Mackintosh, 1998). ABs include hypervigilance, where attention is directed towards relevant stimuli, maintenance, where there is difficulty disengaging attention from relevant stimuli, and avoidance, where attention is directed away from relevant stimuli (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007). Most of the research on AB and psychological disorders has examined an AB for threat in anxiety-related disorders, including post-traumatic stress disorder (PTSD). Some researchers describe the association between AB for threat and post-traumatic stress symptoms (PTSS) as a robust phenomenon (Buckley, Galovski, Blanchard, & Hickling, 2003; Constans, 2005) while others suggest that results supporting this association are mixed and weak at best (Schäfer, Zvielli, Hofler, Wittchen, & Bernstein, 2018). Several studies with null findings have been reported in the literature on the AB for threat and PTSS (e.g., Elsesser, Sartory, & Tackenberg, 2004, 2005), and failure to replicate significant findings is common in the AB literature (e.g., Kimble, Frueh, & Marks, 2009).

Chronic pain has been described as pain that persists for at least 3 months and leads to functional impairment (International Association of the Study of Pain, 1986). Researchers and clinicians have largely shifted away from a purely biomedical understanding of chronic pain and moved towards a biopsychosocial perspective, including a focus on how cognition contributes to chronic pain. For example, the fear-avoidance model recognizes the important role of attentional processes in the maintenance of chronic pain (Crombez, Eccleston, Van Damme, Vlaeyen, & Karoly, 2012). When pain is acute, hypervigilance for pain information can be adaptive in the

short-term and help the physical recovery process by encouraging avoidance of behaviors that may cause further injury; but, hypervigilance and behavioral avoidance after the acute pain stage can lead to disuse of muscle and a lower pain threshold (Crombez et al., 2012). Despite theoretical support for chronic pain-related ABs, empirical support for these biases has been inconsistent. According to Crombez and colleagues (2013), there is a small ($d = 0.134$), but significant, within-group AB towards sensory pain words in individuals with chronic pain. Healthy controls did not demonstrate the same AB; however, there was no significant difference in the AB for pain-related stimuli between individuals with chronic pain and healthy controls.

Chronic pain frequently co-occurs with anxiety disorders, and with PTSS in particular. An estimated 18.9% of individuals with chronic pain reported trauma exposure and PTSS (Ravn, Vaegter, Cardel, & Andersen, 2018). Prevalence estimates are even greater when examining specific populations. For example, recent reviews found that 50% of veterans with chronic pain also had PTSS (Fishbain, Pulikal, Lewis, & Gao, 2017; Siqveland, Hussain, Lindstrom, Ruud, & Hauff, 2017). Various theoretical models posit potential explanations for the association between chronic pain and PTSS/PTSD. The mutual maintenance model put forth by Sharp and Harvey (2001) suggests that chronic pain and PTSD maintain and exacerbate one another through specific cognitive, affective, and behavioral components (e.g., avoidance, attentional and reasoning biases). The shared vulnerability model proposed by Asmundson and colleagues (Asmundson, Coons, Taylor, & Katz, 2002; Asmundson & Katz, 2009) also includes ABs as one of the potential mechanisms that contribute to the co-occurrence of chronic pain and PTSD. However, once again, theoretical support exceeds empirical support as there is very little research examining ABs in individuals with comorbid chronic pain and PTSD.

ABs towards pain-related stimuli have been demonstrated in individuals with chronic pain (e.g., Khatibi, Dehghani, Sharpe, Asmundson, & Pouretemad, 2009; Mahmoodi-Aghdam, Dehghani, Ahmadi, Khorrami Banaraki, & Khatibi, 2017) and those with PTSS separately (e.g., Thomas, Goegan, Newman, Arndt, & Sears, 2013); however, to date, only two studies have investigated ABs in participants with comorbid chronic pain and PTSS. Researchers used the modified Stroop task, a variation of the original Stroop task (Stroop, 1935), with lists of emotionally salient (i.e., pain-related, trauma-related, and positive) and neutral words printed in various colors (Beck, Freeman, Shipherd, Hamblen, & Lackner, 2001). Participants were instructed to name the color of each word (e.g., "agony" written in blue). Longer RTs when reading emotionally salient words compared to neutral words indicates the presence of an AB (Bar-Haim et al., 2007). The modified Stroop task only provides an overall index of AB; that is, the paradigm cannot be used to assess the direction of an AB (i.e., hypervigilance, maintenance, or avoidance). The researchers compared biases across participants with comorbid chronic pain and PTSD, those with chronic pain only, and trauma-exposed controls (Beck et al., 2001). Individuals with comorbid chronic pain and PTSD and those with chronic pain only displayed an AB for pain-related words, as evidenced by both within- and between-group effects. In other words, individuals with chronic pain (with or without comorbid PTSD) responded slower to pain-related words compared to neutral or positive words, and they responded slower to pain-related words compared to trauma-exposed controls.

More recently, researchers used the startle probe paradigm in combination with pain-related, trauma-related, health-related, pleasant, and neutral words to compare ABs in individuals with chronic pain alone, PTSD alone, comorbid chronic pain and PTSD, any other anxiety disorder, and trauma-exposed controls (Carleton, Duranceau, McMillan, & Asmundson, 2018).

The researchers hypothesized that participants would display AB towards diagnosis-congruent stimuli (e.g., pain-related stimuli for participants with chronic pain), which were thought to be perceived as the most threatening. However, compared to participants with anxiety disorders and the control group, individuals with PTSD or chronic pain showed greater startle intensity and delayed startle peak (responded more slowly, indicating higher fear-related reactivity) for all words, regardless of their types. The authors concluded that their results suggest psychophysiologically measurable differences that accompany chronic pain and PTSD, which could be indicative of an AB that is not specific to disorder-relevant stimuli.

