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The effects of trauma exposure and posttraumatic stress disorder (PTSD) on the emotion-induced memory trade-off

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Many past examinations of memory changes in individuals with posttraumatic stress disorder (PTSD) have focused on changes in memory for trauma. However, it is unclear if these mnemonic differences extend beyond the memory of the trauma to memory for other positive and negative information and if they are specific to individuals with PTSD or extend to other individuals who have experienced trauma. The present study examined the influences of trauma exposure and PTSD on an effect that may parallel tunnel memory in PTSD: the emotion-induced memory trade-off, whereby emotional aspects of an experience are remembered at the expense of the nonemotional context. Three groups of participants (25 with current PTSD, 27 who had experienced trauma but did not have current PTSD, and 25 controls who had neither experienced significant trauma nor met criteria for current PTSD) were shown complex visual scenes that included an item (positive, negative, or neutral) placed on a neutral background. Forty-five minutes later, participants underwent a recognition memory test for the items and backgrounds separately. An emotion-induced memory trade-off was said to occur when there was a significant difference in item and background memory for emotional scenes, but not for neutral scenes. Results indicated that people with PTSD, like the other groups, were more likely to remember positive and negative items than neutral items. Moreover, people with PTSD exhibited a memory trade-off comparable in magnitude to that exhibited by the non-trauma control group. In contrast, trauma-exposed people without a current diagnosis of PTSD did not show a trade-off, because they remembered items within scenes better than their accompanying contexts not only for emotional but also for neutral scenes. These results suggest that (1) the effect of emotion on memory for visual scenes is similar in people with PTSD and control participants, and (2) people who have experienced trauma, but do not have PTSD, may have a different way of attending to and remembering visual scenes, exhibiting less of a memory trade-off than either control participants or people with PTSD.

Keywords: emotion, memory, PTSD, trauma

INTRODUCTION

Exposure to trauma may induce cognitive changes in the memory system (see Vasterling and Brewin, 2005). These mnemonic changes may be especially pronounced when posttraumatic stress disorder (PTSD; Breslau, 2002) develops. PTSD is characterized by abnormalities in memory and attention (American Psychiatric Association, 2000). Individuals with PTSD have difficulty concentrating on or attending to neutral stimuli, while at the same time exhibiting hypervigilance, or increased sensitivity to detecting threat (see Vasterling and Brewin, 2005). People with PTSD also exhibit involuntary re-experiencing of their trauma (e.g., flashbacks) despite intentionally avoiding stimuli associated with the trauma (American Psychiatric Association, 2000).

Although PTSD is defined by cognitive changes in *involuntary* memory for a traumatic incident (American Psychiatric Association, 2000), there is also interest in understanding how PTSD may affect the *voluntary* retrieval of emotional experiences. Studies assessing memory for trauma-related information have

yielded mixed results as to whether people with PTSD remember stimuli that are related to their trauma better than people who have experienced trauma but do not have PTSD. Some studies have found that when participants are asked to freely recall trauma-related and non-trauma-related words embedded in an attentional task (such as an emotional Stroop task), people with PTSD remember proportionally more traumatic words than do non-patient controls (Kaspi et al., 1995; Vrana et al., 1995; Chemtob et al., 1999). Yet other studies have suggested that PTSD patients may show a response bias to endorse any trauma-related stimulus (Litz et al., 1996) or may have particularly bad memory for non-trauma stimuli rather than particularly good memory for trauma-relevant stimuli (McNally et al., 1998; Paunovic et al., 2002; Golier et al., 2003).

While no consensus has been reached regarding the effect of PTSD on voluntary retrieval of trauma-related information, even less is known about the effect of PTSD on memory for emotional information that is not related to the trauma. The findings

for negative stimuli have been mixed, with some studies finding no exaggerated enhancement in memory in people with PTSD (Bremner, 2003; Dickie et al., 2008; Brohawn et al., 2010) and others showing that PTSD patients may be biased to endorse negative stimuli (Thomaes et al., 2011) or to claim to vividly recollect negative stimuli (Tapia et al., 2012).

