HHS Public Access
Author manuscript
J Anxiety Disord. Author manuscript; available in PMC 2023 January 01.

Published in final edited form as:
J Anxiety Disord. 2022 January ; 85: 102509. doi:10.1016/j.janxdis.2021.102509.

Association of attention and memory biases for negative stimuli with post-traumatic stress disorder symptoms

Gabriella Imbriano[1], **Aprajita Mohanty**[1]

[1]Department of Psychology, Stony Brook University

Abstract

Cognitive models have highlighted attentional and memory biases to negatively valenced emotional stimuli, and their association, in the development and maintenance of post-traumatic stress disorder (PTSD). However, research has focused mainly on attentional biases towards distracting (not task-relevant) negative stimuli and the links of attentional biases with memory remain underexplored. We manipulated attention during encoding of trauma-irrelevant negative and neutral words and examined the differential relationship of their encoding and recall with PTSD symptoms. Responders to the World Trade Center disaster performed tasks in which they read negative and neural words (full attention, FA) and reported the color of another set of such words (divided-attention, DA). Subsequently, participants used word stems to aid retrieval of words shown in both tasks. PTSD symptoms were associated with slower performance for negative vs neutral words in FA but not DA tasks. Furthermore, greater PTSD symptoms severity was associated with more accurate recall of negative vs neutral words, irrespective of whether words were presented on FA or DA tasks. These findings suggest that PTSD symptoms in a trauma-exposed population are related to encoding of trauma-irrelevant negative information when attention is fully deployed and subsequent recall of negative information, irrespective of whether attention was fully deployed.

Introduction

Cognitive models of post-traumatic stress disorder (PTSD) have emphasized the importance of attentional and memory biases in understanding how PTSD symptoms arise and persist (for review, see e.g., Buckley, Blanchard, and Neill, 2000; Bomyea, Johnson, & Lang, 2017; Woud, Verwoerd, & Krans, 2017; Durand, Isaac, & Januel, 2019). These models suggest that patients remember emotional information better than neutral information due to an attentional bias toward (Chemtob, Roitblat, Hamada, Carlson, & Twentyman, 1988) or difficulty disengaging from (Chemtob et al., 1999) threat-related information, which may lead to greater resources applied to processing and encoding of negative information. However, the hypothesized link between attentional biases favoring negative emotional information and stronger memory for this information in PTSD is not clearly defined. An examination of this link will help advance our understanding of the factors that contribute to the development and maintenance of PTSD symptomatology and support the improvement

Corresponding Author: Aprajita Mohanty, Ph.D., Department of Psychology Stony Brook University Stony Brook, NY, 11794-2500 Phone: 631-632-7843 Fax: 631-632-7876, Aprajita.Mohanty@stonybrook.edu.

of treatments that intervene by addressing such biases. Hence, in two different tasks, we manipulated attention during encoding of negative and neutral words and examined whether encoding and subsequent memory for these words was differentially related with PTSD symptoms.

Attentional biases towards trauma-related information are commonly seen in PTSD (McNally, Kaspi, Riemann, & Zeitlin, 1990; Bryant, Harvey, Gordon, & Barry, 1995), although some studies have shown an absence of such biases (for review, see Hayes, VanElzakker, & Shin, 2012; Bomyea et al., 2017). Studies investigating selective attention such as the dot-probe paradigm have shown biases towards (Bryant & Harvey, 1997; Dalgleish, Moradi, Taghavi, Neshat-Doost, & Yule, 2001; Dalgleish et al., 2003; Fani et al., 2012) and away from (Pine et al., 2005; Fani, Bradley-Davino, Ressler, & McClure-Tone, 2011) trauma-related or other negative stimuli in PTSD, while other studies have shown no bias (Badura-Brack et al., 2015; Iacoviello et al., 2014). While the emotional Stroop task cannot separate bias towards and away from stimuli, studies using this task have demonstrated greater attentional bias for threat in PTSD. For example, individuals with PTSD are slower to identify font color of trauma-consistent words due to interference from semantic processing of word content (Metzger, Orr, Lasko, McNally, & Pitman, 1997). This finding has been replicated in different media and modalities, different types of trauma populations, and with other negative words that may not be trauma relevant (Constans, 2005; Ashley, Honzel, Larsen, Justus, & Swick, 2013; Willebrand et al., 2002; Paunovic, Lundh, & Öst, 2002; Metzger et al., 1997; Beck, Freeman, Shipherd, Hamblen, & Lackner, 2001; Vrana, Roodman, & Beckham, 1995); however, several studies have yielded null findings suggesting that the effect is not reliable (Kimble, Frueh, & Marks, 2009). Importantly, most research on attentional biases in PTSD has been conducted using paradigms in which trauma-relevant or negative stimuli are irrelevant to task goals; for example, the task-relevant aspect is word color in emotional Stroop, target detection in dot probe, and lexical decision making in visual search tasks (for review, see Hayes et al., 2012; Bomyea et al., 2017). In real life, emotional stimuli are frequently the target of attention and processed voluntarily. Indeed, eye-tracking studies show greater fixation, greater pupil dilations, and longer gaze durations for negatively valenced and trauma-relevant stimuli in PTSD (for review, see Bomyea et al., 2017). This suggests that it is important to clarify whether PTSD symptoms are also related to biases toward negative vs neutral stimuli when attention is fully deployed.

In addition to attentional biases, PTSD is associated with greater explicit, and to a lesser extent, implicit recall of trauma-consistent information (Brewin & Holmes, 2003; Vrana et al., 1995; Amir, McNally, & Wiegartz, 1996; for review, see Banich et al., 2009). For example, Ehring and Ehlers (2011) examined both explicit (stated reference to encoding phase) and implicit retrieval (no reference to encoding phase) of trauma specific words in a sample of recent motor vehicle accident survivors. Greater implicit retrieval of trauma-related words was related to chronic PTSD diagnoses over time. Another study showed that veterans with PTSD exhibited an explicit and implicit memory bias for combat words (Zeitlin & McNally, 1991). In addition to increased retrieval, individuals with PTSD exhibit difficulty forgetting trauma material (McNally, Metzger, Lasko, Clancy, & Pitman, 1998). While a majority of the studies have examined memory biases for trauma-relevant material in PTSD, fewer studies have demonstrated a memory advantage for negative words in general (Thomaes et al., 2013; Vrana et al., 1995; McNally et al., 1998; Golier et al., 2002; Paunovic et al., 2002).