The two studies described above provide somewhat inconsistent results for AB in individuals with chronic pain and PTSS. Due to methodological limitations, it is difficult to confidently draw conclusions about ABs in co-occurring chronic pain and PTSS from these studies. First, pictorial stimuli are more ecologically valid than word stimuli (Dear, Sharpe, Nicholas, & Refshauge, 2011a); but, both investigations discussed above used word stimuli. Second, concerns have been raised in the literature regarding how results from the modified Stroop task are interpreted and the potential mechanisms underlying longer RTs (e.g., Algom, Chajut, & Lev, 2004). Results from the modified Stroop task also do not provide information on whether an AB is characterized by hypervigilance, maintenance, or avoidance. A different measure of AB, the pictorial dot-probe task, may provide a more valid assessment of AB for individuals with chronic pain and PTSS. Another strength of the dot-probe task is that it allows researchers to calculate variability-based measures of AB, such as Trial-Level Bias Scores (TL-BSs) and the attentional bias variability (ABV) index, which account for intra-individual fluctuations of attention toward and away from stimuli over time (Iacoviello et al., 2014; Zvielli, Bernstein, & Koster, 2015). Elevated ABV has been associated with higher levels of emotion dysregulation (Bardeen, Daniel,

Hinnant, & Orcutt, 2017) and impaired cognitive control (Swick & Ashley, 2017). Some researchers have employed TL-BSs and observed positive associations between within-subject variability in ABs and PTSS (Yuval, Zvielli, & Bernstein, 2016). To the best of our knowledge, no investigation to date has used variability-based measures when examining individuals with chronic pain and PTSS.

The current investigation examined ABs for pain-related stimuli in individuals with chronic pain and PTSS. Focusing on the severity of PTSS, as opposed to PTSD as a diagnosis, may be more informative given that subsyndromal levels of PTSD are also associated with significant impairments (Bryant et al., 2015; Ravn et al., 2018; Stein, Walker, Hazen, & Forde, 1997). We hypothesized that compared to controls, veterans with chronic pain and PTSS would demonstrate an AB towards painful facial expressions. Consistent with past research (Carlson, Aday, & Rubin, 2018), we also hypothesized that veterans with chronic pain and PTSS would display greater temporal variability in the AB for both types of emotional stimuli, irrespective of valence. Finally, we expected the temporal dynamics of AB to be associated with PTSS.

(Introduction: 1364 words)

2. Method

2.1. Participants

Veterans referred to a medical council between April 2015 to March 2016 for chronic pain (i.e., persistent pain for at least 3 months) were approached by the experimenter (M.M.) while waiting for their medical visits and invited to participate in the research. All veterans had long-term injuries (not including traumatic brain injuries) due to war participation. Age and education cohort-matched control participants without any history of military service were recruited from the general population to serve as the control group. Individuals were eligible to

participate in the investigation if they were between 18 and 65 years old, had normal or corrected to normal vision, were able to use both hands, and could understand and speak Persian fluently. Exclusion criteria included any diagnosis of a neurological disorder, a history of psychotic disorder, or current substance abuse. The investigation was approved by the research ethics committee at AJA medical university. All participants provided written informed consent prior to participation.

Sixty-five male veterans with chronic pain and 30 controls agreed to participate in the investigation. Data from 11 veterans were excluded from analysis; two were removed due to technical problems, five returned questionnaires incomplete, and four were removed due to poor performance in the dot-probe task (i.e., more than 20% skipped trials or incorrect responses). This cut-off for poor performance has been used in past AB research (Fani et al., 2012; Fani, Bradley-Davino, Ressler, & McClure-Tone, 2011). The final sample included 54 veterans (mean age = 51.44 years, SD = 3.78, range = 43-60 years; 100% married; mean education = 12.06 years, SD = 3.84, range = 5-22 years) and 30 controls (mean age = 49.17 years, SD = 6.60; range = 36-59 years; 93.3% married; mean education = 13.33 years, SD = 3.62, range = 5-22 years). The average pain duration among veteran participants was 24.81 years (SD = 9.32), and the distribution of pain locations was as follows: 10.33% upper limbs, 10.34% lower limbs, 5.16% back pain, and 74.13% pain in more than one location. The majority of the veterans attributed their chronic pain to an injury sustained during a traumatic experience (81.13%).

2.2. Materials and procedure

2.2.1. Mississippi Scale for Combat-Related PTSD (M-PTSD; Keane, Caddell, & Taylor, 1988)

The M-PTSD is a 35-item self-report scale that produces a total score indicative of PTSD symptom severity. Both military and civilian versions of this scale have shown good psychometric properties, with a test-retest reliability of .97 (Keane et al., 1988), and internal consistency of .96 for help-seeking (McFall Miles, Smith Dale, Mackay Priscilla, & Tarver David, 1990) and .93 for community-based veterans, respectively (Kulka et al., 1990). This scale has been validated in Iran in a comparable sample of individuals and showed good to excellent psychometric properties (Goodarzi, 2003). Original and civilian versions of the M-PTSD were used to assess PTSS in veterans and healthy controls, respectively. In the current investigation, internal consistency (Cronbach's alpha) of the M-PTSD was .91.

2.2.2. Visual analogue scale (VAS)

The pain VAS was used to assess past, present, and anticipated future pain severity. A VAS is a 10-cm ungraded horizontal line with one anchor at either end. The left anchor indicates "no pain at all" and the right anchor indicates "maximum possible pain". Participants were asked to use three VAS lines to rate their average pain intensity in the previous week, current pain, and expected pain in the next week. VAS has shown adequate test-retest reliability among literate chronic pain patients ($r = 0.94$; Ferraz et al., 1990). It also has been shown to be highly correlated with other measures of pain (Hawker, Mian, Kendzerska, & French, 2011). Given our clinical sample, we chose VAS because of its simple administration and understandability.

2.2.3. Fear of Pain Questionnaire (FPQ-III; McNeil & Rainwater, 1998)

The FPQ-III is a 30-item self-report questionnaire designed to evaluate fear of various painful experiences (e.g., "*Biting your tongue while eating"*). Participants rate items on a 5-point Likert scale from 1 (*not at all*) to 5 (*extreme*). The FPQ-III has high test-retest reliability ($r =$ 0.92), and internal consistency (Cronbach's alpha = 0.74; McNeil & Rainwater, 1998) and has

been used in both clinical and non-clinical populations (Roelofs, Peters, Fassaert, & Vlaeyen, 2005). The Persian version of the questionnaire has reported good psychometric properties in previous research (Dehghani, Mohammadi, Sharpe, & Khatibi, 2018). In the current investigation, the internal consistency for the FRQ-III was .92. Fear of pain was assessed due to its theoretical relevance to chronic pain (Leeuw et al., 2007).