Fewer studies have investigated memory for positive information. Because one of the symptoms of PTSD is emotional numbness to positive stimuli, it is possible that people with PTSD may experience changes in memory for positive information (Jatzko et al., 2006). However, the existing studies examining memory for positive stimuli did not find group differences in memory for positive images when comparing individuals with and without PTSD (Brohawn et al., 2010; Tapia et al., 2012), and when comparing those with and without acute stress disorder (Paunovic et al., 2002). However, in the studies conducted by Brohawn et al. (2010) and Paunovic et al. (2002), the positive stimuli were significantly less arousing than the negative stimuli. So although these studies suggest that memory for positively valenced information is preserved in PTSD, the results cannot speak to potential effects of PTSD on memory for positive images that are also high in arousal. Thus, the impact of PTSD on memory for positive or negative stimuli is still an open question. The first goal of the present study, then, is to examine whether PTSD affects the ability to remember emotional items—positive or negative.

Despite the lack of consensus about the effect of PTSD on the *quantity* of emotional information retained, there may be differences in the *quality* of the trauma memory. Trauma narratives in PTSD have been described as exhibiting “tunnel memory,” or a detailed memory for the emotional element or gist of the scene without much memory for the surrounding elements or contextual details (Safer et al., 1998; LaBar, 2007). For example, an individual with PTSD might have a vivid memory of a body in combat but not remember the details of where the body was found. However, it is unclear if tunnel memory in PTSD is qualitatively different from tunnel memory in people without PTSD.

The concept of tunnel memory—characterized by differential memory for central and peripheral elements of a scene, as well as missing pieces of information—is notably similar to a now well-established phenomenon of memory in individuals without a history of trauma or PTSD: the emotion-induced memory trade-off. The trade-off refers to the retention of emotional information at the expense of surrounding nonemotional information (see Reisberg and Heuer, 2004; Levine and Edelstein, 2009). For instance, after viewing a scene that contains an emotional element—such as a snake in the forest—people will often remember the snake well but have poor memory for the forest.

There is reason to believe that tunnel memory in individuals with PTSD is supported by mechanisms similar to those that evoke the emotion-induced memory trade-off in individuals without PTSD. Higher anxiety levels and lower levels of cognitive control (e.g., lower ability to manage other cognitive processes, leading to poorer ability to plan, think abstractly, etc.) have been correlated with a stronger memory trade-off (Waring et al., 2010). Because those who develop PTSD tend to have higher levels of anxiety and lower levels of cognitive control than those

who do not develop PTSD (see van der Kolk, 2004), people with PTSD might be expected to show more of a trade-off. However, the magnitude of the trade-off effect has not been systematically tested in a population with PTSD, and so the validity of this hypothesis is unknown. The second goal of the present study is to examine whether individuals with PTSD might show an enhanced trade-off as compared to control participants. In other words, would the tunnel memory reported for trauma memory extend to a memory trade-off in voluntary recall of other types of emotional information?

Lastly, despite the research that has been done specifically looking at individuals with PTSD, it is often not clear if these changes in memory are unique to PTSD or if they are a consequence of extreme stress. Many of the studies that have examined emotional memory in PTSD have not included a trauma-exposed control group without current PTSD. Thus, these studies show that people with PTSD exhibit differences in emotional and cognitive processing compared to non-traumatized individuals but cannot determine if these processes are caused by PTSD specifically or trauma exposure itself.

There is reason to believe that exposure to trauma—or extreme or repeated stress—can cause changes in memory (see Kim and Diamond, 2002 for review). It has been fairly well established that exposure to chronic and severe stress can decrease hippocampal connectivity and impair memory (see McEwen, 1999; Starkman et al., 2001). However, much less work has been done on the effects of stress exposure on the retention of emotional information. The few existing studies have revealed that chronic stress may enhance amygdala functioning (Vyas et al., 2002, 2003) and enhance fear conditioning in rats (Conrad et al., 1999). Because the amygdala has been shown to enhance memory for emotional items, but not for their contexts (Kensinger and Schacter, 2006; Waring and Kensinger, 2011), there is reason to believe that exposure to stress may enhance emotional memory but decrease memory for surrounding neutral information.