It has been hypothesized that this memory bias for negative information is due to attentional biases to threat in PTSD. However, this hypothesis has not been thoroughly tested. One study has shown that attention and memory are closely linked in PTSD by demonstrating a greater Stroop effect for trauma-relevant words compared to neutral words, and greater subsequent explicit recall for trauma-relevant words (Paunovic et al., 2002). However, the absence of a control condition in which undivided attention was provided to emotional words limits the ability to attribute observed recall biases to attentional mechanisms. Furthermore, due to the focus on trauma-relevant words, it is unclear if the bias extends to generally negative or threatening words. There is also a paucity of insight into the time course of processing biases, such that the relationship of attention to later memory remains untested. Finally, it is unclear whether attentional and memory biases towards negatively valenced information are linked with specific symptom dimensions of PTSD because the majority of studies have utilized overall symptom scores as opposed to specific symptom clusters. Recent work found that attentional biases were related to re-experiencing and avoidance symptoms of PTSD (Powers et al., 2019), but remains to be replicated.

Hence, in the present study, a sample of trauma-exposed individuals performed two separate tasks; a full-attention (FA) task in which they read negative (but trauma-irrelevant) or neutral words and a divided-attention (DA) task in which they reported the color of an independent set of negative and neutral words. Both tasks involved a subsequent recall task in which participants were asked to use word stem cues to aid retrieval of words shown to them in the FA and DA tasks (Rajaram, Srinivas, & Travers, 2001). Prior studies have shown that words are still identified at the lexical and semantic levels in the DA task despite their identification being irrelevant to the color-naming task (see Dyer, 1973; MacLeod, 1991 for reviews). However, attentional resources are diverted away from the word itself towards task-relevant information (i.e., the color of the words) which allows examination of both encoding and recall of words processed with full or divided attention (Rajaram et al., 2001).

Based on earlier studies highlighting a generic slow down for negative words (Algom, Chajut, & Lev, 2004), we predicted slower reading and color naming of negative vs neutral in the FA and DA tasks. Based on earlier research examining the effect of attention on subsequent recall (Rajaram et al., 2001), we predicted more accurate recall of words presented in FA vs DA condition, an effect that would be increased for negative vs neutral words due to greater time at encoding. Finally, based on eye tracking research showing longer gaze durations when processing negative or trauma-relevant stimuli (Bomyea et al., 2017), we predicted that greater severity of PTSD symptoms would be associated with slower reading and more accurate recall of negative vs neutral words on the FA task in which attention is fully engaged during encoding. However, the association of PTSD symptoms with color-naming and recall of negative vs neutral words on the DA task was expected to be less robust due to reduced attention during encoding. Additionally, we explored if different symptom clusters of PTSD have unique relationships with encoding and recall on the DA and FA tasks.

Method

Participants

Data were collected from 392 (42 female, 348 male; M age= 55.17 yrs, SD= 8.700; 90.4 % Caucasian, 6.7% Black, Asian 0.8 %; 7.7% Hispanic) participants from the first assessment wave of the World Trade Center (WTC) Personality and Health study, a longitudinal study that begun in 2017. Study participants were contacted after a health monitoring visit at the Stony Brook University WTC Health Program, which serves over 10,000 WTC responders from Long Island (Desaro et al., 2015). A majority of the participants (64%) were active law enforcement personnel on 9/11. Occupations of the remaining subset of the sample included construction workers, electricians, and paramedics. The sample was broadly representative of patient's served by the program, and patients were excluded only if linguistic, cognitive, or physical limitations prevented them from completing study procedures. For the encoding task, 11 participants were excluded for having lower than 50% accuracy during the encoding task and 6 participants were excluded due to incomplete task data. In addition, for the recall task, 142 participants were excluded from FA and DA recall-related analyses due to technical problems during this task (described below). The excluded participants did not differ significantly from participants included in the FA and DA recall tasks on PCL scores, age, or gender (all p's >.05). This resulted in a final sample of 375 participants for the FA and DA encoding tasks and 233 participants for FA and DA recall tasks. Four participants had incomplete questionnaire data and were thus excluded from PCL-related analyses. This study was approved by the Stony Brook Institutional Review Board. All participants provided informed consent.

Measures

PTSD Checklist for DSM-5 (PCL).—The PCL (Weathers et al., 2013) is a 20-item questionnaire used to dimensionally assess symptoms of traumatic stress occurring within the past month. The PCL has four subscales to more precisely measure symptom clusters of re-experiencing (Cluster B), avoidance (Cluster C), negative cognitions and mood (Cluster D), and arousal/reactivity (Cluster E). Participants are asked to report on their level of distress experienced due to symptoms such as, "repeated, disturbing dreams of the stressful experience", using a 0 ("Not at all") to 4 ("Extremely") scale. The PCL has been shown to have good diagnostic efficiency as a brief screening assessment (Blanchard, Jones-Alexander, Buckley, & Forneris, 1996). In addition, the PCL has demonstrated good internal consistency (a= .94), test-retest reliability (r= .82), convergent validity (rs= .74 to .85), and discriminant validity (rs= .31 to .60) (Blevins, Weathers, Davis, Witte, & Domino, 2015).

Stimuli

For each participant, a total of 120 (60 negative, 60 neutral) words were used across both encoding and recall tasks. The words were nouns that ranged from four to eight letters in length and were selected on the basis of established norms for valence, arousal, and frequency of usage in the English language (Bradley & Lang, 1999). Of these words, 80 were chosen at random to be shown during the encoding task. Then, 40 of the remaining words were utilized as the unshown control set of words during the recall task. Of the 80 words selected for the encoding tasks, half of the words were negative and the remaining half were neutral valence. Forty (20 negative, 20 neutral) were presented in the FA task, whereas the remaining 40 (20, negative, 20 neutral) were presented in the DA task. Words were counterbalanced across shown/unshown, and DA/FA conditions across participants. Of the 80 words included in the encoding task, an equal number were shown in each of the four colors; blue, red, green, and yellow. Word stems at recall were all presented in black font and consisted of the first three letters of each word shown to the subjects.