2.2.4. Depression Anxiety Stress Scales (DASS-42; Lovibond & Lovibond, 1995)

The DASS-42 includes three 14-item sections designed to assess depression, anxiety, and stress in the past week. Participants rate items on a 4-point Likert scale from 0 (*did not apply to me at all*) to 3 (*applied to me very much, or most of the time*). Given our chronic pain sample, the DASS-42 was chosen because it focuses less on somatic symptoms compared to other measures of depression and anxiety (Wood, Nicholas, Blyth, Asghari, & Gibson, 2010). The DASS-42 has strong construct validity and reliability (Antony, Bieling, Cox, Enns, & Swinson, 1998) and has been used in previous studies with chronic pain patients (Dehghani, Sharpe, & Nicholas, 2004). For the current sample, internal consistency for the depression, anxiety, and stress subscales were .95, .91, and .93, respectively.

2.2.5. Dot-probe task (MacLeod, Mathews, & Tata, 1986)

The pictorial version of the dot-probe task used in this investigation was programmed using the Affect 4 software package (Spruyt, Clarysse, Vansteenwegen, Baeyens, & Hermans, 2010) and presented on a 14-inch monitor ASUS X44H Intel Pentium computer. Each trial began with the presentation of a fixation cross in the center of the monitor. After 500 ms, two pictures of facial expressions were presented one above the other. Each trial consisted of one painful or happy (i.e., target) face and one neutral face from the same person. Faces remained on screen for 500 ms. After the pictures disappeared, a probe (i.e., a dot) appeared in the location of either the

neutral or target face. Participants were instructed to respond as quickly and accurately as possible by pressing the down-arrow key if the probe replaced the bottom face or the up-arrow key if the probe replaced the top face. The trial ended automatically after 2000 ms or immediately after the participant pressed one of the response keys. Inter-trial durations ranged from 800-1000 ms.

The dot-probe task included 16 practice trials, which used nature pictures, and 80 experimental trials. Experimental trials included pairs of painful-neutral and happy-neutral faces set against a grey background. Stimuli consisted of photos of 10 adults (5 females) that were taken from the Montreal Database of Facial Expressions (Roy et al., 2007). Non-facial features were removed to avoid distracting participants from processing the facial expressions (Nusseck, Cunningham, Wallraven, & Bulthoff, 2008). Each target face was randomly presented four times in all possible combinations (i.e., target up/dot down; target up/dot up; target down/ dot down and target down/dot up). This version of the dot-probe task has been used in previous studies investigating AB for pain-related information (Mohammadi, Dehghani, Khatibi, Sanderman, & Hagedoorn, 2015). The dot-probe task took 6 minutes to finish on average and was completed before the questionnaires.

2.3. Data preparation

Incorrect responses in the dot-probe task were removed (1.9% of trials for veterans and 1.1% of trials for the control group). There was no significant difference between groups for the number of incorrect responses [$t(78.87) = 1.57$, $p = .119$]. In line with the recommendations provided by Price et al. (2015) to enhance reliability and minimize missing values with dot-probe data, outliers in the dot-probe task were Winsorized, a data-driven method that involves reassigning outliers to the nearest value in the valid (i.e., non-outlier) distribution. Winsorizing is

a modern and robust method for working with outliers that is supported by statisticians (Erceg-Hurn & Mirosevich, 2008). It allows researchers to eliminate extreme values while maximizing power and accuracy because more data points are retained for analysis. Using the values recommended by Price et al., (2015), RTs outside 1.5 interquartile ranges from the 25th and 75th percentiles of each participant's RT distribution were rescaled to the closest non-outlier value.

We calculated traditional indices of AB, as well as TL-BS parameters as measures of the temporal dynamics of AB (Zvielli et al., 2015). Mean AB was calculated by subtracting the mean reaction time of congruent trials (trials where the probe is presented in the same location as the target face) from the mean reaction time of incongruent trials (trials where the probe is presented in the same location as the neutral face). A positive AB value reflects an AB towards the target facial expressions while a negative AB value signifies avoidance or an AB away from the target facial expressions. Separate AB indices were calculated for trials with happy faces and those with painful faces.

TL-BSs were computed by subtracting each incongruent trial from its most proximate congruent trial (but no further than five trials away) for each emotional facial expression type separately (Zvielli et al., 2015). The following TL-BS parameters were computed for painful and happy facial expressions, individually: **Mean TL-BS $_{TOWARD}$**, the mean of all TL-BS scores > 0 ms per person; **Mean TL-BS $_{AWAY}$**, the mean of all TL-BS scores < 0 ms per person; **Peak TL-BS $_{TOWARD}$**, the maximum TL-BS or the peak AB toward target stimuli**; Peak TL-BS $_{AWAY}$**, the minimum TL-BS score or the peak AB away from target stimuli; and **TL-BS Variability,** an overall measure of the temporal stability of the AB towards and away from target stimuli over time, which is calculated by summing the distances between sequential TL-BS bias scores and dividing by the total number of TL-BS scores.

In line with best practice recommendations for AB research (Dear, Sharpe, Nicholas, & Refshauge, 2011b; Price et al., 2015; Waechter, Nelson, Wright, Hyatt, & Oakman, 2014), we calculated reliability estimates for traditional AB scores and TL-BS parameters. The Splithalf package (Parsons, 2018) was used to measure split-half reliability of the traditional AB scores, which allows bootstrapped split-half correlations performed for 5000 random splits, yielding more stable reliability estimates than the conventional method of odd-even splits of trials (Enock, Hofmann, & McNally, 2014). The Spearman-Brown prophecy formula was used to correct for test length. The reliability of TL-BSs was measured by testing the association between each parameter from the first half of the task with its second half (Zvielli, Vrijsen, Koster, & Bernstein, 2016).