This pattern of results has been found when stress is induced in a laboratory setting. Payne et al. (2006) found that acute psychosocial stress may enhance thematically induced trade-offs in emotional memory. In this study participants were exposed to a psychosocial stressor before watching a slide show with an emotional narrative. During a later memory test, participants who had undergone this stressor (as opposed to those who were not stressed at encoding) were more likely to remember emotional aspects of the slide show and were more likely to forget the neutral aspects. This finding indicates that stress at encoding may play a role in trade-offs between emotional and neutral aspects—at least in the instance of a thematically induced emotional narrative (as opposed to an emotional visual scene). However, it is unclear if a previously experienced stress in trauma-exposed individuals would also have similar trade-off-inducing effect. Thus, the third goal of this study is to investigate the effects of trauma-exposure, without current PTSD, on the emotion-induced memory trade-off.

To summarize, the purpose of this study is to investigate these three questions: (1) What is the effect of PTSD on memory for positive, negative, and neutral items? (2) What is the effect of PTSD on an emotion-induced memory trade-off? (3) What is

the effect of trauma-exposure on an emotion-induced memory trade-off? In the current study, these questions were addressed by testing people with PTSD, people who experienced trauma but do not currently have PTSD, and a control group who reported no experience of trauma. All participants studied scenes that included a positive, negative, or neutral item placed on a neutral background. Memory was then tested separately for emotional and neutral items and their accompanying backgrounds. In this way, we can compare memory for emotional versus neutral items in the three participant groups (addressing question 1), as well as the relation between memory for the emotional item and memory for the surrounding information in the background (addressing questions 2 and 3).

METHODS

PARTICIPANTS

Eighty-six individuals were recruited via postings on the Internet, throughout the community, and at a local trauma center. Presence of PTSD was determined by diagnosis on the Structured Clinical Interview for the DSM-IV (SCID; First et al., 1995) by a qualified clinician. Trauma exposure was determined by the SCID and according to DSM-IV criteria. Of the 86 individuals recruited for the study, 77 were used in the analysis. Two participants were excluded from analysis because they had high PTSD Checklist and Depression scores although they reported that they had never experienced trauma. Two were excluded due to psychotic disorders and one was excluded for current alcohol dependence. One was excluded for refusing to answer questions on the PTSD portion of the SCID, and three were excluded for failure to complete the second part of the study. Of the remaining 77 participants, 25 met criteria for current PTSD (PTSD group, 8 Males); 27 had undergone trauma but did not meet criteria for current PTSD (Trauma-Exposed group, 14 Males); and 25 neither had experienced significant trauma nor met criteria for current PTSD (Non-Trauma Exposed group, 12 Males; See **Table 1**). In the Non-trauma Exposed Group, there were no comorbidities. None of these 77 participants had a psychotic disorder or current alcohol or substance dependence. The groups did not differ on age or education level (See **Table 2**).

STIMULI

Stimuli consisted of complex visual scenes that were created by placing images of positive, negative and neutral items onto neutral background scenes (see **Figure 1**). The stimulus set included objects and backgrounds used in prior studies (Kensinger et al., 2007a; Waring and Kensinger, 2009; Waring et al., 2010; Steinberger et al., 2011). Composite images were created by placing an item onto a plausible background scene. Care was taken to make sure that positive, negative, and neutral items were of comparable size and were placed in the same approximate location across scenes. Across emotion categories, scenes were also matched for visual complexity, congruency between item and background, and number of people, animals and buildings. Each picture was approximately 10 × 13 in. and 700 × 550 pixels.

Items were 180 nameable, photographic-quality, color images that were taken from photo clip art packages (Hemera Technologies, Quebec, Canada), from the International Affective

Picture System (Lang et al., 1999) and from other online databases of images. There were 60 positive images (mean valence = 6.02, SE = 0.81), 60 negative images (mean valence = 3.80, SE = 0.82) and 60 neutral images (mean valence = 5.29, SE = 0.75). Arousal (rated on a five point scale, with low numbers indicating soothing or subduing images and high numbers indicating exciting or agitating images) ratings were as follows: mean (SD): Positive = 3.02 (0.57); Negative = 3.19 (0.66); Neutral = 2.35 (0.61). The positive and negative images were matched on arousal and absolute valence (all $p > 0.30$), and neutral images were considered less arousing than both positive and negative images (all $p < 0.05$).

