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Impulsive responding in threat and reward contexts as a function of PTSD symptoms and trait disinhibition

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ABSTRACT

We examined current posttraumatic stress disorder (PTSD) symptoms, trait disinhibition, and affective context as contributors to impulsive and self-destructive behavior in 94 trauma-exposed Veterans. Participants completed an affective Go/No-Go task (GNG) with different emotional contexts (threat, reward, and a multidimensional threat/reward condition) and current PTSD, trait disinhibition, and risky/self-destructive behavior measures. PTSD interacted with trait disinhibition to explain recent engagement in risky/self-destructive behavior, with Veterans scoring high on trait disinhibition and current PTSD symptoms reporting the highest levels of these behaviors. On the GNG task, commission errors were also associated with the interaction of PTSD symptoms and trait disinhibition. Specifically, PTSD symptoms were associated with greater commission errors in threat vs. reward contexts for individuals who were low on trait disinhibition. In contrast, veterans high on PTSD and trait disinhibition exhibited the greatest number of commission errors in the multidimensional affective context that involved both threat and reward processing. Results highlight the interactive effects of PTSD and disinhibited personality traits, as well as threat and reward systems, as risk factors for impulsive and self-destructive behavior in trauma-exposed groups. Findings have clinical implications for understanding heterogeneity in the expression of PTSD and its association with disinhibited behavior.

1. Introduction

Posttraumatic stress disorder (PTSD) has not classically been conceptualized as a disorder marked by impulse control deficits. However, there is increasing awareness that problematic impulsivity and poor self-regulation are features of posttraumatic psychopathology, as evidenced by the addition of the "reckless and self-destructive" behavior diagnostic criterion in *DSM-5* (American Psychiatric Association, 2013). For example, heavy alcohol consumption, drug abuse, self-harm, gambling, reckless driving, and violence are more prevalent in combat-exposed military Veterans and other traumatized groups than the general population (Elbogen et al., 2014, 2010; Jacobsen, Southwick, & Kosten, 2001; Kang et al., 2015; Killgore et al., 2008; Thomsen, Stander, McWhorter, Rabenhorst, & Milner, 2011). The high prevalence of these behaviors poses a massive public health burden by increasing risk for chronic medical and psychiatric illnesses, criminal justice-system involvement, and premature death (Bogg & Roberts, 2004; Sadeh, Binder, & McNiel, 2014). Trait disinhibition is also a known risk factor for impulsive and reckless behavior as well as trauma exposure and PTSD (Koffel et al., 2016; Miller, 2003; Patrick, Kramer, Krueger, & Markon, 2013; Sadeh, Miller, Wolf, & Harkness, 2015; Sadeh, Spielberg et al., 2015). Given this, the extent to which PTSD symptoms in particular, versus disinhibited personality traits more broadly, contribute to elevated rates of risky and self-destructive behaviors following trauma remains unclear. The goals of this study were to examine the unique and interactive contributions of trait disinhibition and PTSD for impulsive and risky behavior in a sample of trauma-exposed military Veterans.

1.1. PTSD and trait disinhibition

PTSD is characterized by symptoms that may increase behavioral activation and motor readiness and dispose an individual to act impulsively or recklessly. For example, heightened anger may increase the tendency for individuals to act aggressively or self-harm (Chemtob, Novaco, Hamada, Gross, & Smith, 1997; Sadeh & McNiel, 2013), intrusive memories may lead individuals to abuse substances to avoid distressing thoughts (Stewart, Pihl, Conrod, & Dongier, 1998), and avoidance/numbing symptoms may cause an individual to ignore internal threat cues (Krause, Kaltman, Goodman, & Dutton, 2006) and act

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recklessly. Furthermore, evidence suggests that PTSD is associated with elevations on personality dimensions that predispose an individual to engage in risky or uninhibited behavior, including trait disinhibition (Kuhne, Orr, & Baraga, 1993) and sensation seeking (Richman & Frueh, 1997).

Given the link between PTSD and disinhibited personality traits, the first aim of this study was to examine whether PTSD symptoms explain unique variance in impulsive and risky behaviors in trauma-exposed Veterans over and above that accounted for by trait disinhibition. Previous work suggests that PTSD symptoms may exacerbate self-regulatory failures in individuals with a propensity for behavioral disinhibition (e.g., Miller, 2003), although this theory has yet to be tested directly. To test this additional hypothesis, we examined whether PTSD moderates the vulnerability conferred by disinhibited personality traits for impulsive behavior. We expected that individuals high on current PTSD symptoms and trait disinhibition would show the greatest impulsive and risky behavior.

1.2. Impulsive behavior: the role of affective context

Despite growing awareness that impulse control can be deficient in PTSD, relatively few studies have examined the cognitive and emotional mechanisms leading to self-regulation failures. Studies of response inhibition (i.e., the ability to withhold an automatic or dominant response) (Friedman & Miyake, 2004; Nigg, 2000), repeatedly find that PTSD symptoms are associated with more impulsive responding (e.g., DeGutis et al., 2015) and abnormalities in prefrontal brain regions involved in inhibitory control (Falconer, Bryant et al., 2008; Falconer, Felmingham et al., 2008; Sadeh, Miller et al., 2015; Sadeh, Spielberg et al., 2015; Wu et al., 2010). In terms of context processing, research indicates that failures to process contextual information is deficient in PTSD, including in situations that require inhibition (van Rooij et al., 2014, 2015). Deficient contextual processing may contribute to deficits in the inhibition of the fear response in PTSD, for example, by decreasing the influence of safety cues in the environment on inhibitory control processes (Rougemont-Bücking et al., 2011). Further, PTSD has been associated with deficits in proactive inhibition, which involves using contextual cues to predict when stopping behavior is required (van Rooij et al., 2014). One area that has received less attention in the PTSD literature is the extent to which impulsive behaviors are exacerbated by, or specific to, certain affective contexts that are irrelevant to goal-directed behavior and not predictive of inhibition (i.e., in contrast to proactive inhibition). Research shows that risk-taking and impulsivity are more likely to occur in the context of intense emotions, although the affective states that drive different behaviors vary across individuals and psychiatric disorders (Loewenstein, Weber, Hsee, & Welch, 2001; Weiss, Tull, Viana, Anestis, & Gratz, 2012). For example, poor behavioral control has been shown to occur when individuals are seeking pleasurable and rewarding experiences (i.e., appetitive or approach motivation; Horvath & Zuckerman, 1993; Zuckerman & Kuhlman,2000) and when they experience intense negative emotions, such as extreme fear, distress, or anger (i.e., avoidance motivation contexts; James, Strom, & Leskela, 2014; Leyro, Zvolensky, & Bernstein, 2010; Nock, 2010; Whiteside, Lynam, Miller, & Reynolds, 2005). Thus, the emotions that trigger impulsive and risky behaviors are diverse and clarifying the impact of different affective contexts on these behaviors would provide a better understanding of the processes that initiate and maintain them in PTSD.

