

BRIEF REPORT

Punishment Learning in U.S. Veterans With Posttraumatic Stress Disorder

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Learning processes have been implicated in the development and course of posttraumatic stress disorder (PTSD); however, little is currently known about punishment-based learning in PTSD. The current study investigated impairments in punishment-based learning in U.S. veterans. We expected that veterans with PTSD would demonstrate greater punishment-based learning compared to a non-PTSD control group. We compared a PTSD group with and without co-occurring depression ($n = 27$) to a control group (with and without trauma exposure) without PTSD or depression ($n = 29$). Participants completed a computerized probabilistic punishment-based learning task. Compared to the non-PTSD control group, veterans with PTSD showed significantly greater punishment-based learning. Specifically, there was a significant Block \times Group interaction, $F(1, 54) = 4.12, p = .047, \eta^2 = .07$. Veterans with PTSD demonstrated greater change in response bias for responding toward a less frequently punished stimulus across blocks. The observed hypersensitivity to punishment in individuals with PTSD may contribute to avoidant responses that are not specific to trauma cues.

Learning processes have been implicated in the onset and maintenance of posttraumatic stress disorder (PTSD) and have been targeted by effective PTSD treatments (e.g., Lissek & van Meurs, 2015; Rauch & Foa, 2006; VanElzaker, Dahlgren, Davis, Dubois, & Shin, 2013). This literature has emphasized the role of both classical and operant conditioning (e.g., Monson & Shnaider, 2014). For example, according to Pavlovian fear conditioning, the reexperiencing and hyperarousal symptoms of PTSD are acquired via classical conditioning

during trauma exposure and represent persistent conditioned responses (Lissek & Grillon, 2012). An operant conditioning view suggests that avoidance behaviors in PTSD are negatively reinforced and thus repeated due to their function to reduce aversive anxiety symptoms. Surprisingly, little is known about the ways in which other forms of instrumental learning may be altered in those with PTSD. Several recent studies have shown that impairments in the acquisition of reward learning were associated with emotional numbing symptoms in PTSD (e.g., Elman et al., 2005, 2009; Hopper et al., 2009). Limited research, however, has examined responsivity to punishment in PTSD.

Early findings from active duty service members with PTSD found a hypersensitivity to punishment (Dretsch, Thiel, Athy, Born, & Prue-Owens, 2013). Specifically, using a variant Iowa Gambling Task (Dretsch et al., 2013), those with PTSD showed increased sensitivity to immediate monetary losses and hyposensitivity to delayed monetary reward compared to controls. Despite findings showing increased sensitivity to punishment in PTSD, no studies of which we are aware have looked for alterations in punishment-based learning among individuals with PTSD.

This work was supported by VA National Center for PTSD, Behavioral Science Division. Diego A. Pizzagalli was partially supported by NIMH grants R01 MH068376 and R01 MH101521. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH and the Department of Veteran Affairs.

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DOI: 10.1002/jts.22109

The goal of the current study was to fill this gap and determine if impairments in punishment-based learning in PTSD were present. We used a probabilistic punishment-based learning task that assessed change in behavior in response to differential schedules of monetary loss (Santesso et al., 2008) with a sample of veterans comprising both those with and without PTSD. We hypothesized that veterans with PTSD would show a hypersensitivity to punishment-related feedback. Because of the hypersensitivity we also expected an increase in punishment-based learning (i.e., a systematic preference for responding to the less frequently punished stimulus) compared to veterans without PTSD.