2.4. Data analysis

Preliminary analyses included independent *t*-tests to examine the potential differences between groups on demographic and psychological variables. One sample *t*-tests were used to examine within-subject AB for each group separately. A series of two-way ANOVAs were performed with participant group (veterans or controls) as the between-group variable and type of target stimuli (painful or happy) as the within-group variable, with AB indices as dependent variables (i.e., AB, Mean TL-BS_{TOWARD}, Mean TL-BS_{AWAY}, Peak TL-BS_{TOWARD}, Peak TL-BS_{AWAY}, and TL-BS variability). Where significant effects were observed, *t*-tests were used to clarify differences. Additionally, *t*-tests were used to probe differences that were hypothesized a priori and approached significance. Partial eta-squared and Cohen's *d* were applied to quantify effect sizes. The α was set to 0.05 for ANOVAs and *t*-tests. We also examined correlations between self-report measures and attentional indices using Pearson correlations and a Benjamini-Hochberg correction for controlling the false discovery rate (Benjamini & Hochberg, 1995). The Benjamini-Hochberg method of controlling for multiple comparisons has been shown to be more powerful

than comparable procedures that control the traditional familywise error rate (Benjamini & Yekutieli, 2001). As an ancillary analysis designed to examine the role of PTSS more specifically and determine whether the significant effects were driven by PTSS or group status, we ran multiple regression analyses for the dependent variables that differed significantly between groups (see supplementary material).

Results

2.5. Participant characteristics

There were no significant differences between veterans and controls in terms of age, education, or fear of pain (Table 1). Veterans scored significantly higher on measures assessing symptoms of depression, anxiety, and stress compared to controls. On average, the veterans reported moderate-to-severe levels of depression, anxiety, and stress, while controls scored in the normal-to-mild range on these measures. Veterans also reported significantly more PTSS compared to controls (Veterans: $M = 89.93$, $SD = 19.9$; Controls: $M = 59.9$, $SD = 12.48$)

-Table 1 near here-

2.6. Traditional attentional bias Indices

A 2 (groups: veterans, controls) × 2 (type of stimuli: painful, happy) mixed-design ANOVA was conducted to determine whether veterans and controls differed in ABs for the target facial expressions. There was no main effect of group [F (1, 82) = 3.144, $p = 0.08$, $\eta_p^2 = 0.037$] or type of stimuli [F (1, 82) = 0.458, $p = 0.5$, $\eta_p^2 = 0.006$]; however, the interaction effect for group and type of stimuli showed a trend towards significance [F (1, 82) = 3.488, $p = 0.065$, $\eta_p^2 = 0.041$]. Independent t-tests indicated that veterans and controls did not significantly differ [$t(82) = .277$, $p = .78$] in their AB to happy facial expressions (Figure 1). There was a significant difference between groups for painful facial expressions [$t(82) = 2.59$, $p = .011$, $d = 0.57$], where veterans displayed an AB away from the faces, while the opposite was true for controls.

One sample *t*-tests were used for each group separately to examine within-group ABs. AB index scores were compared to 0 as this would be indicative of no bias either towards or away from the target stimuli. The only significant finding was in the veteran group, who showed a significant AB away from painful facial expressions, $t(53) = 3.65$, $p = .001$, $d = 0.49$.

2.7. TL-BS parameters

The mean number of paired trials for happy and painful facial expressions were 13.95 (*SD* = 1.87, range: 10-18) and 13.3 (*SD* =1.83, range: 9-17), respectively. There was no significant difference between groups for the number of paired trials for happy [$t(82) = 0.90$, $p = .37$] or painful facial expressions [$t(82) = 0.36$, $p = .71$]. Due to the high correlation between Mean and Peak TL-BS scores ($r = .88$ to $.93$), only Mean TL-BS_{TOWARD}, Mean TL-BS_{AWAY}, and TL-BS variability are reported to simplify the results. The patterns of results for Peak TL-BS_{TOWARD} and Peak TL-BS_{AWAY} were identical to Mean TL-BS_{TOWARD} and Mean TL-BS_{AWAY}, respectively.

Table 2 presents the main effects of a series of three 2 (groups: veterans, controls) × 2 (type of stimuli: painful, happy) mixed-design ANOVAs for each TL-BS parameter. As expected, veterans had significantly higher scores for all TL-BS parameters compared to control participants. No significant group by stimuli type interaction was found [all Fs(1, 82) = 0.013-0.350, ps >0.55, $\eta_p^2 \leq 0.004$].

-Table 2 near here-

2.8. Controlling for general RT variability

To rule out the alternative explanation that the observed results for TL-BSs are due to general RT variability, we calculated mean and SD of RT for neutral trials using the 16 practice trials as our experimental block did not include neutral trials. This approach has been used in past research (Zvielli et al., 2016). Group status remained significantly associated with TL-BS parameters above and beyond mean RT on neutral trials [F (1, 81) = 5.39 - 6.39, $p \leq .023$, $\eta_p^2 = .062$ - .073] as well as above and beyond the *SD* of RT on neutral trials [F (1, 81) = 6.66 - 7.78, $p \leq .012$, $\eta_p^2 = .076$ - .088].

2.9. Split-half reliability of attentional measures

Split-half reliability measures for both groups and facial expression types are reported in Table 3. For all participants, TL-BS parameters showed higher reliabilities (0.27 to 0.74) than traditional bias scores (-33 to -36).

2.10. Correlation analyses

Correlational analyses for self-report measures and attentional indices were performed for all participants and each group separately using a Benjamini-Hochberg correction. Detailed results of these analyses are provided as supplementary material; here, we provide only a summary. Among all participants, TL-BS parameters from trials with happy facial expressions were significantly correlated with PTSS and symptoms of depression, anxiety, and stress. For trials with painful facial expressions, TL-BS parameters were significantly correlated with PTSS and TL-BS variability was significantly correlated with depression and stress. Among veterans, TL-BS parameters for happy facial expressions were significantly correlated with PTSS and symptoms of depression. The mentioned significant correlations suggest that greater temporal variability in AB is associated with more severe psychological symptoms. No significant correlations were observed for the control group.