The effects of fearful or threatening stimuli on cognitive functioning has been widely studied in PTSD, and the results overwhelming suggest that activating negative valence systems (e.g., amygdala-mediated threat detection) interferes with executive control processes. For example, numerous studies indicate that activation of threat systems compromises inhibitory control in individuals with PTSD, leading to greater attentional bias to aversive stimuli, distracter interference, and intrusive thoughts (Aupperle, Melrose, Stein, & Paulus, 2012; Buckley, Blanchard, & Neill, 2000; Pergamin-Hight et al., 2015). Based on these data, we expected PTSD symptoms to be related to greater impulsive behavior in contexts that activate threat processing.

Rewarding contexts may also be relevant for understanding inhibitory control failures in PTSD, given extensive evidence that dysfunction in reward systems contributes to disinhibited phenotypes, such as substance addiction, gambling, and antisocial behavior (Buckholtz et al., 2010; Goodman, 2008). In contrast to the vast literature on threat processing and PTSD, only one published study has examined how reward processing impacts inhibitory control in this disorder. Using a stop-signal task, Casada and Roache (2005) found that PTSD patients showed greater response inhibition in neutral contexts compared to trauma-exposed controls, but decreased response inhibition in monetary reward conditions. This study provides preliminary evidence that reward stimuli may compromise inhibitory control processes in PTSD as it does in other disinhibited disorders. This finding contradicts speculation by some researchers that PTSD is marked by deficits in reward responsivity as a function of the anhedonia and emotional numbing features of the disorder (Nawijn et al., 2015). Given the preliminary nature of the data on reward processing and inhibitory control in PTSD, more research is needed to examine these processes.

The affective contexts that trigger impulsive actions in everyday life are complex and likely involve multiple emotional components. Indeed, research shows that activation of negative valence systems (e.g., stressful contexts) can increase reward-seeking and impulsive behavior in humans and animals (Shaham, Erb, & Stewart, 2000; Sinha & Jastreboff, 2013), possibly reflecting an attempt to relieve negative affect associated with the stressful context (Koob & Le Moal, 2001). Regarding PTSD, individuals may be more likely to use illicit substances or gamble recklessly during or immediately following stressful events, especially those that activate their symptoms. Thus, multidimensional affective contexts that involve both threat and reward processing may be relevant for understanding impulsive behavior in PTSD. In particular, individuals who are characterized by both a propensity to seek out rewarding stimuli (e.g., high trait disinhibition) and high levels of threat sensitivity (e.g., elevated PTSD symptoms) may be the most likely to manifest impulsive behavior in this type of multidimensional affective context. To date, no published research has examined the interactive effects of threat and reward processing on response inhibition in trauma-exposed individuals. Thus, another goal of this study was to examine how unidimensional and multidimensional threat and reward contexts impacted response inhibition in trauma-exposed Veterans, and to test PTSD and trait disinhibition as moderators of these relationships. Clarifying these relationships can help illuminate the situations that precipitate high-risk impulsive behavior following trauma.

1.3. Present study

The goals of this study were to examine the unique and interactive effects of PTSD and trait disinhibition on impulsive and risky behavior in the laboratory and in everyday life. Trauma-exposed Veterans completed a self-report measure of risky, impulsive, and self-destructive behavior and an affective Go/No-Go (GNG) task with three different emotional contexts (threat only, reward only, and a multidimensional threat/reward condition). We selected the GNG paradigm because it is one of the most widely studied measures of response inhibition and measures effortful control of a motor response without imposing demands on other high-level cognitive control systems (e.g., distractor suppression, interference control) (Rubia, Smith, Brammer, & Taylor, 2003; Schulz et al., 2007).

In terms of self-report behavior, we expected current PTSD symptoms and trait disinhibition to each confer unique risk for impulsive behaviors based on previous research (Green et al., 2005; Justus, Finn, & Steinmetz, 2000; Lusk, Sadeh, Wolf, & Miller, 2017; Thomsen et al., 2011; Zuckerman & Kuhlman, 2000). Additionally, we hypothesized that current PTSD symptoms would exacerbate the propensity for risky

and impulsive behavior conferred by trait disinhibition, such that individuals high on both PTSD symptoms and trait disinhibition would report the greatest engagement in these behaviors in everyday life. Regarding the GNG task, we hypothesized that impulsive responding would be positively associated with PTSD symptoms in contexts that activate threat systems in light of previous research (Aupperle et al., 2012; Buckley et al., 2000; Pergamin-Hight et al., 2015). Given that trait disinhibition is associated with a general propensity to act impulsively (e.g., cognitive deficits leading to poor response inhibition broadly; Young et al., 2009), we expected this trait to correlate with impulsive responding in contexts that activate threat and/or reward systems. Finally, we hypothesized that impulsive responding would be associated with PTSD symptoms and trait disinhibition (PTSD × trait disinhibition interaction) in the multidimensional threat/reward context.