Method

Participants and Procedure

Veterans were recruited through the use of flyers distributed throughout the VA Boston Healthcare System. Eligibility was not restricted to a specific era of service. Veterans who were interested in participating in a computer task were instructed to contact a study staff member for additional information about the study (e.g., time commitment and eligibility requirements). Those who contacted study staff were then provided with additional information about the study and eligibility was assessed briefly on the phone. Those who appeared eligible based on the phone screen were scheduled for an in-person single study visit. Participants were ultimately classified into two groups: those with PTSD and controls who did not have PTSD. The mandatory inclusion criterion for the PTSD group was a diagnosis of current PTSD based on the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; *DSM-IV*; American Psychiatric Association, 1994). The exclusion criteria for all participants were cognitive impairment, a diagnosis of schizophrenia, and a diagnosis of a psychotic disorder. An additional exclusion criterion for the non-PTSD group was a clinical level of symptoms of depression. This exclusion criterion was based on findings that had shown an association between depression and increased punishment responsivity (e.g., Admon & Pizzagalli, 2015). Depression was not an exclusion criterion for the PTSD group due to the high co-occurrence of depression and PTSD (e.g., lifetime comorbidity rates of approximately 50%; Rytwinski, Scur, Feeny, & Youngstrom, 2013).

Of the 99 veterans who attended the study visit, three (3.03%) were excluded due to Blessed Orientation-Memory-Concentration Test scores indicative of significant cognitive impairment; 14 (14.14%) were excluded from the control group because they met criteria for depression. The final sample ($N = 82$; PTSD $n = 40$, non-PTSD control $n = 42$) consisted of 77 male (94%) and 5 female (6%) veterans; all were 18 years of age or older. Participants reported an average age of 55.20 years ($SD = 11.63$, range = 24–83). Self-reported race was White/Caucasian (72.0%), Black/African American (20.7%), American Indian (3.7%), Asian/Pacific Islander (1.2%), and other/multiracial (2.4%). There were no demographic differ-

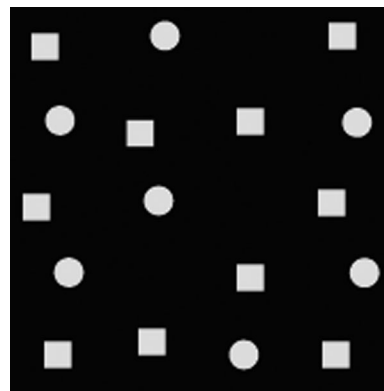


Figure 1. Sample stimulus of the probabilistic punishment learning task.

ences between the two groups. The study was approved by the VA Boston Healthcare System Institutional Review Board. Participants provided written informed consent and completed symptom measures. Participants were compensated \$30.

A computerized punishment-based learning task developed by Pizzagalli and colleagues (Santesso et al., 2008) assessed the ability of individuals to modulate behavior as a function of punishment history. Participants were informed that they would begin with \$10, and the aim of the task was to lose as little money as possible. Stimuli for the task consisted of 1 of 10 possible different patterns of colored squares and circles bound within a black square (see Figure 1); in the depiction, stimuli are either 7 squares and 10 circles or 10 squares and 7 circles. For each trial, participants were asked to identify which type of array had been presented (i.e., more squares or more circles).

The procedure consisted of two blocks of 100 trials. Each stimulus type was presented 50 times per block. Each trial followed an identical sequence: (a) a presentation of a fixation point (500 ms), (b) an appearance of a shape array (350 ms), and (c) a blank screen that remained until a response was made. Twenty incorrect trials per block were followed by punishment feedback (“You lose 10 cents”) in a pseudorandomized sequence. A critical feature was the use of an asymmetrical punishment ratio (3:1 rich/lean) for punishment of incorrect identifications to elicit a response bias. Specifically, incorrect identifications of the rich stimulus were associated with 3 times ($n = 15$) more punishment feedback than the lean stimulus ($n = 5$). Designation of the rich stimulus (more squares vs. more circles) was counterbalanced across subjects.

We derived three outcome variables: (a) response bias (RB), (b) discriminability, and (c) reaction time (RT). Response bias indexed an individual’s preference for the less frequently punished (i.e., lean) stimulus and was calculated using this formula:

$$\log b = \frac{1}{2} \log \left(\frac{(Lean_{correct} + 0.5) * (Rich_{incorrect} + 0.5)}{(Lean_{incorrect} + 0.5) * (Rich_{correct} + 0.5)} \right)$$

Change in response bias was calculated with this formula:

$$\Delta RB = RB (\text{Block 2}) - RB (\text{Block 1})$$

Discriminability is an index of an individual's ability to distinguish between the two sets of stimuli and was calculated using this formula:

$$\log d = \frac{1}{2} \log \left(\frac{(Lean_{correct} + 0.5) * (Rich_{correct} + 0.5)}{(Lean_{incorrect} + 0.5) * (Rich_{incorrect} + 0.5)} \right)$$

Reaction time was the time elapsed in milliseconds between the appearance of the stimulus and the participant's response.