3. Discussion

The current investigation examined ABs in individuals with co-occurring chronic pain and PTSS. The analytic approach involved the traditional measure of AB, which serve to quantify the allocation of attention towards or away from emotional and non-emotional stimuli. The analytic approach also involved TL-BS parameters, variability-based measures that quantify the temporal dynamics of AB. In what follows, the results relevant to each measure of AB and the associated implications will be discussed in turn.

With respect to the traditional AB scores, consistent with our hypotheses, neither veterans nor controls displayed an AB for happy facial expressions; however, veterans displayed an AB for painful facial expressions that was characterized by avoidance. The observed pattern of AB away from painful faces among veteran group was found both compared to controls (between-subject effect) and compared to neutral faces (within-subject effect). Caution is required with the interpretation of the between-subject effect as it was marginally significant. The within-subject effect indicates that veterans displayed a clear avoidance from painful faces compared to neutral faces, an effect that was not found among controls (Bar-Haim et al., 2007).

The avoidance of pain-related stimuli observed in the current investigation is somewhat inconsistent with the literature on ABs in individuals with chronic pain. Past research examining ABs in individuals with chronic pain has more commonly observed hypervigilance, or a bias towards pain-related stimuli (e.g., Haggman, Sharpe, Nicholas, & Refshauge, 2010; Liossi, Schoth, Bradley, & Mogg, 2009). One important difference between our investigation and those that observed hypervigilance for pain-related stimuli is that our participants with chronic pain were veterans with long-term injuries who also had PTSS. It is possible that the PTSS contributed to the observed change in direction of the AB, particularly given the critical

connection between chronic pain and PTSS in the current sample. Since the majority of the veterans attributed their chronic pain to an injury sustained during a traumatic experience, traumatic memories would have a component of pain and experiences of pain could remind the veterans of their traumatic injuries (Liedl et al., 2010). For these individuals, avoiding pain (and reminders of trauma) may be doubly rewarding as it decreases pain and prevents recollections of the traumatic event that accompanied the pain (Fleurkens, Rinck, & van Minnen, 2014). Nonetheless, this is largely speculation as the lack of PTSS-only and chronic pain-only groups for comparison in the current investigation make it impossible to draw conclusions regarding the influence of PTSS on the AB for pain-related stimuli.

A second possible explanation for the observed avoidance of pain-related stimuli in the veteran group relates to the circumstances surrounding their participation. The veterans performed the dot-probe task while they were waiting for a medical visit that required them to describe their traumatic injuries and associated health concerns in order to obtain financial compensation. This is typically a very stressful experience, and past research suggests that stress influences AB. Although anxiety disorders are most often associated with hypervigilance for threat-related stimuli (Bar-Haim et al., 2007), the direction of the bias changes from hypervigilance to avoidance in stressful situations (Bar-Haim et al., 2010; Wald et al., 2013). This suppression of AB in anxious individuals has been demonstrated in response to a range of stressful situations; studies have involved eminent stressors, such as telling veterans they will have to watch a combat video after the attention task (Constans, McCloskey, Vasterling, Brailey, & Mathews, 2004) and intensive stressors such as real life-threatening danger and combat exposure during war (Bar-Haim et al., 2010; Wald et al., 2011). Suppression of AB has been replicated in a series of studies on ABs and PTSD proposing that those who avoided threatening

stimuli under stressful conditions displayed more symptoms and were at greater risk of developing PTSD (Sipos, Bar-Haim, Abend, Adler, & Bliese, 2014; Wald et al., 2011). Given that the veterans who participated in our investigation were tested while they were waiting for a very important medical visit, it is unsurprising that they reported significantly more stress than the control group. This stress may have led to the pattern of avoidance we observed, instead of the hypervigilance often found in past research.

With respect to the temporal dynamics of AB, veterans displayed greater TL-BS_{TOWARD}, TL-BS_{AWAY}, and TL-BS variability for both painful and happy facial expressions compared to controls. We observed significant correlations between TL-BS parameters and PTSS, depression, anxiety, and stress, indicating that greater temporal dynamics in AB are associated with more severe psychological symptoms. With regard to pain, no significant correlation was observed between pain-related measures and traditional attention bias measures or TL-BS parameters across all participants or each group separately. The lack of association between measures of AB and pain is consistent with past meta-analytic work showing no association between AB and pain-related individual difference variables, including pain severity and fear of pain (Crombez et al., 2013). However, replication is needed regarding the specific association between variability-based measures of AB and individual differences in pain as this study was the first to examine the relationship between the two.

Our results for TL-BS parameters support previous research that showed greater ABV for emotional stimuli in individuals with elevated PTSS, positive correlations between ABV and PTSS (Yuval et al., 2016; Naim et al., 2015), and positive correlations between measures of ABV and depression, anxiety and stress (Iacoviello et al., 2014; Swick & Ashley, 2017; Zvielli et al., 2016). The results of the current investigation also support previous research that directly compared

variability-based dot probe measures across positively and negatively valenced emotional stimuli and found that stimulus valence did not influence AB temporal dynamics (Carlson, Aday, & Rubin, 2018; Naim et al., 2015; Schäfer et al., 2016; Zvielli et al., 2016). Moreover, other studies have shown that positively-salient images can disrupt attention in anxious (Chen, Clarke, Watson, MacLeod, & Guastella, 2014; Taylor, Bomyea, & Amir, 2010) and traumatized populations (Blair et al., 2013; Fani et al., 2019).