Stimuli were randomized to create two different study lists with 90 items per list (30 negative, 30 positive and 30 neutral). Those lists were then also presented in reverse order, yielding four total study lists that were counterbalanced across participants. It was never the case that more than three of the same emotion category appeared in a row.

At test, composite scenes from the study sessions were broken down into the isolated item and background components and these two elements were shown independently in the recognition memory test. The recognition memory test was also randomized for a total of four test lists to ensure that there were not effects of placement of a certain picture in context to another picture. These test lists were counterbalanced across participants. In addition, which items and backgrounds were “old” versus “new” were counterbalanced across participants based on the study list that they viewed.

PROCEDURE

Participants first filled out the consent form, a demographics questionnaire, an assessment of their state and trait anxiety [BAI (Beck et al., 1988); STAI-S and STAI-T (Spielberger et al., 1983)] and an assessment of their depressive symptoms (BDI-II; Beck et al., 1961).

Participants then took part in an incidental encoding session. They were told that this first part of the study was designed to measure their reactions to emotional images. During this session, 90 scenes (30 from each emotion category) were shown on a white computer screen for 5 s each. While viewing the scene, participants were asked to rate the valence of the picture on a nine-point scale, nine being the most intensely positive and one being the most intensely negative. After 5 s, a screen appeared that required the participant to press the space bar to move on to the next picture. Each participant completed a short practice version of the task before performing the actual task.

After participants completed the encoding session, a variety of standardized cognitive tasks were administered, creating a retention delay of approximately 45 min: Rey–Osterrieth Complex Figure Test (Rey–O; Rey, 1941; Osterrieth, 1944), Stroop Test (Stroop, 1935), Wechsler Backward Digit Span (Wechsler, 1997), FAS test of verbal fluency (Spreeen and Benton, 1977), Shipley Vocabulary (Shipley, 1986), The Wechsler Adult Intelligence Scale Digit Symbol Test (Wechsler, 1997), Short Michigan Alcoholism Screening Test (SMAST, Selzer et al., 1975). At this point participants were also given a 5–10 min break.

During the unanticipated recognition testing phase, participants viewed 90 items and 90 backgrounds extracted separately

Table 1 | Type of trauma and comorbidities for the PTSD and the Trauma-Exposed Groups.