Procedure

Stimuli were presented on a Fujitsu Lifebook E746 using PsychoPy software. One participant was tested at a time in a quiet, distraction-controlled room. Each participant completed the DA and FA tasks (Figure 1). In the FA task, participants were shown a negative or neutral word in one of four colors (red, green, blue, yellow) and were asked to read the word aloud and press the spacebar when they had completed reading the word. This was done to ensure participants were in fact reading the words and not simply pressing the spacebar. In the DA task, participants viewed a negative or neutral word written in one of the same four colors used in the FA task (red, green, blue, yellow). They were asked to indicate the color of the word by pressing the key on the keyboard that corresponded to the color. Color dots corresponding to each font color were placed on four letter keys on the keyboard. It was presumed that content and word color would compete for attentional resources in the DA task. Both the DA and FA task consisted of four blocks (two negative and two neutral) of 10 trials each. Each trial consisted of a negative or neutral word followed by a fixation cross for 0.5 s. Trials advanced after participants initiated a response or 15 s had elapsed. Blocks of DA and FA tasks were presented in a counterbalanced order to prevent order effects. The presentation sequence of words with respect to valence – negative vs neutral words – was random. Reaction time (RT; milliseconds) and accuracy for key presses were recorded on each trial for both task types.

Next, participants completed the explicit recall portion of the experiment. This included six blocks containing 20 trials per block. In each trial, participants were shown a word stem for 15 seconds corresponding to a word that was presented in the FA or DA task or was not shown during encoding (control). Due to technical errors during recall task, participants were tested on varying numbers of words viewed during FA and DA tasks. Thus, only participants who were shown at least 50% of words from the encoding task were included in analyses (at least 10 negative words & neutral words for both FA and DA tasks). On viewing the stem of these words, participants were asked to type the remaining letters to complete the word. The instructions explicitly directed the participants to complete the stems using words they had seen in the DA and FA task and to not complete stems with simply anything that came to mind. Accuracy and RT were recorded in the recall task, however only accuracy was used in analyses for this portion of the experiment. This is because some of our participants had difficulty using the keyboard to type words. To remediate this barrier to session completion, those participants were instructed to say the word that completed the stem aloud and the experimenter typed in their response verbatim. Accuracy was coded to include correct responses that were misspelled.

Analytic approach

To examine the differential effect of negative vs neutral words during encoding, we used t-tests to compare RT for reading negative vs neutral words in FA task and for color naming negative vs neutral words for DA task separately. We did not directly compare the behavioral responses from the FA and DA tasks during encoding because of differing task demands; in the FA task participants read aloud the word and then pressed the space bar whereas in the DA task they immediately pressed keyboard keys upon identifying word color. After establishing effects of negative vs neutral words on encoding, we utilized Pearson's correlations to examine relationships between differential RT for negative vs neutral word and PCL symptom severity in the FA and DA tasks. If relationships were determined to be significant, regression analyses were used to test whether performance during FA or DA conditions was uniquely related to symptom severity. Similarly, we evaluated relationships of each PCL symptom clusters with behavioral measures.

Since recall for the words presented in FA and DA tasks was measured in an identical manner, task performance was directly comparable. Hence, we examined the effects of attention on recall using a repeated measures analysis of covariance (rmANCOVA) with task type (FA and DA) and word type (negative vs neutral) as within-subject factors and examined the effect of PTSD symptoms by using mean-centered PCL symptom severity as a covariate. We also examined relationships of each PCL symptom clusters with behavioral measures using them as a covariate.

Results

First, we sought to examine performance while encoding negative vs neutral words (Table 1). In the FA task, mean RT for reading negative words was slower than for neutral words ($d = -0.247$, $p = < .001$). In the DA task, mean RT for naming the color of negative words was marginally slower than that for neutral words (d=0.097, $p = .070$). After establishing task effects, we sought to examine whether PTSD symptomatology relates to behavioral differences in encoding of negative vs neutral words. More severe PTSD symptoms were associated with slower reading of negative vs neutral words in the FA task ($p = .001$) but not with slower color naming of negative vs neutral words in the DA task (Figure 2, Table 1). Furthermore, slower reading of negative vs neutral words in the FA task was significantly related with all symptom clusters on the PCL, including re-experiencing (r=.107, $p = .040$), avoidance ($r = .162$, $p = .002$), numbing ($r = .161$, $p = .002$), and arousal/hypervigilance ($r = .185$, $p < .001$). However, slower color naming of negative vs neutral words was not associated with any of the PTSD symptom clusters (all p's > .05).

To examine the differential relationship of FA and DA task encoding with PTSD symptoms, we conducted regression analyses with reading and color naming RT predicting PTSD symptoms. These analyses revealed that there was overall a significant relationship between encoding of negative vs neutral words and PTSD severity, $R^2 = 0.029$, $p = .004$. Additionally, reading negative vs neutral words on FA task was uniquely associated with PTSD symptoms, $b = 18.425$, $p = .001$, 95% CI [7.374, 29.475], even after controlling for DA recall, $b = -3.489$, $p = .704$, 95% CI [−21.407, 14.428].

Next, we examined accuracy differences while recalling negative vs neutral words or presented in the FA and DA tasks (Table 2). Results from an rm-ANCOVA showed a main effect of task type, $F(1, 228) = 148.75$, $p < .001$ such that words presented in the FA task were recalled more accurately than words presented in the DA task, a main effect of word type such that negative words were recalled more accurately than neutral words, $F(1, 228) = 12.66$, $p < .001$ and a significant word type x PCL covariate interaction, $F(1, 228) = 4.11$, $p = 0.044$ such that negative words were recalled more accurately than neutral words at higher levels of PCL severity but the difference was lesser at lower levels of severity (Figure 3). There were no task type x PCL, $F(1, 228) = 0.098$, $p = 0.754$, task type x word type, $F(1, 228) = 1.85$, $p = 0.175$, and task type x word type x PCL, $F(1, 228) = 0.757$, $p = 0.385$ interactions. Results of rm-ANCOVA using PCL symptom clusters as covariates showed that none of them uniquely interacted with task type or word types (all ps = NS).

Discussion

Attentional and memory biases towards trauma-relevant stimuli, specifically, and negative stimuli in general play a key role in cognitive models of PTSD. However, attentional biases in PTSD are typically examined using tasks in which attention is divided between a task-relevant dimension and the emotional nature of stimulus. There is a paucity of research examining how attentional biases may also manifest when emotional stimuli are processed voluntarily due to cues and contexts in the task (Imbriano, Sussman, Jin, & Mohanty, 2019; Sussman, Weinberg, Szekely, Hajcak, & Mohanty, 2017). Furthermore, the enhancement of memory for trauma in PTSD has often been attributed to attentional biases during encoding of content related to the trauma (Metzger et al., 1997). While studies have shown greater attention and recall for trauma-relevant and generally negative information (for review, see Cisler & Koster, 2010) in populations with PTSD, empirical studies examining how these biased cognitive processes influence each other remain limited to date. Hence, in the present study, we manipulated attention during encoding of negative and neutral words and examined the differential relationships of their respective recall with PTSD symptoms in a large sample exposed to the WTC terrorist attack.