Findings from previous studies that have shown that elevated temporal dynamics of AB are associated with higher levels of PTSS are consistent with the possibility that elevated TL-BSs are a marker for PTSS. Identifying markers of psychopathology has theoretical and practical implications (Grant et al., 2003); however, the potential contributions of increased temporal variability in AB as a marker for PTSS are limited by the current state of the literature. The theoretical aspects of the association between variability in AB and PTSS have not been systematically examined. Clearly articulated and theory-driven models that explain the mechanisms by which greater variability in AB is associated with PTSS are needed to advance research in the field. One potential mechanism that may underlie differences in the temporal dynamics of AB is impaired top-down control processes (e.g., attentional control; (Badura-Brack et al., 2015; Swick & Ashley, 2017). As such, impaired top-down control processes serve as a potential target for interventions designed to reduce PTSS. Attentional control training is an approach to attention modification that is believed to exert effects upon temporal dynamics of AB by enhancing attentional control (Badura-Brack et al., 2015). This training method, which is similar to control conditions in most attention bias modification studies, was more effective at decreasing PTSS compared to the usual look-away threat ABM (Badura-Brack et al., 2015) and bias-contingent ABM (Lazarov et al., 2018). Attentional control training does not train attention

in a specific direction (i.e., towards or away from threat) but instead implicitly encourages participants to ignore the spatial locations of threatening stimuli to perform optimally on the task. Enhanced symptom reduction in attentional control training over ABM is thought to be due to improved attentional control (Basanovic, Notebaert, Grafton, Hirsch, & Clarke, 2017). The above-mentioned studies did not directly assess attentional control (or other top-down control processes), precluding conclusive determinations of the mechanisms driving the enhanced effects of attentional control training. Further research specifically designed to elucidate the mechanisms underlying associations between psychopathology and the temporal dynamics of AB is needed to optimize the therapeutic benefits of attentional interventions.

We calculated the reliability scores for all attentional indices and found them to be low in most cases[1]. A few points should be noted when considering the reliability of AB assessment tasks. Low reliability inserts a serious issue for classifying individuals, as very high levels of assessment reliability is needed to classify individuals adequately, however, at the cohort level, patterns can be revealed effectively by instruments with lower levels of psychometric reliability (De Schryver, Hughes, Rosseel, & De Houwer, 2016; MacLeod, Grafton, & Notebaert, 2019; McNally, 2018; van Rooijen, Ploeger, & Kret, 2017). This is considered to be the reason for the relative robustness of the significant differences in AB to threat between cohorts high and low in anxiety vulnerability (Armstrong & Olatunji, 2012; Bar-Haim et al., 2007; Dudeney, Sharpe, & Hunt, 2015). However,

[1] We performed 5000 random splits for calculating the reliability of traditional AB scores, while previous studies mainly used other methods like odd-even splits. When we used odd-even method, the reliability scores that are obtained are higher than the more robust method of 5000 random split, for example -0.33 and -0.36 becomes 0.10 and -0.06 respectively which are closer to previous studies but still low.

the above-mentioned point does not compromise the importance of increasing the reliability of AB assessment which should be a priority for future research.

We also calculated the reliability of TL-BS parameters which showed overall higher reliabilities compared to the traditional AB indices. However, the TL-BS reliabilities in our study were lower compared to previous studies (Schäfer et al., 2016; Zvielli et al., 2016). One contributor to the lower reliability of the TL-BS parameters in the present study is likely to be the smaller number of trials of our dot-probe task (Zvielli et al., 2015).

The findings of the current investigation must be considered in light of important limitations. First, the participants with chronic pain and PTSS were all men with combat-related index traumas, which limits the generalizability of the results. Second, the veteran and control groups were evaluated in different settings, which may have contributed to some of the observed differences. Third, the investigation would have benefited from the addition of threat-related stimuli (e.g., combat-related) and the inclusion of PTSD-only and/or chronic-pain only groups for comparison. These additions would have allowed us to evaluate the specificity of the AB for pain-related stimuli compared to other negative stimuli, informed conclusions about the role of PTSS in the AB for pain-related stimuli, and provided more information about the role of pain as a reminder of trauma. Fourth, both happy and painful facial expressions were presented in the same block of trials and the number of trials per facial expression type was limited. Fifth, the M-PTSD was developed based on the *DSM-III* diagnostic criteria for PTSD, which differs from the current *DSM-5* diagnostic criteria. Unfortunately, no study had tried to validate another PTSD measure in Iran and the existing study using by Goodarzi (2003) failed to report a cut-off point for the Persian version. The reported cut-off point of 107 for the English version appears to be much less sensitive and inefficient for categorizing in Iranian samples. Sixth, similar to many previous studies

(Iacoviello et al., 2014; Swick & Ashley, 2017), depression scores were correlated with AB scores that raise the question about the specificity of findings. Addressing this limitation has been a challenge for many studies in the literature as depression is highly comorbid with chronic pain and PTSD (Bair, Robinson, Katon, & Kroenke, 2003; Stander, Thomsen, & Highfill-McRoy, 2014).

Future research may address these limitations in a number of ways. First, including females and individuals with other types of traumas would improve the generalizability of these results. Second, assessing all participants in the same setting would increase confidence that observed differences are attributable to the variables of interest. Third, a greater number of trials and presenting different stimuli types in separate blocks would help a more effective reliability calculation and prevent possible carry-over effects of emotional stimuli respectively. Addition of neutral-neutral trials for buffering between experimental trials has been suggested as well (Zvielli et al., 2016). Fourth, future research could include clinician-administered measures of PTSD. Other future directions include assessing attentional control as a potential moderating variable (Mazidi et al., in press), examining the time course of the AB for pain-related stimuli, and including threat-related stimuli in addition to pain-related stimuli and trials with two neutral stimuli in order to calculate attentional engagement and disengagement indices (Koster, Crombez, Verschuere, & De Houwer, 2004).

In summary, the current investigation provides evidence of attentional dysfunction among veterans with chronic pain and PTSS. According to traditional AB measures, chronic pain and PTSS were associated with an AB away from pain-related stimuli on the pictorial dot-probe task, a finding that included both between-subject and within-subject effects. Furthermore, the current investigation was the first to provide evidence of overall attentional dysfunction for emotional stimuli in individuals with chronic pain and PTSS using variability-based AB

measures. The avoidance of painful facial expressions observed in the current study suggests that the suppression of AB in individuals with chronic pain and PTSS that occurs during stressful situations may generalize to pain-related stimuli.