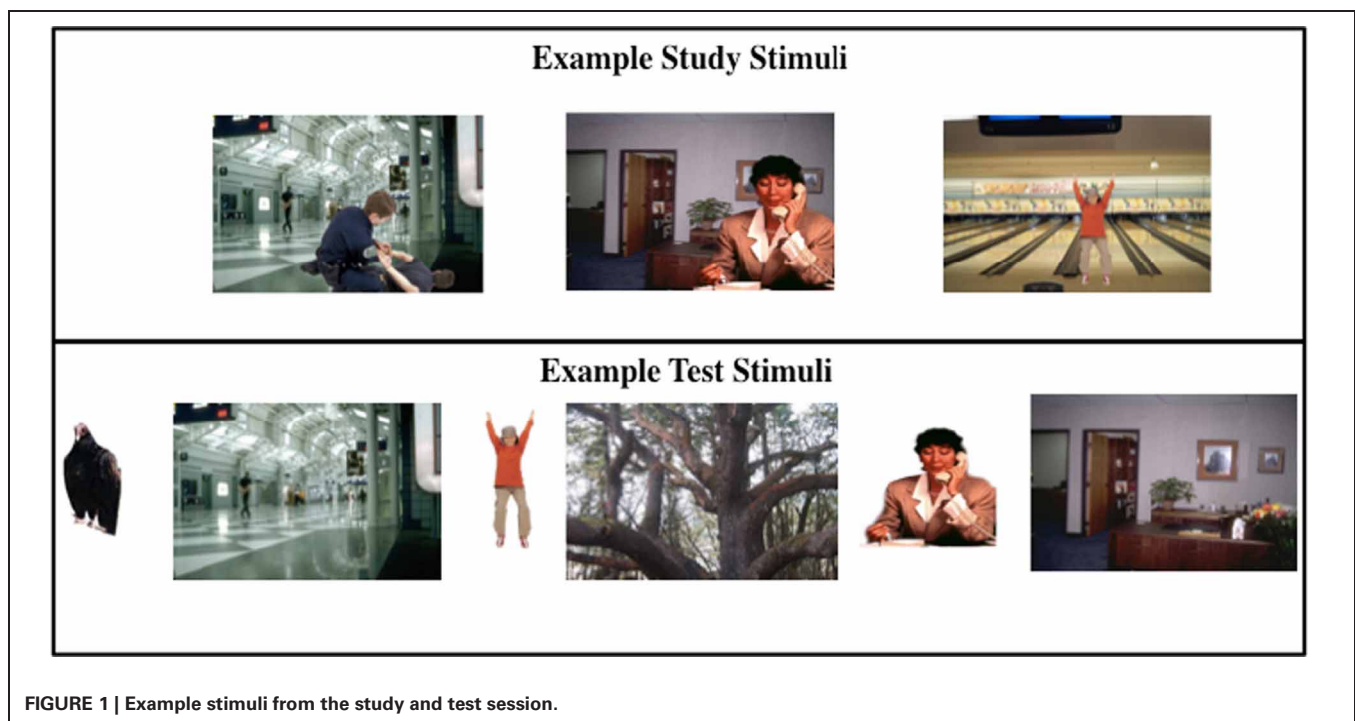
Sex	Trauma	Comorbidity	Past PTSD?
PTSD GROUP			
F	Arrest	None	
F	Captivity	None	
M	Family tragedy	None	
F	Family tragedy	Pho	
F	Family tragedy	None	
F	Family tragedy	None	
F	Physical abuse	None	
M	Physical and psychological abuse	None	
F	Physical and psychological abuse	Epi	
M	Physical and psychological abuse	BPD, BED	
F	Physical and sexual assault	MDD, Pho, OCD	
F	Physical and sexual assault	None	
M	Physical assault	GAD	
M	Physical assault	None	
F	Physical assault	MDD, PD, OCD	
F	Physical, sexual, psychological abuse	None	
F	Physical and psychological abuse	MS, MDD, PD, Pho	
M	Physical and psychological abuse	MDD	
F	Sexual assault	MDD, GAD, BED	
M	Sexual assault	MDD, GAD	
F	Sexual assault	MDD, PD	
F	Sexual assault	Epi, MDD	
F	Sexual assault	None	
M	Sexual assault	MDD	
F	Sexual assault	None	
TRAUMA-EXPOSED GROUP			
M	Arrest	None	No
M	Arrest	GAD	No
M	Captivity	None	Yes
M	Family tragedy	Pho	No
M	Family tragedy	GAD	No
F	Family tragedy	None	No
F	Family tragedy	None	Yes
M	Motor vehicle accident	BPD, Pho, OCD	No
M	Motor vehicle accident	Epi	No
M	Motor vehicle accident	None	No
M	Motor vehicle accident	None	No
F	Motor vehicle accident	None	No
F	Motor vehicle accident	None	Yes
F	Physical and psychological abuse	MDD, Dys	Yes
F	Physical and psychological abuse	Dys	Yes
F	Physical assault	Pho	Yes
M	Physical assault	Pho	Yes
F	Physical assault	PD	Yes
M	Physical assault	None	No
M	Physical assault	BPD	Yes
F	Physical assault	None	Yes
M	Physical assault	GAD	Yes
F	Sexual abuse	None	Yes
F	Sexual abuse, captivity	MDD, Pho	Yes
F	Sexual assault	None	No
M	Witnessed death	Pho, BED	No
F	Witnessed death	Dys	Yes

MDD, major depressive disorder; GAD, generalized anxiety disorder; BED, binge eating disorder; PD, panic disorder; Pho, phobia; OCD, obsessive compulsive disorder; Epi, epilepsy; BPD, bipolar disorder; Alc, alcohol dependence; Dys, dysthymic disorder.

Table 2 | Demographic, cognitive, and psychopathological characteristics of the samples.