Firstly, our results showed that encoding of negative vs neutral words was slower when attention was fully deployed and marginally slower when it was divided across the trauma-exposed sample. The slowed RT for negative vs neutral words is in line with research showing that there is a generic slowdown for such words, whether they are the focus of attention or distracting (Algom et al., 2004). It is hypothesized that negatively valenced stimuli may involuntarily capture attention in a ‘bottom-up’ manner (e.g., Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van Ijzendoorn, 2007) or participants may voluntarily pay greater attention to them in a ‘top-down’ manner (Mohanty & Sussman, 2013). Either way, this effect may be increased in disorders that are characterized by heightened response (behavioral and physiological) to threat (Niles et al., 2018; Sun et al., 2020) and inflated expectations regarding threat (Grupe & Nitschke, 2013). In line with this, our results show that when attention was fully deployed, longer encoding time of negative vs neutral words was associated with PTSD symptoms even after controlling for encoding time during the divided attention condition, and this relationship was for all PTSD symptoms including re-experiencing, avoidance, negative cognitions, and arousal/hypervigilance. However, contrary to some earlier studies (Vythilingam et al., 2007; El Khoury-Malhame et al., 2011), this relationship was not observed when attention was divided (i.e., speed of color naming of negative vs neutral words and PTSD symptoms). While the relationship between slower color naming of trauma-relevant words and PTSD is more reliable, the relationship between trauma-irrelevant negative words and PTSD is less reliable and has not survived meta-analytic investigation (Joyal et al., 2019). Indeed, PTSD is characterized not only by "capture" of attention by trauma-related stimuli typically assessed in divided attention paradigms but also by greater vigilance for threatening information (Kimble et al., 2014) and difficulty disengaging attention from trauma-related words (El Khoury-Malhame et al., 2011; Pineles, Shipherd, Mostoufi, Abramovitz, & Yovel, 2009; Pineles, Shipherd, Welch, Yovel, 2007), suggesting the need for using more paradigms where threatening or negative stimuli are task-relevant and the target of attention.

Secondly, in line with the idea that greater attention at encoding aids subsequent recall, our results showed that words encoded when attention was fully deployed were recalled more accurately than words encoded under divided attention. Similarly, in line with the idea that negative words receive greater attention than neutral words and attention facilitates recall, negative words were recalled more accurately than neutral words. Furthermore, more accurate recall of negative vs neutral words was seen for more severe PTSD symptoms than for less severe symptoms, irrespective of whether the words were encoded in full or divided attention conditions.

Influential models of emotion-related memory enhancement propose that, compared to neutral stimuli, emotional stimuli recruit greater cognitive resources such as attention, distinctive processing, and organization which results in a memory benefit for emotional stimuli (Talmi, Schimmack, Paterson, & Moscovitch, 2007; Talmi, 2013). It is possible that even when attention is reduced in the DA attention task, emotional stimuli remain distinctive and are easier to organize based on thematic relatedness than neutral stimuli and are thereby associated with improved memory. Grouping by valence generally does not override other types of grouping such as categorical relationships to influence memory as evidenced by a lack of increase in false recognition for emotionally linked items in college students (Choi, Kensinger, & Rajaram, 2013). However, emotion may still serve as an organizational framework in individuals with heightened sensitivity to threatening information. This stronger organization of the negatively valenced stimuli in PTSD could operate as a schema to facilitate encoding and subsequent recall. Indeed, a similar argument has been applied to explain intrusive memories in PTSD, such that activation of systems of traumatic information facilitate the accessibility of related traumatic memories (Foa & Kozak, 1986; Hayes et al., 2012). For example, PTSD is thought to contain fear networks in which nodes representing states of arousal (e.g., threats) predispose individuals to interpret events (even innocuous ones) as potential threats. Furthermore, spreading activation in this network leads to the triggering of related threat nodes that might result in the development of intrusive recollections. Several theories assert that in PTSD, traumatic autobiographical memories are highly associated with each other in that traumatic memories can automatically activate other related memories (Ehlers & Clark, 2000; Weber, 2008).

In addition to cognitive mechanisms like organization, arousal elicited by negative words during encoding may encourage stronger memory for these words. It is hypothesized that emotional arousal, for example, to the negative words results in activation of adrenergic and glucocorticoid stress hormones, which help in consolidating memory (McGaugh, 2018; Mohanty & Flint, 2001). One of the pathways in which stress hormones can influence memory formation is through their enhancing effects on the amygdala (Cahill & McGaugh, 1998). Prior research has shown that improved accuracy for emotional stimuli is associated with increased amygdala and hippocampal activity as well as greater coupling between the two regions when processing emotional stimuli (Kensinger & Schacter, 2005). Indeed, both physiological arousal (Keane et al., 1998) and amygdala activation in response to trauma-related or generally emotional stimuli is exaggerated in PTSD compared to control subjects (for review, see Pitman et al., 2012). Given the evidenced significance of arousal in PTSD presentations, our results demonstrating a non-differentiated relationship between symptom clusters, particularly the lack of a unique relationship between the hyperarousal symptom cluster and recall biases towards negative information was non-intuitive. However, this pattern of results suggests that recall biases for negative information might be more broadly related to the mechanisms that influence not only hyperarousal symptoms but foster other symptoms as well such as negative cognitions about the self and the world, avoidance of traumatic reminders, etc.

One of the most prominent limitations of this work is that the results from our investigation are prospective in nature and cannot establish temporal relationships between cognitive variations and PTSD symptomatology due the cross-sectional nature of the design. As additional waves of data are collected from this cohort of participants, future studies will be able to investigate the stability of these cognitive effects, as well as whether cognitive and behavioral biases for negative information might be able to inform or predict symptom changes over time. In addition, there were challenges with our code and software that limited use of the entire dataset in the recall task. However, we confirmed that the participants who were excluded did not differ from the included participants and due to our large sample size, we retained the power to examine our effects.

