

Probing reward function in posttraumatic stress disorder: Expectancy and satisfaction with monetary gains and losses

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Abstract

Background: Posttraumatic stress disorder (PTSD) may be associated with dysfunctional reward processing. The present study assessed for such dysfunction in both the expectancy and outcome phases of reward processing.

Methods: Male Vietnam veterans with ($n = 15$) and without ($n = 11$) combat-related PTSD were administered a wheel of fortune-type gambling task. Self-reported ratings of expectancy and satisfaction were collected respectively before and after each experience of monetary gain or loss.

Results: PTSD participants reported both lower expectancy of reward and lower satisfaction with reward when it was received. The latter result was manifest in a failure of PTSD participants to show the greater satisfaction that normally accompanies rewards received under conditions of low expectancy.

Conclusion: These results suggest reward function impairment in PTSD related to expectancy, satisfaction, and the expectancy-satisfaction relationship.

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1. Introduction

In addition to high rates of comorbidity between posttraumatic stress disorder (PTSD) and substance use disorders (Kessler et al., 1995; Jacobsen et al., 2001), both the diagnostic and clinical features of PTSD suggest impaired reward function. For example, the symptom of “markedly diminished interest or participation in significant activities” (American Psychiatric Association, 2000) suggests low expectations that personally significant activities will be

rewarding. Also, PTSD patients commonly report pervasive anhedonia that encompasses not only diminished interest and motivation, but also lack of pleasure in potentially rewarding activities. It has been proposed that dysfunction of the brain’s reward circuitry accounts for these symptoms in major depressive disorder (MDD) (Nestler et al., 2002; Nestler and Carlezon, 2006), which is also highly comorbid with PTSD (Kessler et al., 1995).

In a prior study, we assessed reward function in PTSD using a validated behavioral probe (Elman et al., 2005). Male heterosexual Vietnam veterans with or without PTSD performed two tasks, viz., key pressing to view images of attractive or average male or female faces, and rating their attractiveness. There were no significant differences

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between the PTSD and non-PTSD groups in attractiveness ratings. However, the PTSD participants expended less effort, i.e., made significantly fewer key-presses, to extend the duration time for viewing the attractive female faces. These findings suggest that persons with PTSD make normal subjective valuations of potentially rewarding stimuli but show decreased reward-seeking behavior.

The above study's design did not probe the anticipatory aspect of reward (i.e., expectancy). Importantly, the anticipatory aspect of reward (e.g., hunting, sexual foreplay) can be distinguished from its consummatory aspect (e.g., eating, orgasm). This traditional distinction by ethologists (Sherrington, 1906; Craig, 1918) was introduced to psychiatry two decades ago by Klein (1987). Since then considerable evidence for these separable components of reward processing has emerged in several fields, including neuroscience (Berridge and Robinson, 1998; Knutson et al., 2001; Burgdorf and Panksepp, 2006), personality psychology (Depue and Collins, 1999; Morrone-Strupinsky and Depue, 2004; Gard et al., 2006), social psychology (Gilbert and Wilson, 2000) and behavioral economics (Kahneman and Snell, 1992). Also, research in healthy populations has demonstrated an inverse relationship between expectancy and satisfaction with outcomes, i.e., the lower the probability, and expectancy, of a rewarding outcome, the greater the emotional response when it occurs (Mellers et al., 1997). Thus assessment of reward function in persons with PTSD may benefit from distinguishing rewarding experiences from their anticipation.

The current study employed a wheel of fortune-type gambling task that assessed subjective responses during (a) an "expectancy phase," when a promising (good), unpromising (bad), or intermediate roulette-like spinner was presented, and (b) an "outcome phase," when the arrow landed on one sector of that spinner and indicated the participant's monetary gain or loss (Breiter et al., 2001). In contrast to our previous work (Elman et al., 2005), this task does not require any choices or reward-seeking behavior, and thus segregates reward expectancy and outcome satisfaction from both decision-making (c.f., Ernst et al., 2004; Rogers et al., 2004) and instrumental responding (c.f., Monetary Incentive Delay task; Knutson et al., 2000, 2001, 2003). Whereas such paradigm differences likely explain some inconsistencies in functional neuroimaging findings across prior studies, these monetary incentive tasks, including the one used in the current study (Breiter et al., 2001), have been uniformly linked with robust neural response in brain reward regions (Trepel et al., 2005).