	PTSD N = 25	Trauma-exposed N = 27	Non-trauma-exposed N = 25	Statistics
Sex (male/female)	(8/17)	(14/13)	(12/13)	$\chi^2(1) = 1.05$, ns
Age	39.68 (14.28)	42.0 (15.22)	36.2 (15.11)	$F(2,74) = 0.99$, ns
Years of education	14.52 (3.12)	14.44 (2.38)	14.84 (2.51)	$F(2,74) = 0.16$, ns
Age of trauma	20.76 (12.99)	26.0 (13.99)	n/a	$t_{(47)} = 1.36$, ns
Years since trauma	17.04 (14.4)	16.0 (13.53)	n/a	$t_{(47)} = 0.26$, ns
PCL	55.78 (13.04)	36.74 (13.62)	21.88 (6.27)	$F(2,74) = 54.27$, $p < 0.001$
BDI	20.24 (10.61)	11.89 (8.34)	4.32 (4.67)	$F(2,74) = 23.32$, $p < 0.001$
BAI	28.24 (10.72)	18.78 (14.39)	6.92 (7.6)	$F(2,74) = 22.17$, $p < 0.001$
STAI-T	53.26 (10.83)	42.33 (10.21)	31.56 (7.02)	$F(2,74) = 32.49$, $p < 0.001$
STAI-S	43.56 (11.78)	37.93 (12.84)	29.36 (8.37)	$F(2,74) = 10.18$, $p < 0.001$
FAS	45.28 (10.83)	39.59 (12.64)	44.48 (11.69)	$F(2,74) = 1.80$, ns
FAS perseverations	0.92 (1.29)	1.56 (2.98)	1.56 (1.78)	$F(2,74) = 0.73$, ns
Stroop_word	96.4 (23.2)	97.07 (18.32)	100.8 (17.13)	$F(2,74) = 0.37$, ns
Stroop_X	68.88 (17.0)	65.7 (12.76)	72.72 (12.96)	$F(2,74) = 1.56$, ns
Stroop_color	43.04 (14.46)	38.81 (9.34)	48.68 (7.92)	$F(2,74) = 5.39$, $p < 0.01$
Stroop_interference	102.44 (10.29)	99.76 (7.72)	106.67 (6.73)	$F(2,73) = 4.51$, $p < 0.05$
Digit symbol	36.16 (10.96)	34.15 (8.09)	40.52 (8.45)	$F(2,74) = 3.21$, $p < 0.05$
Digit span backward	7.24 (2.83)	6.26 (2.19)	8.44 (2.77)	$F(2,74) = 4.56$, $p < 0.05$
Shiplay	31.04 (7.07)	28.33 (7.06)	31.68 (4.61)	$F(2,74) = 2.04$, ns
Rey-O copy	34.4 (3.65)	33.56 (3.03)	34.64 (3.17)	$F(2,74) = 0.79$, ns
Rey-O immediate	20.78 (7.09)	17.33 (6.3)	20.8 (9.21)	$F(2,74) = 1.81$, ns
Rey-O delayed	21.54 (6.55)	16.35 (6.5)	21.38 (9.39)	$F(2,74) = 3.99$, $p < 0.05$
Rey-O recognition	19.92 (1.74)	19.07 (1.75)	20.04 (2.03)	$F(2,73) = 2.12$, ns
SMAST	1.84 (2.51)	1.74 (2.6)	0.56 (1.12)	$F(2,74) = 2.66$, ns
CAPS frequency	1.34 (1.25)	0.74 (1.29)	n/a	$t_{(43)} = 1.59$, ns
CAPS intensity	2.0 (1.8)	0.86 (1.55)	n/a	$t_{(42)} = 2.24$, $p < 0.05$

ns, not significant; M (SD).



from the studied composite scenes (30 from each emotion category), as well as 90 new items (30 from each emotion category) and 90 new backgrounds (note that all new backgrounds were by definition neutral; for the studied backgrounds, the emotionality was defined by the type of item that had been placed onto the background). For each item or background, participants were asked to indicate whether they believed the picture was new, whether they “remembered” it (recollected specific details of its presentation during the encoding session) or “knew” it (felt a sense of familiarity with the picture, without remembering details from the encoding session). Participants underwent an extensive practice and instruction phase to ensure their understanding of remember versus know ratings. This test was self-paced and the next picture appeared after participants made their response. There were no group differences in reaction time for the test responses.