In sum, this investigation builds on previous work while also expanding on our conceptualization and understanding of cognitive processes in PTSD. By focusing on only trauma-relevant content, prior research has been limited to memory biases related to retroactive events as opposed to thoroughly understanding downstream effects of trauma exposure in future-oriented scenarios. Furthermore, this study highlights the importance of attentional biases to negative stimuli that are task-relevant and the target of attention as well as subsequent recall of negative information. Treatments for PTSD have focused on influencing attentional biases for negative or aversive stimuli. However, assessment of this intervention methodology has not yielded consistently promising results (Schoorl, Putman, & Van Der Does, 2013). Incorporation of knowledge generated from the present study on how voluntary attention and recall function for emotional information in PTSD can continue to help inform treatment approaches that target cognitive processes. Although research on trauma-related memory is crucial to our understanding of PTSD pathology, it is of equal importance to understand how PTSD symptomatology may have bi-directional relationships with cognitive processes that can influence schemas, beliefs, and expectations that trauma survivors then utilize to navigate their surrounding environments. Longitudinal research may help elucidate whether cognitive vulnerabilities that are associated with PTSD symptoms are present before trauma exposure, which may help differentiate pathological trajectories and identify those at higher risk for this disorder.

References

Algom D, Chajut E, & Lev S (2004). A rational look at the emotional stroop phenomenon: a generic slowdown, not a stroop effect. Journal of experimental psychology: general, 133(3), 323. [PubMed: 15355142]

American Psychiatric Association. (2013). Diagnostic and statistical manual of mental disorders (DSM-5®). American Psychiatric Pub.

Amir N, McNally RJ, & Wiegartz PS (1996). Implicit memory bias for threat in posttraumatic stress disorder. Cognitive Therapy and Research, 20(6), 625–635.

Ashley V, Honzel N, Larsen J, Justus T, & Swick D (2013). Attentional bias for trauma-related words: exaggerated emotional Stroop effect in Afghanistan and Iraq war veterans with PTSD. BMC psychiatry, 13(1), 86. [PubMed: 23496805]

Badura-Brack AS, Naim R, Ryan TJ, Levy O, Abend R, Khanna MM, … Bar-Haim Y (2015). Effect of attention training on attention bias variability and PTSD symptoms: randomized controlled trials in Israeli and US combat veterans. American Journal of Psychiatry, 172(12), 1233–1241.

Banich MT, Mackiewicz KL, Depue BE, Whitmer AJ, Miller GA, & Heller W (2009). Cognitive control mechanisms, emotion and memory: a neural perspective with implications for psychopathology. Neuroscience & Biobehavioral Reviews, 33(5), 613–630. [PubMed: 18948135]

Bar-Haim Y, Lamy D, Pergamin L, Bakermans-Kranenburg MJ, & Van Ijzendoorn MH (2007). Threat-related attentional bias in anxious and nonanxious individuals: a meta-analytic study. Psychological bulletin, 133(1), 1. [PubMed: 17201568]

Beck JG, Freeman JB, Shipherd JC, Hamblen JL, & Lackner JM (2001). Specificity of Stroop interference in patients with pain and PTSD. Journal of abnormal psychology, 110(4), 536. [PubMed: 11727943]

Blanchard EB, Jones-Alexander J, Buckley TC, & Forneris CA (1996). Psychometric properties of the PTSD Checklist (PCL). Behaviour research and therapy, 34(8), 669–673. [PubMed: 8870294]

Blevins CA, Weathers FW, Davis MT, Witte TK, & Domino JL (2015). The posttraumatic stress disorder checklist for DSM-5 (PCL-5): Development and initial psychometric evaluation. Journal of traumatic stress, 28(6), 489–498. [PubMed: 26606250]

Bomyea J, Johnson A, & Lang AJ (2017). Information processing in PTSD: Evidence for biased attentional, interpretation, and memory processes. Psychopathology Review, 4(3), 218–243.

Bradley MM, & Lang PJ (1999). Affective norms for English words (ANEW): Instruction manual and affective ratings. Retrieved from

Brewin CR, & Holmes EA (2003). Psychological theories of posttraumatic stress disorder. Clinical psychology review, 23(3), 339–376. [PubMed: 12729677]

Bryant R, Harvey A, Gordon E, & Barry RJ (1995). Eye movement and electrodermal responses to threat stimuli in post-traumatic stress disorder. International Journal of Psychophysiology, 20(3), 209–213. [PubMed: 8788223]

Bryant RA, & Harvey AG (1997). Attentional bias in posttraumatic stress disorder. Journal of traumatic stress, 10(4), 635–644. [PubMed: 9391946]

Buckley TC, Blanchard EB, & Neill WT (2000). Information processing and PTSD: A review of the empirical literature. Clinical psychology review, 20(8), 1041–1065. [PubMed: 11098399]

Cahill L, & McGaugh JL (1998). Mechanisms of emotional arousal and lasting declarative memory. Trends in neurosciences, 21(7), 294–299. [PubMed: 9683321]

Chemtob C, Roitblat H, Hamada RS, Carlson JG, & Twentyman CT (1988). A cognitive action theory of post-traumatic stress disorder. Journal of anxiety disorders, 2(3), 253–275.

Chemtob CM, Roitblat HL, Hamada RS, Muraoka MY, Carlson JG, & Bauer GB (1999). Compelled attention: The effects of viewing trauma-related stimuli on concurrent task performance in posttraumatic stress disorder. Journal of Traumatic Stress: Official Publication of The International Society for Traumatic Stress Studies, 12(2), 309–326.

Choi H-Y, Kensinger EA, & Rajaram S (2013). Emotional content enhances true but not false memory for categorized stimuli. Memory & Cognition, 41(3), 403–415. [PubMed: 23196385]

Cisler JM, & Koster EH (2010). Mechanisms of attentional biases towards threat in anxiety disorders: An integrative review. Clinical psychology review, 30(2), 203–216. [PubMed: 20005616]

Constans JI (2005). Information-processing biases in PTSD. Neuropsychology of PTSD: Biological, cognitive, and clinical perspectives, 105–130.

Dalgleish T, Moradi A, Taghavi M, Neshat-Doost H, & Yule W (2001). An experimental investigation of hypervigilance for threat in children and adolescents with post-traumatic stress disorder. Psychological medicine, 31(3), 541. [PubMed: 11305862]

Dalgleish T, Taghavi R, Neshat-Doost H, Moradi A, Canterbury R, & Yule W (2003). Patterns of processing bias for emotional information across clinical disorders: A comparison of attention, memory, and prospective cognition in children and adolescents with depression, generalized anxiety, and posttraumatic stress disorder. Journal of Clinical Child and Adolescent Psychology, 32(1), 10–21. [PubMed: 12573928]

Durand F, Isaac C, & Januel D (2019). Emotional Memory in Post-traumatic Stress Disorder: A Systematic PRISMA Review of Controlled Studies. Frontiers in psychology, 10, 303. [PubMed: 30890976]

Dyer FN (1973). The Stroop phenomenon and its use in the stlldy of perceptual, cognitive, and response processes. Memory & Cognition, 1(2), 106–120. [PubMed: 24214501]

Ehlers A, & Clark DM (2000). A cognitive model of posttraumatic stress disorder. Behaviour research and therapy, 38(4), 319–345. [PubMed: 10761279]

Ehring T, & Ehlers A (2011). Enhanced priming for trauma-related words predicts posttraumatic stress disorder. Journal of abnormal psychology, 120(1), 234. [PubMed: 21058753]

El Khoury-Malhame M, Reynaud E, Soriano A, Michael K, Salgado-Pineda P, Zendjidjian X, … Rouby F (2011). Amygdala activity correlates with attentional bias in PTSD. Neuropsychologia, 49(7), 1969–1973. [PubMed: 21440563]

Fani N, Bradley-Davino B, Ressler KJ, & McClure-Tone EB (2011). Attention bias in adult survivors of childhood maltreatment with and without posttraumatic stress disorder. Cognitive Therapy and Research, 35(1), 57–67.