We predicted that, consistent with impairment of the anticipatory component of reward function, PTSD participants would expect worse outcomes than non-PTSD participants. We also predicted that, consistent with a deficiency in the consummatory aspect of reward processing, PTSD participants would exhibit lower ratings of satisfaction with spinner outcomes. Finally, based on prior research (Mellers et al., 1997), we made the subsidiary

prediction that expectancy and satisfaction ratings would exhibit an inverse relationship.

2. Materials and methods

Participants comprised 26 male Vietnam combat veterans, 15 with and 11 without current, combat-related PTSD diagnosed according to the Clinician-Administered PTSD Scale (CAPS; Weathers et al., 2001). Most had previously participated in the facial stimuli experiment described above (Elman et al., 2005). Non-PTSD participant candidates with CAPS total score >15 were excluded to minimize contributions of partial PTSD symptomatology. Participant candidates with other Axis I psychiatric diagnoses according to the Structured Clinical Interview for DSM-IV (SCID; First et al., 1997), including current substance abuse or dependence (including nicotine), were excluded, with the following exception. Comorbid PTSD/MDD was allowed if the MDD developed after the PTSD ($n = 4$). Mean group ages (SD) were: PTSD, 53.7 (6.9); non-PTSD 58.6 (6.5), $t(24) = 1.8$, $p = .08$. Mean group CAPS scores were: PTSD 67.3 (18.8); non-PTSD 0.4 (1.3), $t(24) = 11.7$, $p < .0001$. PTSD participants had suffered from the disorder for a mean of 33.7 (3.9) years. Ten PTSD participants were using psychotropic medication at the time of testing, primarily antidepressants and anxiolytics. All participants gave written informed consent after the procedures were fully explained. All procedures were carried out in accordance with the latest version of the Declaration of Helsinki (2000), and the protocol was approved by the Institutional Review Boards of McLean Hospital and the Manchester, New Hampshire Veterans Affairs Medical Center.

The task was as described by Breiter et al. (2001), with four exceptions. First, seated participants viewed stimuli and self-ratings questions on a computer monitor. Second, although the trial sequence was pseudorandom and fully counterbalanced, it included fixation point trials such that trials of a given (spinner + outcome) type were both preceded and followed equally often by all nine spinner/outcome combinations and fixation trials. The trial sequence was subdivided into 9 blocks of 17 trials that included a total of 115 spinner/outcome trials. Third, participants completed behavioral ratings during each phase of the trial, as described below. Fourth, neuroimaging was not employed.

The *expectancy* phase had three sub-phases: (1) the spinner for each trial was presented, with the following question underneath: "What do you expect the outcome of this trial to be?" (2) participants used the computer mouse to select a point along a 100 mm visual analog scale (VAS) beneath the question, with anchors "very negative" and "very positive" at the far left and right, respectively. (3) The question and VAS scale then disappeared, and an arrow was superimposed over the spinner, which then commenced spinning. In the *outcome* phase, the arrow landed on one sector, which then flashed several times to highlight

the monetary outcome of that trial. Then the question “How happy are you with the outcome?” appeared below the spinner, and participants rated their satisfaction with the outcome on a 100 mm VAS with anchors of “not happy at all” and “very happy” at the far left and right, respectively. Fig. 1 depicts the three spinner types, including the potential monetary gains and losses associated with each.

Participants began with an endowment of \$50 and were informed in advance that the spinner outcome amounts would be added to or subtracted from their balance. Unbeknownst to them, gains were set larger than losses to compensate for the assignment of a greater weight to a loss than to a gain of equal magnitude (Kahneman and Tversky, 1979). The pseudorandom trial sequence resulted in each participant ending the task with a gain of \$78.50, added to the \$50 endowment.

Expectancy and satisfaction with outcomes were separately analyzed using linear mixed models. For expectancy ratings, the model included a random effect for participant, a between-participants effect for group, and a within-participants effect for spinner type. The hypothesis that PTSD participants would exhibit lower expectancies was tested via the group main effect.