2. Methods

2.1. Sample

100 Veterans were recruited from VA Boston Healthcare System through flyers posted in the hospital, outpatient and residential psychotherapy groups, and a database of research volunteers. Veterans between the ages of 18–55, who had experienced a traumatic event, and had no prior history of a psychotic disorder were eligible to participate.[1] The final sample consisted of 83 men and 11 women ages 21–55 (M = 41.3, SD = 9.2).[2] Most self-identified as Caucasian (75%), followed by African American (20%), and Asian American (5%). Almost half of the participants were either unemployed or receiving disability payments (48%), and the rest were either employed full time (28%), part time (11%), retired (7%), students (5%), or on active duty military status (1%). Over half of the sample served in the wars in Iraq and Afghanistan (56.4%), followed by Operation Desert Storm (23.4%), the Vietnam War (2.1%), and another era of service (17.1%). On the Life Events Checklist for *DSM-5* (Weathers, Blake et al., 2013; Weathers, Litz et al., 2013), participants reported an average of 8.1 different types of potentially traumatic experiences in their lifetimes (SD = 2.6), including assault (84%), transportation accident (89%), natural disaster (71%), combat (65%), fire or explosion (45%), exposure to toxic substances (56%), serious accident (48%), sexual assault (31%), caused serious injury or death to another person (31%), life-threatening illness/injury (30%), severe human suffering (22%), sudden death of another (15%), and captivity (10%).

All necessary institutional review boards approved the study procedures prior to data collection, and participants gave written informed consent after they were provided with a detailed description of the study.

2.2. Measures

2.2.1. Current PTSD symptoms

The PTSD Checklist for *DSM-5* (PCL-5; Weathers, Blake et al., 2013; Weathers, Litz et al., 2013) is a 20-item self-report measure reflecting the 20 *DSM-5* symptoms of PTSD. Participants were asked to rate the degree to which they had been bothered by a particular symptom in the last month on a Likert scale ranging from 0 (“*Not at all*”) to 4 (“*Extremely*”). A total score was created by summing the scores for each item (M = 41.8, SD = 16.8, *Min/Max* = 6.0/76.0; Cronbach’s alpha = 0.95).

2.2.2. Trait disinhibition

The Externalizing Spectrum Inventory-Brief (ESI-Brief; Patrick et al., 2013) is a 160-item self-report measure that assesses a range of behavioral and personality characteristics associated with the externalizing spectrum of psychopathology. Participants were asked to choose the option that best describes them for each statement on a scale from 1 (“*True*”) to 4 (“*False*”). To assess trait disinhibition, we used the ESI-Brief General Disinhibition scale (M = 23.6, SD = 12.4, *Min/Max* = 4.0/52.0). The ESI-Brief demonstrates good internal consistency (Cronbach’s alpha for General Disinhibition = 0.88 in this sample) and construct validity (Patrick et al., 2013).

2.2.3. Risky and self-destructive behavior

The Risky, Impulsive, and Self-destructive behavior Questionnaire (RISQ; Sadeh & Baskin-Sommers, 2016) is a 38-item self-report questionnaire composed of a total score that measures general tendencies to engage in risky and self-destructive behaviors and eight domain-specific factors measuring drug behaviors, aggression, self-harm, gambling, risky sexual behavior, heavy alcohol use, impulsive eating, and reckless driving/spending behavior. For each item, participants were asked to report how many times they engaged in the behavior in their lifetime and in the last month. To reduce positive skewness, we categorized responses into 5 bins that constrained the range of possible responses at the high end of the distribution: 0, 1–10, 11–50, 51–100, > 100 times (Sadeh & Baskin-Sommers, 2016). Given that we assessed PTSD symptoms in the last month, analyses focused on total past month behaviors (Cronbach’s alpha = 0.75; skewness/kurtosis = 1.1/0.9).

2.2.4. Affective Go/No-Go task

The Affective Go/No-Go Task (GNG) measured behavioral inhibition in the context of rewarding and threatening stimuli (see Fig. 1 for an illustration of the task). Participants were presented with a fixation point for 1000 ms and then a target slide for 3000 ms of either a circle (80% of the trials) or a square (20% of trials) superimposed on a picture and told to press a button box when a circle appeared on the screen (“Go” trial) and to withhold their response when a square appeared on the screen (“No-Go” trial). The shape stimulus and background picture appeared simultaneously and were removed from the screen at the same time (i.e., after 3000 ms). Each trial was followed by an intertrial interval of 900 ms. To encourage participants to respond quickly, they only had 500 ms to correctly respond to “Go” trials, even though the picture stimuli were presented for 3000 ms. The task consisted of block types that varied in the motivational and emotional nature of the stimuli presented. During reward-only blocks (2 blocks/50 trials each), each trial consisted of a circle or square superimposed on a different picture of U.S. currency and participants were told that they would receive 5 cents for every correct Go and No-Go response (up to $5). During threat-only blocks (2 blocks/50 trials each), a circle or square was superimposed on a different picture selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008) that was chosen based on normative ratings of unpleasantness and arousal (e.g., attacking animals, aimed weapons, assaults, injury). During combined threat/reward blocks (2 blocks/50 trials each), participants were presented with a circle or square superimposed on a different IAPS image and told that they would receive 5 cents for every correct response they made during this block (up to $5). In total, participants had the opportunity to gain up to an additional $10 compensation based on the accuracy of their performance. A total of three hundred unique stimuli were used as background images across the three affective context conditions. The reward and threat manipulations used in this task are well-validated and widely-used methods for activating motivational and emotional processes. Research shows that linking task performance with monetary compensation strongly and reliably activates reward systems (e.g., Thut et al., 1997), and a large literature has

[1] There were inconsistencies between the age of two participants and the military service era they reported, indicating they were older than their reported age (i.e., age 55). We did not notice this discrepancy until after data collection was complete and were unable to query the participants about this discrepancy.

[2] Data from six participants were excluded due to low accuracy rates, inability to complete study procedures, a technical malfunction of the task, and inconsistences on self-report measures, resulting in a final sample of 94.