Fani N, Tone EB, Phifer J, Norrholm SD, Bradley B, Ressler KJ, … Jovanovic T (2012). Attention bias toward threat is associated with exaggerated fear expression and impaired extinction in PTSD. Psychological medicine, 42(3), 533–543. [PubMed: 21854700]

First MB, Spitzer RL, Gibbon M, & Williams JBW (1996). Structured clinical interview for DSM-IV axis I disorders, patient edition (February 1996 Final) SCID-I/P (Version 2.0). Biometrics Research Department, New York State Psychiatric Institute, New York, NY.

Foa EB, & Kozak MJ (1986). Emotional processing of fear: exposure to corrective information. Psychological bulletin, 99(1), 20. [PubMed: 2871574]

Golier JA, Yehuda R, Lupien SJ, Harvey PD, Grossman R, & Elkin A (2002). Memory performance in Holocaust survivors with posttraumatic stress disorder. American Journal of Psychiatry, 159(10), 1682–1688.

Grupe DW, & Nitschke JB (2013). Uncertainty and anticipation in anxiety: an integrated neurobiological and psychological perspective. nature Reviews neuroscience, 14(7), 488–501. [PubMed: 23783199]

Hayes JP, VanElzakker MB, & Shin LM (2012). Emotion and cognition interactions in PTSD: a review of neurocognitive and neuroimaging studies. Frontiers in integrative neuroscience, 6, 89. [PubMed: 23087624]

Iacoviello BM, Wu G, Abend R, Murrough JW, Feder A, Fruchter E, … Pine DS (2014). Attention bias variability and symptoms of posttraumatic stress disorder. Journal of traumatic stress, 27(2), 232–239. [PubMed: 24604631]

Imbriano G, Sussman TJ, Jin J, & Mohanty A (2019). The role of imagery in threat-related perceptual decision making. Emotion.

Joyal M, Wensing T, Levasseur-Moreau J, Leblond J, T. Sack A, & Fecteau S (2019). Characterizing emotional Stroop interference in posttraumatic stress disorder, major depression and anxiety disorders: A systematic review and meta-analysis. PloS one, 14(4), e0214998. [PubMed: 30964902]

Keane TM, Kolb LC, Kaloupek DG, Orr SP, Blanchard EB, Thomas RG, … Lavori PW (1998). Utility of psychophysiology measurement in the diagnosis of posttraumatic stress disorder: Results from a department of Veteran's Affairs cooperative study. Journal of consulting and clinical psychology, 66(6), 914. [PubMed: 9874904]

Kensinger EA, & Schacter DL (2005). Emotional content and reality-monitoring ability: fMRI evidence for the influences of encoding processes. Neuropsychologia, 43(10), 1429–1443. [PubMed: 15989934]

Kimble M, Boxwala M, Bean W, Maletsky K, Halper J, Spollen K, & Fleming K (2014). The impact of hypervigilance: Evidence for a forward feedback loop. Journal of anxiety disorders, 28(2), 241–245. [PubMed: 24507631]

Kimble MO, Frueh BC, & Marks L (2009). Does the modified Stroop effect exist in PTSD? Evidence from dissertation abstracts and the peer reviewed literature. Journal of anxiety disorders, 23(5), 650–655. [PubMed: 19272751]

MacLeod CM (1991). Half a century of research on the Stroop effect: an integrative review. Psychological bulletin, 109(2), 163. [PubMed: 2034749]

McGaugh JL (2018). Emotional arousal regulation of memory consolidation. Current Opinion in Behavioral Sciences, 19, 55–60.

McNally RJ, Kaspi SP, Riemann BC, & Zeitlin SB (1990). Selective processing of threat cues in posttraumatic stress disorder. Journal of abnormal psychology, 99(4), 398. [PubMed: 2266215]

McNally RJ, Metzger LJ, Lasko NB, Clancy SA, & Pitman RK (1998). Directed forgetting of trauma cues in adult survivors of childhood sexual abuse with and without posttraumatic stress disorder. Journal of abnormal psychology, 107(4), 596. [PubMed: 9830247]

McNally RJ, Clancy SA, Schacter DL, & Pitman RK (2000). Cognitive processing of trauma cues in adults reporting repressed, recovered, or continuous memories of childhood sexual abuse. Journal of abnormal psychology, 109(3), 355. [PubMed: 11016105]

Metzger LJ, Orr SP, Lasko NB, McNally RJ, & Pitman RK (1997). Seeking the source of emotional Stroop interference effects in PTSD: a study of P3s to traumatic words. Integrative Physiological and Behavioral Science, 32(1), 43–51. [PubMed: 9105913]

Mohanty A, & Flint RW (2001). Differential effects of glucose on modulation of emotional and nonemotional spatial memory tasks. Cognitive, Affective, & Behavioral Neuroscience, 1(1), 90–95.

Mohanty A, & Sussman TJ (2013). Top-down modulation of attention by emotion. Frontiers in Human Neuroscience, 7, 102. [PubMed: 23554590]

Niles AN, Luxenberg A, Neylan TC, Inslicht SS, Richards A, Metzler TJ, … O'Donovan A (2018). Effects of threat context, trauma history, and posttraumatic stress disorder status on physiological startle reactivity in Gulf war veterans. Journal of traumatic stress, 31(4), 579–590. [PubMed: 30058728]

Paunovic N, Lundh L-G, & Öst L-G (2002). Attentional and memory bias for emotional information in crime victims with acute posttraumatic stress disorder (PTSD). Journal of anxiety disorders, 16(6), 675–692. [PubMed: 12405525]

Pine DS, Mogg K, Bradley BP, Montgomery L, Monk CS, McClure E, … Kaufman J (2005). Attention bias to threat in maltreated children: Implications for vulnerability to stress-related psychopathology. American Journal of Psychiatry, 162(2), 291–296.