For satisfaction ratings, the model included a random effect for participant, a between-participants main effect for group, a within-participants main effect for spinner type, and a within-participants main effect for monetary outcome. Expectancy was a covariate.

The effect of trial was not modeled because, given the pseudorandom and fully counterbalanced trial order, any potential “experience effect” was considered negligible. Thus mean expectancy and satisfaction ratings from each participant in each spinner × outcome condition were used in all analyses. Mixed model analyses were conducted using SAS 8.2 (Cary, NC), and descriptive statistics using SPSS 12.0 (Chicago, IL).

Bonferroni-corrected significance levels were set at $p < .025$ for the statistical tests corresponding to the two major hypotheses (or group effects), viz., PTSD subjects

would show lower expectancy of receiving rewards and lower satisfaction with the rewards they received.

3. Results

Complete data were available from all participants for all analyses. For *expectancy* ratings there was (as would be expected) a significant main effect of spinner type, $F(2,48) = 68.8$, $p < .0001$. Most importantly, there was, as hypothesized, a significant main effect of group, $F(1,24) = 7.4$, $p = .01$, with PTSD participants giving overall lower expectancy ratings. There was no group × spinner interaction, $F(2,48) = 0.2$, $p = .81$. Fig. 2 presents means and standard errors for ratings of expectancy by group and spinner type.

For *satisfaction* ratings, there were (as would be expected) large and significant main effects of spinner type $F(2,190) = 6.0$, $p = .003$ and monetary outcome, $F(2,185) = 13.0$, $p < .0001$, but no spinner × monetary outcome interaction, $F(4,178) = 0.4$, $p = .82$. Most importantly, there were, as hypothesized, significant main effects of group, $F(1,129) = 6.8$, $p = .01$ and expectancy, $F(1,132) = 4.9$, $p = .03$. There was also a significant group × expectancy interaction $F(1,132) = 5.7$, $p = .02$. Otherwise, there were no significant interactions involving group (all p 's $> .26$) or expectancy (all p 's $> .13$). The nature of the group × expectancy interaction is illustrated in Fig. 3. Specifically, the non-PTSD group exhibited the hypothesized inverse relationship between expectancy and satisfaction, whereas the PTSD group did not.

Given the sample composition, a series of *post hoc* analyses were undertaken to address potential confounds and threats to the validity of our interpretations of the above findings. Due to the reduced statistical power of these analyses, corrections for multiple tests were not applied. Because four PTSD participants had current MDD, which

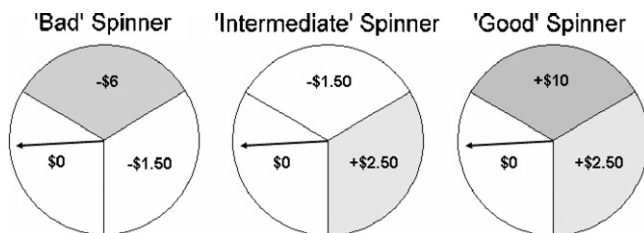


Fig. 1. The three “spinner” types used in the wheel of fortune-type task. For the “bad” spinner, none of the three possible outcomes involves winning money; for the “intermediate” spinner, possible outcomes involve loss, win, and neither; and for the “good” spinner, possibilities are winning or breaking even. After initial presentation in the expectancy phase of the task, the arrow appears and spins until stopping over one of the three sectors, which flashes to highlight the monetary outcome of that trial. See Section 2 for details.

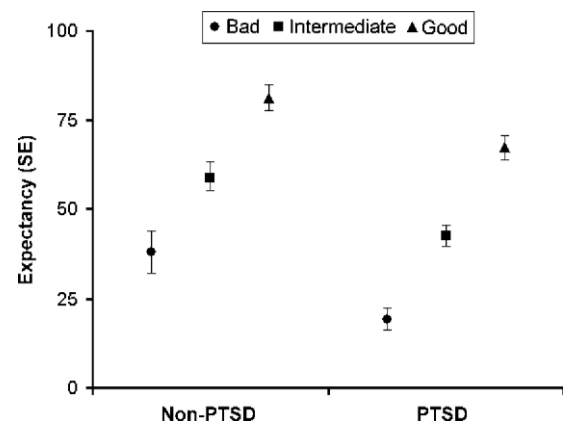


Fig. 2. Means and standard errors for self-report ratings of expected spinner outcomes, on a 100 mm horizontal visual analog scale with the anchors “very negative” and “very positive” at the far left (0) and right (100), respectively. Ratings were made during the expectancy phase of each trial, immediately after presentation of the spinner type for that trial (Fig. 1). See Section 2 for details.