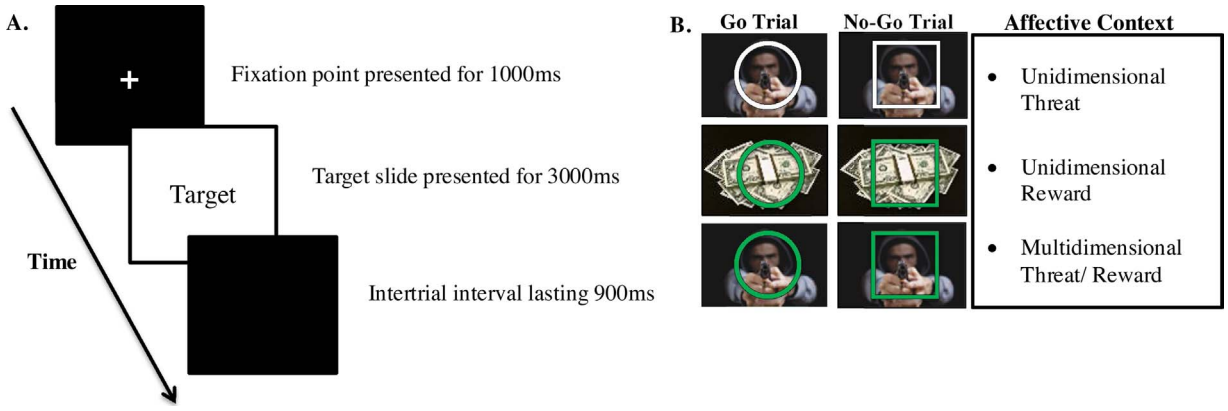

Fig. 1. A. Affective go/no go task design **B.** Examples of target slides in each affective context condition.

demonstrated that IAPS stimuli activate emotional systems involved in fear processing and threat reactivity, including in studies of PTSD with Veterans (e.g., Wolf, Miller, & McKinney, 2009).[3] Participants completed one of two condition orders.

2.2.5. Mood changes

The Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1998) is a 20 item self-report questionnaire that asks participants to rate how much they felt 20 different emotions at the present moment on a five-point Likert scale from 1 ("*Very slightly or not at all*") to 5 ("*Extremely*"). This measure was administered before and after the GNG task. Positive affect and negative affect difference scores were calculated to reflect changes in mood pre- to post-task.

2.2.6. General distress

Participants completed the Mood and Anxiety Symptoms Questionnaire – Short Form (MASQ; Clark & Watson, 1991), a measure that asked participants to rate how much they experienced emotional symptoms in the previous week from 1 ("*Not at all*") to 5 ("*Extremely*"). We included the General Distress subscale as a covariate in analyses of the affective GNG task to ensure PTSD results could not be accounted for by individual differences in general distress.

2.3. Data analysis

Self-reported behaviors were analyzed using hierarchical linear regressions, with total PTSD symptoms, trait disinhibition, and their interaction entered in separate blocks predicting dimensional RISQ scores. Age and gender were included as covariates. For the GNG task, commission errors and reaction time (RT) were analyzed using ANOVA with Emotional Context (Reward only, Threat/Reward, and Threat only) as the within-subjects factor. Dimensional PTSD scores, trait disinhibition, and their interaction were entered as between-subject predictors in sequential models, and MASQ General Distress, counterbalancing order, age, and sex were entered as covariates. Emotional context effects were examined using planned orthogonal contrasts: Threat vs. Reward (linear contrast) and Multidimensional Threat/Reward vs. Unidimensional Affective Context (quadratic contrast). In addition to *p*-values, we report partial eta squared or ΔR^2 as effect size estimates. All tests were two-tailed. Missing data were replaced with the sample mean (max missingness across variables = 4%).

[3] The IAPS stimuli that were included in this study were selected to be highly aversive (valence: $M = 2.70$, $SD = 1.60$) and arousing (arousal: $M = 5.91$, $SD = 2.19$).

3. Results

3.1. PTSD symptoms and trait disinhibition

Based on a recommended diagnostic cut-off of 33 on the PCL-5 in Veteran samples (Bovin et al., 2016), 63.8% ($n = 60$) of the sample met criteria for current probable PTSD. Current PTSD symptoms on the PCL-5 correlated positively with total scores on the ESI-Brief trait disinhibition measure ($r = 0.47$, $p < 0.001$).

3.2. Risky and self-destructive behavior[4]

Participants reported engaging in a variety of harmful behaviors in the month prior to the assessment (Table 1). Analysis of the RISQ past month behaviors was conducted using the total score that summed frequencies across different types of behavior. Results of this analysis revealed a positive effect of current PTSD symptoms on risky and self-destructive behavior ($\beta = 0.25$, $p = 0.015$, $\Delta R^2 = 0.061$). With the addition of trait disinhibition to the model, however, PTSD symptoms were no longer statistically significant ($p > 0.15$) and disinhibition was associated with RISQ behaviors at a trend level ($\beta = 0.20$, $p = 0.079$, $\Delta R^2 = 0.031$). This finding was qualified by a trait disinhibition x PTSD interaction ($\beta = 0.87$, $p = 0.034$, $\Delta R^2 = 0.044$) that indicated the relationship of trait disinhibition with past month risky behavior varied as a function of current PTSD symptom severity. Follow-up analysis using a median-split on PTSD symptoms indicated that trait disinhibition was associated with RISQ past month behavior in Veterans with higher current PTSD symptoms ($r = 0.35$, $p = 0.023$), but not those with lower symptom severity ($r = 0.06$, $p = 0.72$). These relationships are depicted in Fig. 2. This finding is consistent with theoretical models suggesting that PTSD symptoms may acutely exacerbate predispositions toward disinhibited behavior.