Data were screened for outliers according to established procedures (see Pizzagalli, Jahn, & O'Shea, 2005). Reaction times < 150 ms or > 2,500 ms were used to determine outlier trials within blocks. Outlier task administrations were defined based on the following criteria: < 80% of valid trials within a block, < 10 rich punishment/block, > 30 outlier trials for any block, < 60% accuracy for each block ($n = 22$); response bias scores > 3 SD from the sample mean ($n = 2$). Two participants did not complete the task. Based on these procedures, data from 26 participant task administrations were excluded, which is a rate consistent with research using similar tasks in veteran and psychiatric samples (e.g., Liverant et al., 2014). Analyses did not detect differences between included and excluded participants in demographic variables, PTSD/control group status, depression, and severity of PTSD. Quality control analyses were performed by coauthor collaborators located at McLean Hospital who were blinded to group assignment (A.L.J., S.L.D., and D.A.P.). The final sample consisted of 56 participants (PTSD group $n = 27$; non-PTSD control group $n = 29$).

Measures

We used the Structured Clinical Interview for *DSM-IV* (SCID-IV; Spitzer, Williams, Gibbon, & First, 1994) psychotic screening module to identify the presence of current or lifetime psychotic symptoms. The Clinician-Administered PTSD Scale (CAPS; Blake et al., 1995) was used to diagnose current PTSD. The CAPS assesses PTSD symptoms occurring over the course of the past month. Although the diagnosis is made using established scoring rules (Blake et al., 1995), CAPS total scores of 65 or above have been shown to be associated with having the diagnosis (Weathers, Ruscio, & Keane, 1999). The Hamilton Rating Scale for Depression (HAM-D; Williams, Link, Rosenthal, & Terman, 1988) was used to establish the depression-exclusion criterion for the control group. HAM-D total scores of 17 or above are associated with moderate to severe depression (Zimmerman, Martinez, Young, Chelminski, & Dalrymple, 2013); participants scoring this threshold were excluded from the control group. The HAM-D was completed in reference to symptoms occurring in the past two weeks. The Blessed Orientation-Memory-Concentration Test (BOMC; Katzman et al., 1983) assessed current cognitive impairment. Individuals scoring 10 or higher were excluded due to the likelihood of substantial cognitive impairment.

Data Analysis

A 2 (Block: 1, 2) \times 2 (Group: PTSD, control) mixed model repeated measures two-tailed analysis of variance (ANOVA) was conducted to examine differences on outcome measures for response bias and discriminability. For reaction time, the repeated measure of stimulus was added to evaluate change in reaction time for the rich versus lean stimulus. A review of histograms, skew, and kurtosis values showed that variables were normally distributed. Variances of the two groups were equal. Only one value for one participant was missing; it was handled using pairwise deletion. Analyses were performed using SPSS statistical software version 21.

Results

The mean CAPS score for the PTSD group was 71.56 ($SD = 20.48$). The mean HAM-D score for the PTSD and control groups was 12.36 ($SD = 10.12$) and 2.70 ($SD = 2.89$), respectively. In the PTSD group, 36% ($n = 14$) met clinical levels of depression.

The main effects for response bias of the block and group were not statistically significant. There was a significant Block \times Group interaction, $F(1, 54) = 4.12, p = .047, \eta^2 = .07$. The groups were significantly different on ΔRB . Paired samples t tests showed that response bias significantly increased from Block 1 to Block 2 in the PTSD group (Block 1, $M = -0.001, SD = 0.17$, vs. Block 2, $M = 0.10, SD = 0.24, t(26) = -2.07, p = .049$), but not in the control group (Block 1, $M = 0.03, SD = 0.25$, vs. Block 2, $M = 0.02, SD = 0.31, t(28) = 0.52, p = .610$; see Figure 2).