Pineles SL, Shipherd JC, Mostoufi SM, Abramovitz SM, & Yovel I (2009). Attentional biases in PTSD: More evidence for interference. Behaviour research and therapy, 47(12), 1050–1057. [PubMed: 19716122]

Pineles SL, Shipherd JC, Welch LP, & Yovel I (2007). The role of attentional biases in PTSD: Is it interference or facilitation? Behaviour research and therapy, 45(8), 1903–1913. [PubMed: 17049337]

Pitman RK, Rasmusson AM, Koenen KC, Shin LM, Orr SP, Gilbertson MW, … Liberzon I (2012). Biological studies of post-traumatic stress disorder. nature Reviews neuroscience, 13(11), 769–787. [PubMed: 23047775]

Rajaram S, Srinivas K, & Travers S (2001). The effects of attention on perceptual implicit memory. Memory & Cognition, 29(7), 920–930. [PubMed: 11820751]

Rubin DC, Berntsen D, & Bohni MK (2008). A memory-based model of posttraumatic stress disorder: evaluating basic assumptions underlying the PTSD diagnosis. Psychological review, 115(4), 985. [PubMed: 18954211]

Schoorl M, Putman P, & Van Der Does W (2013). Attentional bias modification in posttraumatic stress disorder: a randomized controlled trial. Psychotherapy and psychosomatics, 82(2), 99–105. [PubMed: 23295710]

Sun D, Gold AL, Swanson CA, Haswell CC, Brown VM, Stjepanovic D, … Morey RA (2020). Threat-induced anxiety during goal pursuit disrupts amygdala–prefrontal cortex connectivity in posttraumatic stress disorder. Translational psychiatry, 10(1), 1–11. [PubMed: 32066695]

Sussman TJ, Weinberg A, Szekely A, Hajcak G, & Mohanty A (2017). Here comes trouble: prestimulus brain activity predicts enhanced perception of threat. Cerebral Cortex, 27(4), 2695–2707. [PubMed: 27114179]

Talmi D (2013). Enhanced emotional memory: Cognitive and neural mechanisms. Current Directions in Psychological Science, 22(6), 430–436.

Talmi D, Schimmack U, Paterson T, & Moscovitch M (2007). The role of attention and relatedness in emotionally enhanced memory. Emotion, 7(1), 89. [PubMed: 17352566]

Thomaes K, Dorrepaal E, Draijer N, de Ruiter MB, Elzinga BM, Sjoerds Z, … Veltman DJ (2013). Increased anterior cingulate cortex and hippocampus activation in Complex PTSD during encoding of negative words. Social cognitive and affective neuroscience, 8(2), 190–200. [PubMed: 22156722]

Vrana SR, Roodman A, & Beckham JC (1995). Selective processing of trauma-relevant words in posttraumatic stress disorder. Journal of anxiety disorders, 9(6), 515–530.

Vythilingam M, Blair KS, McCaffrey D, Scaramozza M, Jones M, Nakic M, … Mitchell D (2007). Biased emotional attention in post-traumatic stress disorder: a help as well as a hindrance? Psychological medicine, 37(10), 1445. [PubMed: 17559703]

Weathers FW, Litz BT, Keane TM, Palmieri PA, Marx BP, & Schnurr PP (2013). The ptsd checklist for dsm-5 (pcl-5). Scale available from the National Center for PTSD at www.ptsd.va.gov, 10.

Weber DL (2008). Information processing bias in post-traumatic stress disorder. The open neuroimaging journal, 2, 29. [PubMed: 19639038]

Willebrand M, Norlund F, Kildal M, Gerdin B, Ekselius L, & Andersson G (2002). Cognitive distortions in recovered burn patients: The emotional Stroop task and autobiographical memory test. Burns, 28(5), 465–471. [PubMed: 12163286]

Woud ML, Verwoerd J, & Krans J (2017). Modification of cognitive biases related to posttraumatic stress: A systematic review and research agenda. Clinical psychology review, 54, 81–95. [PubMed: 28445840]

Zeitlin SB, & McNally RJ (1991). Implicit and explicit memory bias for threat in post-traumatic stress disorder. Behaviour research and therapy, 29(5), 451–457. [PubMed: 1741732]

- Attentional biases to negative stimuli and their relationship with memory biases in PTSD are understudied
- Higher PTSD symptoms were related to slower encoding of negative vs neutral words viewed under full but not divided attention
- Higher PTSD symptoms were associated with more accurate recall of negative vs neutral words, irrespective of whether words were viewed under full or divided attention
- Attention voluntarily directed towards negative stimuli and their greater recall may be important treatment targets for PTSD.