3.3. Affective Go/No-Go task

3.3.1. Mood changes

A paired-samples *t*-test of pre- and post-task PANAS scores indicated that positive affect decreased ($t_{(93)} = -4.6$, $p < 0.001$) and negative affect increased ($t_{(93)} = 6.4$, $p < 0.001$) during the task. Current PTSD symptoms (controlling for trait disinhibition) was associated with an increase in negative affect ($r = 0.28$, $p = 0.007$) following completion of the GNG task, whereas trait disinhibition (controlling for PTSD symptoms) was associated with an increase in positive affect ($r = 0.21$,

[4] We tested whether results were due to item overlap between the PCL-5 and the RISQ measure by re-conducting the analyses after removing the PCL-5 items asking about aggression (#15) and risk-taking/harmful activities (#16). All significant findings remained significant using the revised PCL-5 total score ($ps < 0.03$) and no new findings emerged.

Table 1
Risky, Impulsive, and Self-destructive behavior Questionnaire (RISQ) Descriptive Statistics.

RISQ Behaviors	Past Month
Drug Behaviors	22.6%
Aggressive Behavior	17.2%
Gambling	35.5%
Risky Sexual Behavior	17.2%
Heavy Alcohol Use	35.5%
Self-harm Behavior	15.1%
Impulsive Eating	33.3%
Reckless Driving/Spending Behavior	51.6%

Note: Percentage of participants who reported engaging in behaviors at least once in the month prior to the assessment.

PTSD x Emotional Context linear effect was significant for Veterans scoring low ($F_{(1,38)} = 6.65$, $p = 0.014$, $\eta_p^2 = 0.15$), but not high, ($F_{(1,42)} < 0.72, p > 0.40$) on trait disinhibition. Thus, the association of PTSD with relatively greater commission errors in the threat vs. the reward condition was specific to Veterans who scored low on trait disinhibition and was not present for those scoring high on this trait (see Fig. 3).

Next, we examined how PTSD moderated the effect of Disinhibition on the multidimensional-unidimensional contrast described above by dividing the sample into Veterans scoring low and high on PTSD symptoms using a median split. This follow-up analysis indicated that the Disinhibition x Emotional Context quadratic effect was significant for Veterans reporting high ($F_{(1,40)} = 5.01$, $p = 0.030$, $\eta_p^2 = 0.11$), but not low, ($F_{(1,40)} < 0.20, p > 0.65$) current PTSD symptoms. Thus, the

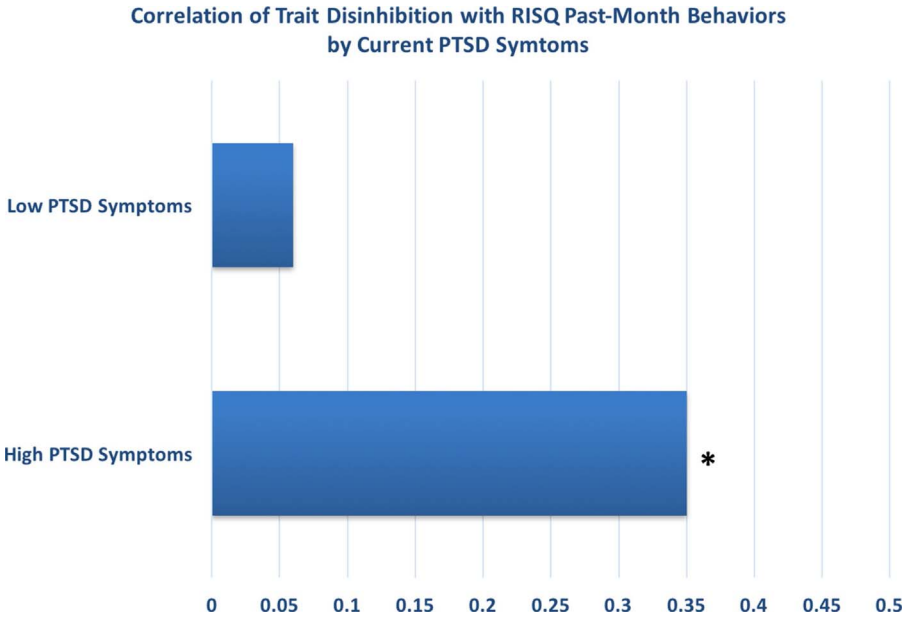

Fig. 2. *Trait disinhibition correlates with greater risky and self-destructive behaviors in participants high, but not low, on current PTSD symptoms.* Graph depicts the magnitude of the correlation between trait disinhibition and the number of risky self-destructive behaviors reported as a function of current PTSD symptoms. PTSD group membership was determined by a median-split. *$p < 0.05$.

$p = 0.048$).

3.3.2. Task performance

Descriptive statistics and emotional context effects for the GNG task are presented in Table 2. Commission errors were higher on average in the multidimensional threat-reward context than the unidimensional affective contexts. Emotional context also impacted RT, with participants responding slower on average in the threat only context than reward only context.

Next, we examined the effects of trait disinhibition and PTSD symptoms on task performance. There were no significant PTSD or trait disinhibition effects on reaction time. Effects of PTSD and trait disinhibition did emerge for commission errors, and the results of these analyses are displayed in Table 3. First, the threat-reward contrast varied as a function of PTSD symptom level, such that PTSD symptoms were associated with relatively greater commission errors in the threat vs. reward condition ($r = 0.21$). Second, Disinhibition moderated the multidimensional-unidimensional affective contrast, reflecting the tendency for individuals high on trait disinhibition to make relatively more commission errors in the multidimensional threat/reward condition than the unidimensional affective conditions ($r = 0.23$).

Significant PTSD x Disinhibition x Emotional Context (linear and quadratic) interactions emerged for commission errors that qualified these associations (Table 3). To examine how Disinhibition moderated the effect of PTSD on the threat-reward contrast described above, we divided the sample by Veterans scoring low and high on trait disinhibition using a median split. This follow-up analysis indicated the

Table 2
Affective Go/No-Go Descriptive Statistics and Emotional Context Effects on Task Performance.