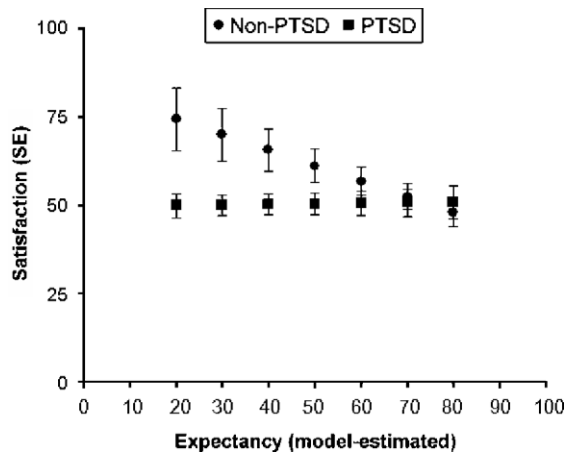


Fig. 3. Means and standard errors for self-report ratings of satisfaction with spinner results as a function of group and expectancy. Satisfaction with each spinner outcome was rated on a 100 mm VAS, with anchors of “not happy at all” and “very happy” at the far left (0) and right (100), respectively. See Section 2 for details.

could have skewed the results, analyses of expectancy and satisfaction ratings were re-conducted with the MDD participants excluded. The main effect of group on expectancy was reduced to a trend $F(1,20) = 3.6$ ($p = .07$); the main effect of group on satisfaction remained significant, $F(1,108) = 9.3$, $p = .003$, as did the group \times expectancy interaction for satisfaction, $F(1,115) = 7.5$ ($p = .007$). Additionally, all analyses were re-conducted with the 10 PTSD participants who were using psychotropic medication excluded. Despite the very low statistical power of these analyses, results replicated the results found using all PTSD participants: main effect of group on expectancy, $F(1,14) = 5.2$, $p = .04$; main effect of group on satisfaction $F(1,64.4) = 8.3$, $p = .005$; group \times expectancy effect interaction for satisfaction, $F(1,73.4) = 5.5$, $p = .02$. Finally, we conducted analyses within PTSD participants only, using medication versus non-medication as the group term. For both the expectancy and the satisfaction analyses, there was no significant main effect of group or interaction of group with any other variable, F 's < 2.4 , p 's $> .10$.

4. Discussion

This study, like our previous one (Elman et al., 2005), provides evidence that PTSD is associated with deficient reward function. More specifically, the findings are consistent with the view that, in male veterans with chronic PTSD, such impairment is evident across situations with different probabilities of reward, and entails (1) low expectancies of receiving rewards, (2) low satisfaction with the rewards that are received, with the latter manifest in (3) failure to experience the extra satisfaction that is normally incumbent upon obtaining a reward when reward expectancy is low.

Future research on reward function in PTSD may benefit from recent work by Gard and colleagues in the

domains of personality assessment and anhedonia in schizophrenia. Their Temporal Experience of Pleasure Scale (TEPS; Gard et al., 2006) is a self-report measure that separately assesses trait dispositions to experience anticipatory and consummatory pleasure. Using experience sampling in the daily lives of schizophrenics, they found deficiency in the former but not the latter (Gard et al., 2007). These methods could be used to investigate whether deficient reward function contributes to anhedonia in PTSD, and whether it arises, from a deficit in anticipatory and/or consummatory pleasure.