The results of the ANOVA revealed no significant effects for block or group or the Block \times Group interaction. There was a main effect for block, $F(1, 54) = 10.58, p = .002, \eta^2 = .16$, due to faster reaction time in Block 2 ($M = 988.54$ ms, $SD = 201.28$) than in Block 1 ($M = 1037.64$ ms, $SD = 208.51$). No other significant effects were found.

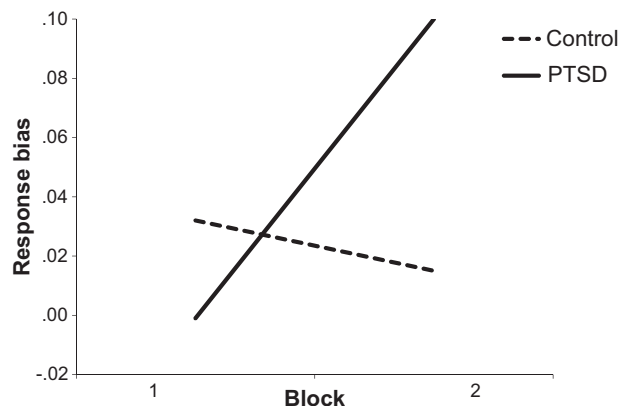


Figure 2. Estimated marginal means for response bias across Blocks 1 and 2 (significant interaction of Block \times Group, $F(1, 54) = 4.12, p = .047, \eta^2 = .07$). PTSD = posttraumatic stress disorder.

Discussion

This study was the first of which we are aware to document alterations in behavioral indices of punishment-based learning among individuals with PTSD when compared to control participants. This suggested that the development of a response bias away from the more frequently punished stimulus may be an avoidant response associated with hypersensitivity to punishment-related feedback. In contrast, the decreased sensitivity to punishment (i.e., lack of ΔRB) among the control participants may have been a more adaptive response (i.e., persistence with accurate responding irrespective of frequency of punishment received). Avoidance of internal and external trauma-related cues is a core symptom of PTSD. Our findings may indicate that this avoidance behavior encompasses a broader hypersensitivity and reactivity to punishing experiences. For example, individuals with PTSD may be more responsive to the variable receipt of punishment in their daily lives (e.g., receipt of negative feedback during interpersonal interactions), thereby promoting increased withdrawal behavior.

Findings showing differences in punishment learning in PTSD might have significant treatment implications. Evidence-based PTSD interventions (e.g., Foa, Hembree, & Rothbaum, 2007; Resick & Schnicke, 1992) focus almost exclusively on reduction of fear to trauma-related cues. Our results suggested that individuals with PTSD could benefit from therapeutic strategies to decrease avoidance of punishment-related feedback (e.g., exposure to punishment-related stimuli/negative affect, behavioral strategies to promote continued adaptive responding when presented with punishment). Including a focus on punishment-related avoidance/learning in PTSD treatment might lead to better engagement or response rates and might better address residual withdrawal and avoidance behaviors after treatment completion.

Despite the novelty of the current investigation, there were a number of study limitations. The small sample size and study design (i.e., exclusion of depressed participants in the control group) precluded the use of data analytic approaches (e.g., hierarchical regression) capable of differentiating the contributions of PTSD and co-occurring depression to punishment learning. Thus, it was unclear whether PTSD, depression, or the co-occurrence contributed to our findings. This is a critical area for future research in light of findings demonstrating associations between depression and punishment responsiveness (Admon & Pizzagalli, 2015). To constitute a representative veteran control group, we used minimal exclusion criteria. Thus, individuals in this group may have had psychiatric diagnoses other than PTSD and depression (e.g., anxiety and substance use), which may have affected the results. Moreover, because the majority of study participants were men, caution should be used when generalizing findings to women. It will be important to replicate and extend the current findings with larger and more diverse samples.

Nonetheless, this study is the first to document differences in punishment-based learning among individuals with PTSD. The findings may have implications for treating PTSD. Future research is needed to better explicate the underlying mechanisms and the nature of changes in punishment learning in PTSD and the contributions of co-occurring psychiatric symptoms to punishment learning.

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