	Descriptive Statistics			
	Commission Errors		Reaction Time	
Emotional Context	*M (SD)*	*Min/Max*	*M (SD)*	*Min/Max*
Reward	3.1 (2.9)	0/13	403.5 (48.7)	275.9 (497.5)
Threat	3.0 (2.6)	0/12	413.7 (55.2)	315.4 (500.0)
Threat/Reward	3.4 (3.2)	0/16	405.4 (54.9)	303.0 (500.0)

	Affective Context Effects on Task Performance			
	F-statistic	*df*	*P-value*	η_p^2
Commission Errors				
Emotional Context Linear	0.3	1, 93	0.611	0.003
Emotional Context Quadratic	**4.1**	**1, 93**	**0.045**	**0.043**
Reaction Time				
Emotional Context Linear	**12.3**	**1, 93**	**0.001**	**0.117**
Emotional Context Quadratic	2.9	1, 93	0.094	0.030

Note: Emotional Context Linear = Threat only vs. Reward only. Emotional Context Quadratic = Multidimensional Threat/Reward vs. Unidimensional Affective Context. Boldness indicates the findings were statistically significant at $p < .05$.

Table 3
Effects of Current PTSD Symptoms and Trait Disinhibition on Affective Go/No-Go Task Performance.

Commission Errors	*F-statistic*	*df*	*P-value*	η_p^2
PTSD Main Effect	0.2	1, 86	0.647	0.002
PTSD x Emotional Context Linear	**5.3**	**1, 86**	**0.024**	**0.058**
PTSD x Emotional Context Quadratic	0.1	1, 86	0.710	0.002
Disinhibition Main Effect	1.8	1, 85	0.182	0.021
Disinhibition x Emotional Context Linear	0.1	1, 85	0.799	0.001
Disinhibition x Emotional Context Quadratic	**4.9**	**1, 85**	**0.030**	**0.054**
PTSD x Disinhibition Main Effect	0.8	1, 84	0.370	0.010
PTSD x Disinhibition Emotional Context Linear	**5.0**	**1, 84**	**0.028**	**0.056**
PTSD x Disinhibition Emotional Context Quadratic	**4.6**	**1, 84**	**0.035**	**0.052**

Note: PTSD = posttraumatic stress disorder. Emotional Context Linear = Threat only vs. Reward only.
Emotional Context Quadratic = Multidimensional Threat/Reward vs. Unidimensional Affective Context.
Age, sex, condition order, and MASQ General Distress were included as covariates in the model.
Boldness indicates the findings were statistically significant at $p < .05$.

association of trait disinhibition with relatively greater commission errors in the multidimensional vs. the unidimensional affective conditions was specific to Veterans who reported high current PTSD symptoms and was not present for those reporting low/no symptoms (see Fig. 4).

4. Discussion

This study examined how PTSD symptoms and disinhibited personality traits uniquely and interactively relate to impulsive behavior in everyday life and in the laboratory. As expected, trait disinhibition conferred risk for recent engagement in risky and self-destructive behaviors, but this effect was only present among Veterans with high current PTSD symptoms. On a go/no-go task that manipulated affective context, commission errors were explained by the interaction of PTSD symptoms and trait disinhibition. First, current PTSD symptoms were associated with greater commission errors in threat than reward contexts among Veterans who scored low on trait disinhibition, suggesting that situations that activate fear systems are more likely to trigger impulsive responding in these individuals than those that activate reward systems. Second, for individuals high on PTSD symptoms *and* trait disinhibition, a multidimensional affective context that involved both threat and reward processing induced the greatest number of commission errors. Present findings provide new evidence that the interaction of PTSD symptoms and disinhibited personality traits relate to impulsive and risky behavior in trauma-exposed Veterans. Results are consistent with prior research linking inhibitory control deficits in PTSD to contexts that activate threat systems (e.g., Aupperle et al., 2012; Buckley et al., 2000), but extend this work by demonstrating that reward contexts may also play a role for trauma-exposed individuals characterized by high trait disinhibition and current PTSD symptoms (as evidenced by the PTSD x Trait Disinhibition x quadratic contrast interaction).

Risky and self-destructive behaviors often co-occur with PTSD, though little is currently known about the mechanisms driving this relationship. We found that, although current PTSD symptoms evidenced a positive relationship with self-reported engagement in high-risk behaviors, this relationship could be accounted for by its association with disinhibited personality traits. However, current PTSD symptoms did emerge as a moderator of the association between disinhibited traits and recent risky and self-destructive behaviors, suggesting that trait-like predispositions toward behavioral disinhibition may be exacerbated by ongoing PTSD symptoms. This finding is consistent with theoretical models positing that traumatic stress serves to accentuate an individual's premorbid personality functioning, including potentially by further compromising the impaired self-regulatory processes associated with trait disinhibition (Miller, 2003; Miller, Vogt, Mozley, Kaloupek, & Keane, 2006). Although the present study did not manipulate acute stress, the findings are consistent with studies that have found that acute stress impairs the neurobiological mechanisms of self-control, resulting in the selection of immediately rewarding stimuli over less salient, but more advantageous long-term rewards (Maier, Makwana, & Hare, 2015). Research on the neurobiological basis of PTSD-related impulsivity has identified structural and functional abnormalities that relate specifically to the interactive effects of PTSD and disinhibition, including brain regions that are critical for inhibiting impulses, maintaining attentional control, and successful emotion regulation (e.g., Sadeh, Miller et al., 2015; Sadeh, Spielberg et al., 2015). Based on these and other findings (Aupperle et al., 2012; Etkin & Wager, 2007; Jovanovic & Ressler, 2010), posttraumatic stress may