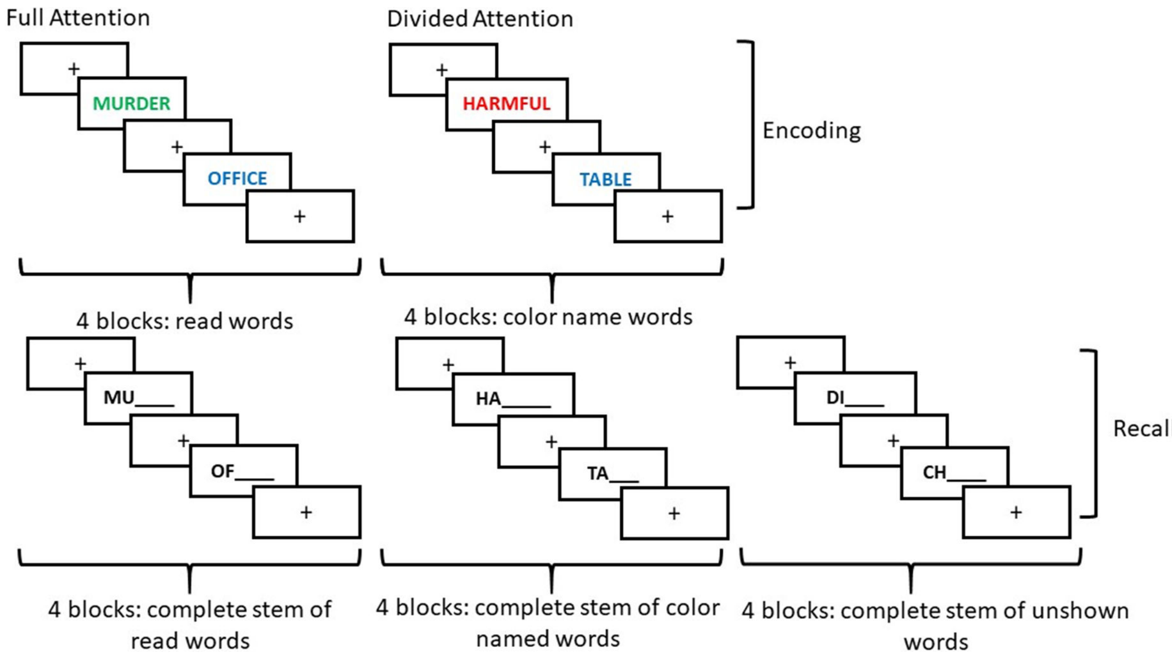

Figure 1.
Design for the full and divided attention tasks

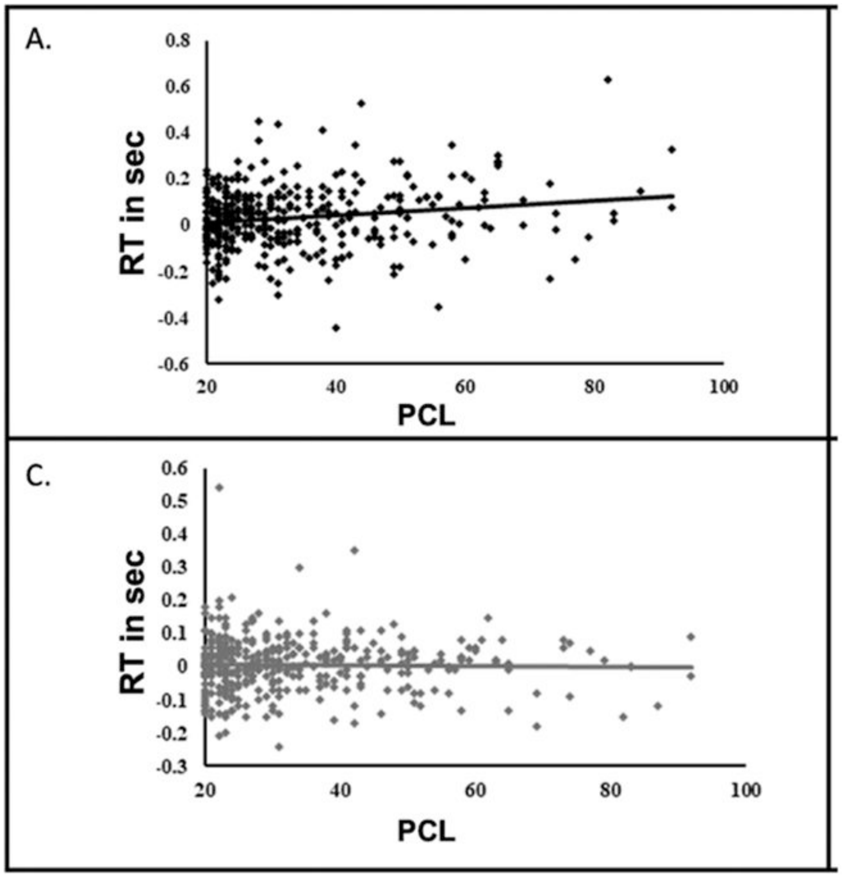

Figure 2.

Correlations between scores on the PCL and A. RT for reading negative vs neutral words when attention was fully deployed. B. RT for naming color of negative vs neutral words when attention was divided between the words and their color.

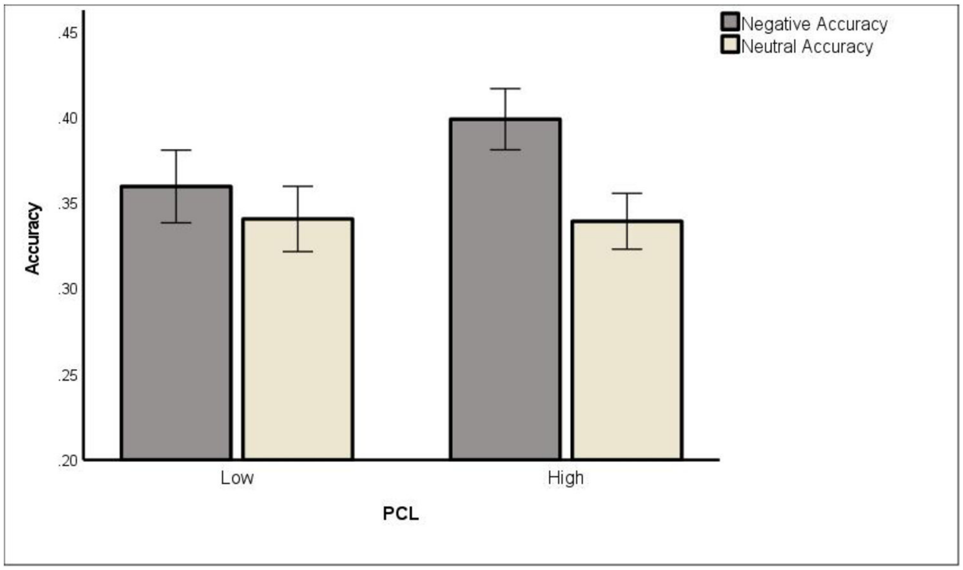

Figure 3.
Figure is for visualization purposes only and depicts the word type x PCL interaction in the Results section. Low and High PCL are groups based on PCL scores below the 25th percentile (Low) and above the 75th percentile (High). Negative and Neutral Accuracy is accuracy for recall of negative and neutral words collapsed across full and divided attention tasks.

Table 1.

Task performance during encoding and relationships with PTSD symptoms

	Task Performance - Encoding						***Correlations with PTSD Symptoms***	
	Negative Mean±SD	**Neutral Mean±SD**	***t***	***df***	***D***	***p***	**Negative – Neutral *r***	***p***
Full Attention (RT, in ms)	1021 ± 255	988 ± 242	4.606	374	−0.247	< .001	0.170	.001
Divided Attention (RT, in ms)	972 ± 173	964 ± 171	1.817	374	−0.097	.070	−0.028	.595

Table 2.

Task performance during recall

Encoding		***Recall Accuracy***
Task type	***Word type***	***Mean±SD***
Reading	**Negative**	0.438 ± 0.012
	Neutral	0.396 ± 0.011
Color Naming	**Negative**	0.320 ± 0.010
	Neutral	0.301 ± 0.009