After the test phase, participants were asked to fill out the PTSD checklist (PCL; Weathers et al., 1993) and the Life Events Checklist (Gray et al., 2004). For the PTSD and the Trauma-exposed groups, the presence of PTSD, as well as other comorbid disorders, was assessed using the SCID in a separate session. The severity of memory problems surrounding the trauma was also assessed using selected questions from the clinician-administered PTSD scale (CAPS).

DATA ANALYSIS

For all of the results presented here, “remember” and “know” responses were collapsed into all “old” responses (When the “remember” and “know” responses were analyzed separately, no main effect of group or interactions with group were found).

For behavioral memory data, corrected memory scores are first reported. For these corrected scores, the proportion of false alarms (new pictures that were incorrectly cited as being old) were subtracted from the proportion of hits (pictures that were correctly recognized as being old) in order to correct for a response bias to call a picture “old.” These corrected recognition scores were computed separately for each item type (positive, negative, neutral) and for backgrounds. Note that only one false alarm rate could be ascertained for backgrounds: by definition new backgrounds are neutral because the emotionality of a background relates to the type of item with which it had been studied. In later analyses, the hit rates and false alarm rates were analyzed separately, to clarify whether differences in corrected recognition stemmed from differences in the hit rate or the false alarm rate.

Analyses of covariance (ANCOVAs) were run in order to compare the memory based on valence and group while controlling for scores on the Beck Depression Inventory (BDI) and Rey–O Complex Figure Test Delayed. A Bonferroni correction was used for the estimated marginal means in the *post hoc* tests. These scores were used as covariates because there were significant group differences in mood and in cognition. Because the various mood measures were intercorrelated, as were the various cognitive measures, we selected the BDI and Rey–O tasks as the covariates because we felt that they were the most representative of the co-morbidities and visuo-spatial cognitive abilities for which we should control.

RESULTS

PARTICIPANT DEMOGRAPHICS AND COGNITIVE TEST SCORES

Groups did not differ on any socio-demographic level (see **Table 2**). However, the groups did differ significantly on the scales measuring the severity of PTSD [PCL; ($F_{(2, 74)} = 54.27, p < 0.001$)], level of depression [BDI-II ($F_{(2, 74)} = 23.32, p < 0.001$)], and level of anxiety [BAI ($F_{(2, 74)} = 22.17, p < 0.001$); STAI-T ($F_{(2, 74)} = 32.49, p < 0.001$); STAI-S ($F_{(2, 74)} = 10.18, p < 0.001$)]. The groups also differed significantly on several cognitive tasks: Stroop Color [$F_{(2, 74)} = 5.39, p < 0.01$]; Stroop Interference [$F_{(2, 73)} = 4.51, p < 0.05$]; Digit-Symbol [$F_{(2, 74)} = 3.21, p < 0.05$]; Digit Span Backwards [$F_{(2, 74)} = 4.56, p < 0.05$]; Rey–O delayed [$F_{(2, 74)} = 3.99, p < 0.05$].

There also were some significant sex differences. Overall, males had higher Shipley vocabulary scores, [$t_{(71.7)} = 2.011, p < 0.05$], than females. Males were also older (“Age”) at the time of test than females, [$t_{(75)} = 2.29, p < 0.05$], and had a higher age of trauma, [$t_{(27.1)} = 2.09, p < 0.05$], than females. Overall, females had higher Beck Anxiety scores, [$t_{(75)} = 3.06, p < 0.01$], than males. Females also scored higher than males on both the Rey–O Immediate, [$t_{(75)} = 2.56, p < 0.05$], and the Rey–O Delayed, [$t_{(75)} = 2.59, p < 0.05$], visual memory tasks.