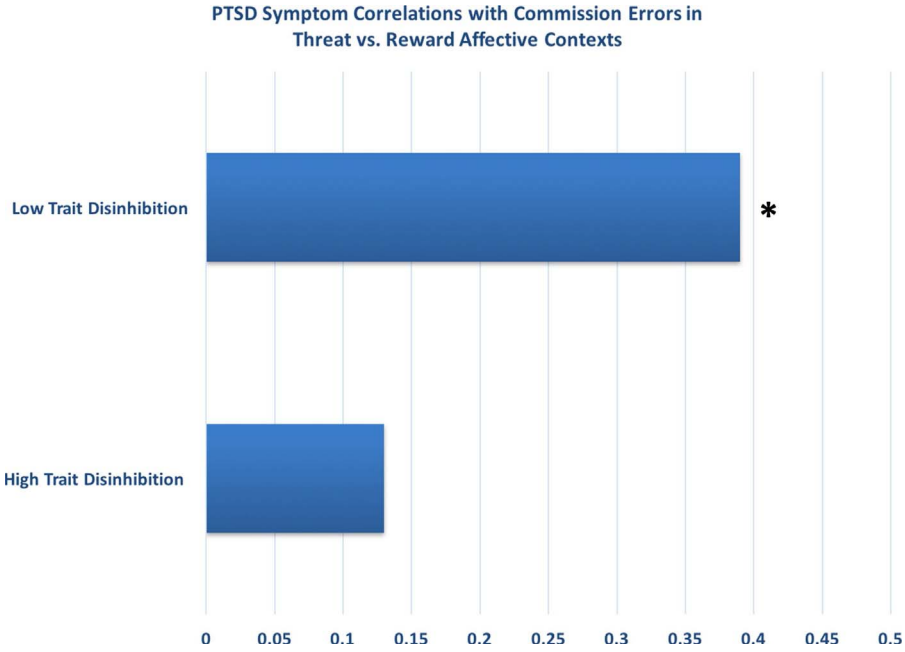

Fig. 3. *PTSD symptoms correlate with relatively more commission errors in threat vs. reward contexts in participants low in trait disinhibition.* Graph depicts the magnitude of the correlation between current PTSD symptoms and the number of commission errors in threat contexts minus those in reward contexts, as a function of trait disinhibition. Trait disinhibition group membership was determined by a median-split. $^*p < 0.05$.

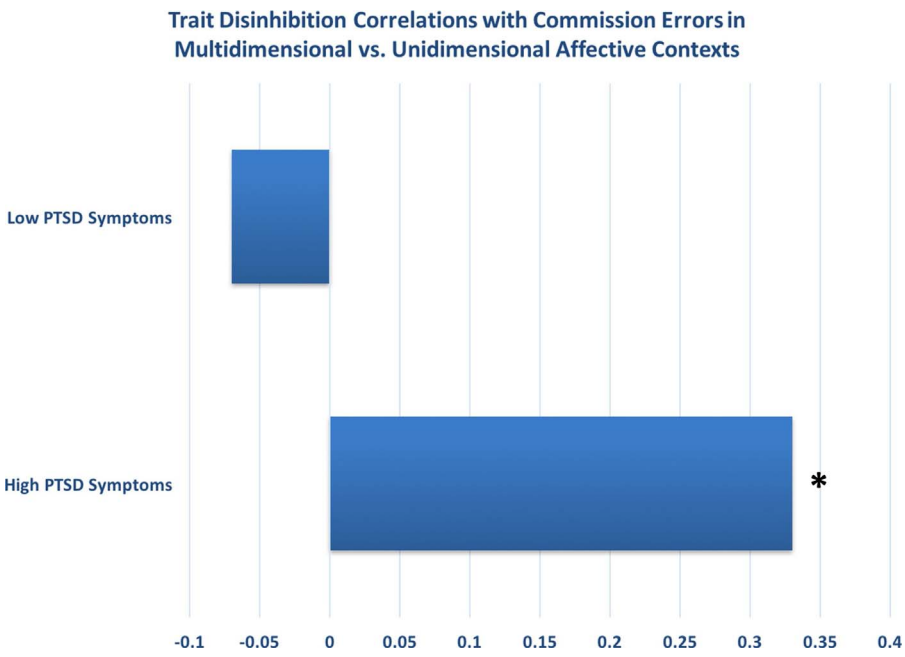

Fig. 4. *Trait disinhibition correlates with relatively more commission errors in multidimensional vs. unidimensional contexts in participants high on current PTSD symptoms.* Graph depicts the magnitude of the correlation between trait disinhibition and the number of commission errors in multidimensional contexts minus those in unidimensional (threat only and reward only) contexts, as a function of current PTSD symptoms. PTSD group membership was determined by a median-split. $^{*}p < 0.05$.

weaken the neural circuitry that supports behavioral and emotional control in individuals with high levels of disinhibition who are likely vulnerable to the deleterious effects of extreme stress on the health of these circuits. From a clinical perspective, present findings suggest that risky behaviors should be monitored and targeted in trauma-exposed persons who score high on personality measures of disinhibition, and acute risk for harmful behaviors may be higher for those with co-occurring PTSD.

Despite substantial research on inhibitory control and PTSD, relatively few studies have examined the affective contexts that trigger impulsive behavior in traumatized groups. Dysfunctional fear processing is a core feature of the disorder (Jovanovic & Ressler, 2010; Shvil, Rusch, Sullivan, & Neria, 2013), and extensive evidence implicates impaired top-down cognitive control and hyperactivity in negative valence systems in the etiology of the disorder (Rauch, Shin, & Phelps, 2006). Research on PTSD also consistently links the disorder to abnormalities in the processing of contextual information and dysfunction in key brain circuits involved in using cues from the environment to generate adaptive behavior (i.e., hippocampal-prefrontal circuitry). These findings are theorized to contribute to impaired inhibition of the fear response and deficient differentiation between threat and safety signals in the environment in PTSD (Liberzon & Abelson, 2016). For example, there is evidence that processing contextual cues that convey information predictive of inhibition is compromised in PTSD (e.g., van Rooij, Geuze, Kennis, Rademaker, & Vink, 2015). Present results extend these findings on proactive inhibition by demonstrating that reactive inhibition is also impaired in PTSD, specifically during the processing of irrelevant negative emotional content. Moreover, we found inhibition failures to be more likely in threatening that reward contexts as symptoms of current PTSD increased, specifically among Veterans low on trait disinhibition. Interestingly, impulsive responding was dependent on the emotional nature of the inhibitory context, with aversive contexts activating greater impulsivity as PTSD symptoms increased than appetitive contexts. This finding suggests that contexts that activate negative emotional processing compromise inhibitory control processes in PTSD, regardless of whether or not the emotional cues are predictive of inhibition. The same pattern of findings was not found for rewarding contexts, indicating that the emotional/ motivational context impacts the behavioral deficits that will be observed in individuals with PTSD. This finding also suggests that, unlike many other disorders characterized by impulse control problems where reward contexts can be particularly dysregulating (e.g., antisocial personality disorder, substance abuse disorder; Finn, Mazas, Justus, & Steinmetz, 2002; Glenn & Yang, 2012), impulsive behavior in PTSD is more likely to occur in contexts that evoke strong negative emotions, at least for those individuals that are also low on trait disinhibition (Fig. 3). Thus, rash actions may be more likely to occur in threatening contexts when the behavior acts as a mechanism for avoiding or relieving distress, an important question to address in future research. Longitudinal studies are also needed to decipher whether impulsive responding during processing of threat stimuli is a vulnerability for the development of PTSD or a consequence of the disorder.