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Figure Legends

Fig. 1. Attentional biases for happy and painful facial expressions for veterans and controls (error bars represent 95% confidence interval)

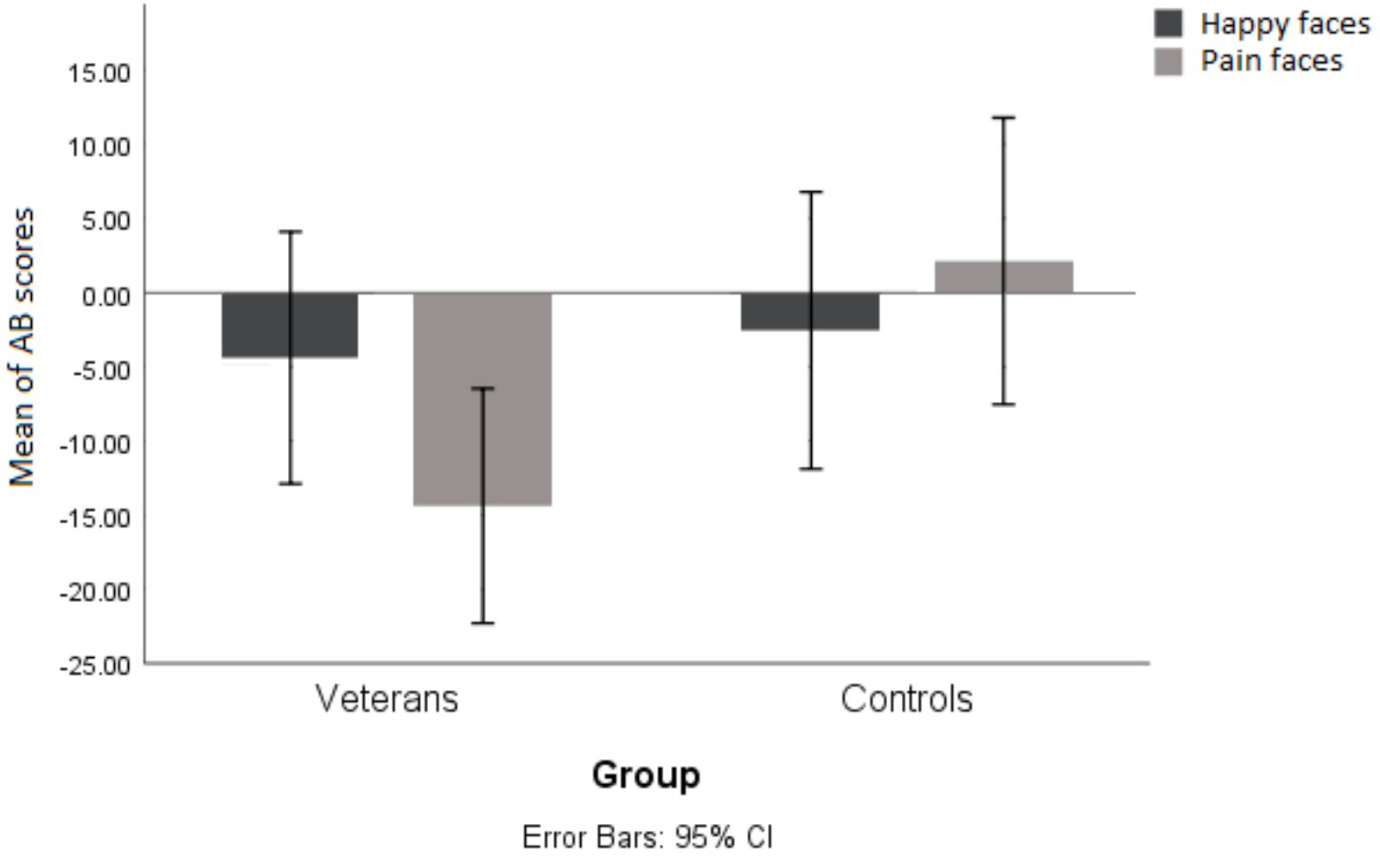
Happy faces
Pain faces
Mean of AB scores
15.00
10.00
5.00
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
Veterans
Controls
Group
Error Bars: 95% CI

Table 1
Comparison between characteristics of two groups

	Veterans	*Controls*	*t(df)*	*p-value*
Age	51.44 (3.78)	49.17 (6.6)	1.73 (39.8)	0.09
Years of education	12.06 (3.84)	13.33 (3.62)	1.49 (82)	0.14
VAS-last week	53.76 (21.94)	-	-	-
VAS-current week	42.15 (24.62)	-	-	-
VAS-next week	50.17 (22.16)	-	-	-
Fear of pain	79.09 (16.78)	72.3 (19.54)	1.67 (82)	0.098
DASS – Depression	19.83 (10.45)	5.73 (5.06)	8.3 (80.8)	< 0.001
DASS – Anxiety	20.11 (8.06)	5.8 (4.89)	10.11 (81.3)	< 0.001
DASS - Stress	27.63 (8.37)	13.93 (8.27)	7.21 (82)	< 0.001
PTSD symptoms	89.93 (19.9)	59.9 (12.48)	8.48 (80.6)	< 0.001

Table 2
Descriptive statistics by Stimuli Types and main Effects for Group on TL-BS indices

TL-BS indices Stimuli (Faces)	Veterans (n = 54) *M (SD)*	Controls (n = 30) *M (SD)*	$F_{(1, 82)}$	p	η^2_p	M_{diff}	95% CI
Mean TL-BS_{TOWARD}			10.77	.002	.116	36.96	[19.17, 54.74]
Pain	108.01 (81.45)	66.86 (24.10)					
Happy	102.51 (57.03)	69.80 (28.57)					
Mean TL-BS_{AWAY}			10.19	.002	.111	-33.89	[-150.90, -16.87]
Pain	-104.31 (66.73)	-69.89 (24.70)					
Happy	-102.43 (53.48)	-69.07 (27.48)					
TL-BS Variability			11.38	.001	.122	45.69	[24.51, 66.87]
Pain	139.29 (87.77)	92.31 (27.77)					
Happy	133.93 (73.17)	89.52 (28.91)					

Note. There was no significant interaction effect for Group × Stimuli types.