Research on the brain bases of reward dysfunction in PTSD appears promising as well, and prior work suggests structures and circuits that merit particular attention in future studies. Prefrontal regions involved in reward, including the orbitofrontal and medial prefrontal cortices (e.g., Breiter et al., 2001; Knutson et al., 2003), have also been implicated in the pathophysiology of PTSD (e.g., Shin et al., 2004; Milad et al., 2006). Similarly, findings of abnormal amygdala reactivity in PTSD (Shin et al., 1997; Rauch et al., 2000) are accompanied by evidence of amygdala involvement in reward processing (Baxter and Murray, 2002). In addition, Schultz and colleagues' work on the neural bases of reward prediction and “prediction errors” (e.g., Mirenowicz and Schultz, 1994; Tremblay and Schultz, 2000) has implicated dopaminergic neurons and the orbitofrontal cortex.

Our findings may have implications for theories of emotional numbing in PTSD, particularly the prominent model of Litz and Gray (Litz, 1992; Litz and Gray, 2002), which posits that emotional numbing in PTSD is explained by deficient expression of positive emotions associated with appetitive motivation. Their model countenances a role of reward function in emotional numbing. The findings reported here, like those of impaired reward-seeking behavior in our prior study (Elman et al., 2005), complement their account by indicating other alterations in reward-related processes that may underlie numbing symptoms. For example, deficient reward expectancy may contribute to the sense of a foreshortened future or to markedly diminished interest or participation in significant activities.

Research on reward function in PTSD may have significant treatment implications. Interventions that include “behavioral activation,” typically used to treat major depression by helping patients to increase contact with positive reinforcement in their environments (Jacobson et al., 1996, 2001; Dimidjian et al., 2006), may also help to ameliorate PTSD reward dysfunction by countering behavioral withdrawal or disengagement associated with diminished expectation of reward (Blanchard et al., 2003; Mulick and Naugle, 2004; Jakupcak et al., 2006). As described by Blanchard and colleagues, “when patients [said] ‘I will go back to doing X when I feel better,’ [w]e told them it had to be turned around, that is, that he/she had to go back to doing X, and afterwards would begin to feel better” (Blanchard et al., 2003, p. 86).

This study has limitations. The sample is modest in size and limited to male veterans with chronic combat-related PTSD. In terms of generalizing to females, we are not aware of data on sex differences in subjective ratings during anticipatory or outcome phases of reward processing. However, females' brain responses during both phases of reward processing have been found to differ from those of males as a function of menstrual phase, though only in amplitude, not location (Dreher et al., 2007). The current findings may not generalize to PTSD samples with acute or relatively early-onset forms of the disorder, which may be associated with less reward dysfunction than chronic forms (Kardiner, 1941; McFarlane, 1997). Because the present design is cross-sectional, inferences about chronic or trait-like reward function deficiencies are necessarily tentative and require testing with repeated measurements over time, even within chronic PTSD samples. Also, the observed reward function deficiencies could stem, at least in part, from pre-existing dispositions, including genetically based ones (e.g., Chakrabarti et al., 2006), which could be risk factors for PTSD (Gilbertson et al., 2002). Only prospective and twin studies can conclusively address this issue.

In summary, this study of male Vietnam veterans with chronic combat-related PTSD found evidence for deficient expectancy of reward outcomes, deficient satisfaction with received rewards, and a functional dissociation between the expectancy and satisfaction components of reward processing. These findings build on prior work demonstrating deficient reward behavior in the same population (Elman et al., 2005) and suggest promising new avenues of research and treatment, including interventions that foster behavioral activation in the pursuit of rewarding personal and social experiences.

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Conflict of interest

None of the authors have any actual or potential conflict of interest including any financial, personal or other relationships with other people or organizations within 3 years of beginning the work submitted that could inappropriately influence, or be perceived to influence, their work.

Contributors

Dr. Hopper took the lead in writing the manuscript. Dr. Pitman assisted in designing the study, interpreting the results, and writing the manuscript. Dr. Zhaohui

performed the statistical analysis. Dr. Heyman assisted in the study design. Dr. Lasko performed the psychodiagnostic assessments. Mr. Macklin recruited the subjects and screened them with regard to eligibility to participate. Dr. Orr assisted in the data analysis. Dr. Lukas assisted in the implementation of the study and the interpretation of the results. Dr. Elman designed the study, oversaw its implementation, and supervised Dr. Hopper and the other authors in their writing of the manuscript.

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