Unlike laboratory settings, real-world emotional situations are often complex and characterized by diverse motivational and emotional cues. Despite this, few studies have investigated the impact of multifaceted emotional contexts on impulsive behavior and inhibitory control processes. In this study, we found that contexts involving both threat and reward processing induced the most impulsive responding in Veterans who scored high on trait disinhibition and current PTSD symptoms. Numerous studies have shown that disorders marked by high trait disinhibition (e.g., substance disorders, antisocial personality disorder) are hypersensitive to reward stimuli and this sensitivity can lead to behavioral dysregulation, including impulsivity (e.g., Gatzke-Kopp et al., 2009; MacKillop et al., 2011). Present results suggest this behavioral dysregulation in pursuit of rewards may be exacerbated by co-activation of negative valence systems for disinhibited individuals with active PTSD symptoms, perhaps reflecting the impact of dual sensitivity to threat and reward on executive control systems. Salient threat- and reward-related stimuli have been shown to occupy cognitive resources in individuals with PTSD (Aupperle et al., 2012) and disinhibited phenotypes (e.g., Byrne, Patrick, & Worthy, 2016), respectively. Consequently, prefrontal functions important for self-regulation, such as inhibiting impulsive urges and implementing goal-based decision-making, may be highly taxed in multidimensional affective contexts among individuals high on both PTSD and disinhibition, resulting in poor self-control. This group may also be the most likely to engage in high-risk behaviors to alleviate symptoms of PTSD due to their pre-morbid hyper-responsivity to reward.

The present findings may also help clarify some discrepancies in the literature regarding reward functioning in PTSD. The anhedonic and emotional numbing symptoms have led researchers to posit that PTSD is marked by a hyporesponsive reward system, resulting in a reduction

in the hedonic response to rewards and diminished desire to seek them out (Elman et al., 2005, 2009). A recent meta-analysis of 29 studies found only mixed support for this hypothesis, however, with evidence for both increased and decreased processing of positive stimuli depending on the task demands (Nawijn et al., 2015). Our findings suggest that heterogeneity in the personality characteristics of the sample may contribute to inconsistent findings regarding reward dysfunction in PTSD and indicate that accounting for individual differences in trait disinhibition may be important when examining these relationships. Although outside the scope of this study, an interesting question for future research would be to examine the extent to which personality dimensions relate to alterations in the consumption ("liking") versus motivation ("wanting") phases of reward processing. For example, the inability to derive pleasure from rewards (especially those previously experienced hedonic) following a traumatic event may actually lead individuals high on trait disinhibition to increase reward-seeking behavior due to elevated levels of approach motivation and a desire to experience a hedonic response. Studying the impact of comorbid personality pathology on reward processing in PTSD could help clarify previous observations of hypo- and hyper-responsivity to reward in trauma-exposed groups.

As with all studies, limitations must be considered when interpreting the results. First, the modest size and primarily male composition of the sample may impact the generalizability of the findings. Future research with larger and more diverse samples is needed. Second, we relied on self-report measures to assess individual differences in PTSD symptoms, trait disinhibition, and risky/self-destructive behavior. Examining the replicability of the findings using clinical diagnostic interviews is an important next step in this line of research. Also, our measure of PTSD symptoms did not assess how long participants have experienced symptoms or the time since the traumatic events occurred. This assessment strategy limited our ability to evaluate how chronicity of PTSD symptoms or time since exposure may have impacted the results. Third, longitudinal data are needed to ascertain how impulsivity and trait disinhibition are impacted by trauma exposure and the development of PTSD symptoms. Fourth, there are other conditions that are common in Veteran populations that may have impacted performance on the affective go/no-go task that we did not assess, and therefore, could not account for in our analyses. For example, traumatic brain injury, attention-deficit hyperactivity disorder, bipolar disorder, substance use, and personality disorders (Amick et al., 2013; Depue et al., 2014; Wright, ipszyc, Dupuis, Thayapararajah, & Schachar, 2014; Swick, Honzel, Larsen, Ashley, & Justus, 2012) may have influenced task performance and need to be examined in future research. Fifth, we did not have a measure of omission errors, which prevented us from assessing potential differences in response bias across the conditions. Despite these limitations, this study has several strengths, including being one of the first to examine impulsive responding in the context of multidimensional affective contexts and recruitment of a highly clinically-relevant sample of trauma-exposed Veterans. Understanding who is at greatest risk for harmful behavior following trauma exposure, and under what circumstances, can enhance current risk prediction models and assist clinicians working with PTSD patients. The present results provide new evidence of heterogeneity in the risk conferred by PTSD for impulsive and self-destructive behaviors, indicating that trait disinhibition and reactivity to affective context are critical moderators of these relationships.

Conflicts of interest

None.

Acknowledgments

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