Table 3

Split-Half reliability for Traditional Attentional Bias scores and TL-BS Parameters

Stimuli (Faces)	Traditional AB	Mean TL-BS TOWARD	Mean TL-BS AWAY	Peak TL-BS TOWARD	Peak TL-BS AWAY	TL-BS Variability
Pain						
All (n = 84)	-.36	.52	.44	.50	.43	.74
Veterans (n = 54)	-.77	.51	.42	.45	.41	.74
Controls (n = 30)	.26	.32	.24	.59	.27	.40
Happy						
All (n = 84)	-.33	.31	.27	.40	.43	.44
Veterans (n = 54)	-.50	.26	.21	.39	.43	.44
Controls (n = 30)	.16	.14	.33	.14	.09	.03

Note: Zvielli et al. (2015) advised 80 trials per emotional type for a meaningful calculation of TL-BS reliability.

Regression analyses

To examine the role of PTSS more specifically, we ran multiple regression analyses for ANOVA significant effects to examine whether the effects were driven by PTSS or group status.

With respect to the significant difference between the veteran and control groups in AB to painful facial expressions, multiple regression was used with AB to painful facial expressions as the outcome variable and PTSS and group status as predictor variables. The model significantly predicted AB to painful facial expressions (R^2s = 0.05, $F(2,83) = 3.37$, $p = 0.039$), but neither PTSS ($\beta = -0.05$, $p = 0.77$), nor group status ($\beta = -14.95$, $p = 0.075$) uniquely predicted AB to painful facial expressions. This suggests that the difference could not be attributed uniquely to each PTSS or group status alone and is driven by the combination of both of these factors.

Concerning the significant between-subject effects of the mixed-design ANOVAs for each TL-BS parameter, a series of multiple linear regressions were calculated to predict TL-BS parameters based on PTSS and group status. As the ANOVA did not show significant interaction effects, the mean scores for each TL-BS parameter were calculated from happy and painful facial expressions and were included as criterion variables. Results indicated that for TL-BS variability, TL-BS $_{\text{AWAY}}$, and TL-BS $_{\text{TOWARD}}$, the predictors explained 19%, 18% and 16% of the variance, respectively (R^2s = 0.19, 0.18, 0.16, Fs(2,83) = 10.7, 10.4, 8.64, ps $\leq$ 0.013). PTSS was the only significant predictor for TL-BS variability ($\beta = 1.06$, $p = 0.004$), TL-BS $_{\text{TOWARD}}$ ($\beta = 0.88$, $p = 0.004$), and TL-BS $_{\text{AWAY}}$ ($\beta = -0.72$, $p = 0.013$). Beta values (both positive and negative) indicate that increases in PTSS scores are associated with increases in the temporal dynamics of attentional bias. Therefore, the group differences in TL-BS parameters seem to be mainly driven by higher PTSS scores in the veteran group as the

regression analyses showed that M-PTSD scores, not group status, predicted TL-BS parameters.

Correlational analyses between self-report measures and attentional indices were performed for all participants and each group separately using Benjamini-Hochberg correction.

Table S1
Pearson correlation coefficients between attentional measures with questionnaire measures for all participants (n = 84)

	Attentional measures	PTSD	FOP	Depression	Anxiety	Stress
Pain faces	Aggregated Mean Bias	-.200	-.216	-.215	-.226	-.191
	TL-BS variability	.370*	.123	.296*	.240	.304*
	Mean TL-BS Toward	.363*	.052	.293	.256	.276
	Mean TL-BS Away	-.311*	-.196	-.269	-.224	-.257
Happy faces	Aggregated Mean Bias	-.043	.110	.046	-.010	.010
	TL-BS variability	.447*	.176	.437*	.343*	.337*
	Mean TL-BS Toward	.419*	.116	.392*	.300*	.315*
	Mean TL-BS Away	-.458*	-.238	-.387*	-.341*	-.352*

* Significant correlations

Table S2

Pearson correlation coefficients between eye movement measures with questionnaire measures for veterans (n = 54)

	Attentional measures	PTSD	FOP	Depression	Anxiety	Stress	VAS-last week	VAS-current pain	VAS-next week
Pain faces	Aggregated Mean Bias	-.082	-.215	-.098	-.099	-.076	-.182	-.065	-.089
	TL-BS variability	.237	.130	.150	.034	.159	.080	-.040	.081
	Mean TL-BS Toward	.253	.021	.151	.072	.134	.162	.016	.214
	Mean TL-BS Away	-.184	-.252	-.122	-.027	-.092	-.116	-.005	-.107
Happy faces	Aggregated Mean Bias	-.060	.183	.087	-.030	.032	-.061	.141	.012
	TL-BS variability	.365*	.213	.353*	.184	.237	.100	.131	.122
	Mean TL-BS Toward	.344*	.205	.310*	.123	.220	.092	.117	.092
	Mean TL-BS Away	-.385*	-.290	-.299*	-.199	-.271	-.079	-.057	-.132

* Significant correlations

Table S3
Pearson correlation coefficients between eye movement measures with questionnaire measures for controls (n = 30)

	Attentional measures	PTSD	FOP	Depression	Anxiety	Stress
Pain faces	Aggregated Mean Bias	.126	-.110	.078	.119	.078
	TL-BS variability	.350	-.157	.167	.153	.231
	Mean TL-BS Toward	.226	-.108	.238	.209	.195
	Mean TL-BS Away	-.114	.181	-.158	-.101	-.210
Happy faces	Aggregated Mean Bias	.077	-.004	.067	.190	.049
	TL-BS variability	.056	-.165	-.055	.035	-.042
	Mean TL-BS Toward	.075	-.362	-.022	.137	-.004
	Mean TL-BS Away	-.081	.057	.127	.054	.037

No significant correlations were found for the control group