PICTURE RATINGS

An analysis was conducted on the picture ratings at encoding in order to make sure that there were not differences in the way that the pictures were rated by the three different groups. These ratings were made on a nine-point scale, one being intensely negative and nine being intensely positive. A valence (positive, negative, neutral images) \times group (PTSD, Trauma-Exposed, Non-Trauma Exposed) ANOVA was conducted. This analysis revealed a main effect of valence on the ratings, [$F_{(2, 74)} = 148.82, p < 0.001$], but no group effect or valence \times group interactions (all $F < 1.0, p > 0.45$). As expected, all valence types differed significantly from each other: positive greater than negative, [$t_{(76)} = 13.93, p < 0.001$]; positive greater than neutral, [$t_{(76)} = 9.80, p < 0.001$]; neutral greater than negative, [$t_{(76)} = 10.57, p < 0.001$]. Arousal scores for each participant were calculated as the mean absolute distance from the neutral rating of five. An arousal (positive, negative, neutral images) \times group (PTSD, Trauma-Exposed, Non-Trauma Exposed) ANOVA was also conducted. This analysis revealed a main effect of arousal on the ratings, [$F_{(2, 74)} = 10.34, p < 0.001$], but no group effect or arousal \times group interactions (all $F < 1.0, p > 0.50$). As expected, neutral images were less arousing than both positive images, [$t_{(76)} = 6.74, p < 0.001$], and negative images, [$t_{(76)} = 2.93, p < 0.01$]; there was no significant difference in arousal between positive and negative images, [$t_{(76)} = 1.12, p > 0.25$].

EMOTION-INDUCED MEMORY TRADE-OFF SCORE

The memory data were first analyzed to determine the difference in memory for emotional items and backgrounds as compared to neutral. The emotion-induced memory trade-off has been defined as the combined increase in memory for emotional items as compared to neutral items and decrease in memory for backgrounds accompanying emotional items compared to neutral items. Thus, to calculate a memory trade-off score, corrected

recognition scores (hits—false alarms) for neutral items were subtracted from corrected recognition scores for positive or negative items, and corrected recognition scores for backgrounds paired with neutral items were subtracted from corrected recognition scores for backgrounds paired with positive or negative backgrounds (see Leclerc and Kensinger, 2008; Waring and Kensinger, 2009, for use of these types of difference scores).

To then calculate the magnitude of the trade-off effect (e.g., the discrepancy between item and background memory), these corrected scores for the backgrounds were subtracted from the corrected scores for the items. The overall formula was: (memory for emotional item—memory for neutral item)—(memory for background paired with emotional item—memory for background paired with neutral item). Thus, the largest trade-off occurs when there is both better memory for the emotional item and worse memory for the accompanying background as compared to neutral.

For the analyses using this memory trade-off score, a Group (PTSD, Trauma, Non-Trauma) \times Valence (positive, negative) ANCOVA was conducted with the Beck Depression Inventory and Rey–O Complex Figure Test Delayed score used as covariates. The pattern of results remained the same when no covariates were used or when other mood and cognitive scores were used as covariates. This ANCOVA revealed a main effect of group [$F_{(2, 72)} = 4.48, p < 0.05, PES = 0.111$; see **Figure 2**]. As indicated by Bonferroni *post hoc* tests and adjusted marginal means, for both positive and negative items there was a smaller trade-off score for the trauma group (mean = 0.10, SE = 0.03) as compared to the PTSD group (mean = 0.23, SE = 0.04), and a marginally smaller trade-off for the trauma group as compared to the Non-trauma group (mean = 0.20, SE = 0.04). There was not a significant difference between trade-off scores for positive or negative scenes and there were no interactions (all $F < 0.5, p > 0.4$). There were also no interactions with any of the covariates.

To confirm that depression was not driving this group difference, a multiple regression was conducted with the emotional trade-off score as the dependent measure and the predictors as PTSD Group, Trauma Group (both dummy coded), and depression. The model was significant overall [$F_{(3, 76)} = 3.886, p < 0.05$]. The analysis revealed only a main effect of the Trauma Group ($\beta = 0.314, t = 2.32, p = 0.02$), suggesting that the trauma group, and not depression, was the significant predictor of the trade-off score.

MEMORY ANALYSES BY COMPONENT

In order to investigate the basis for this difference in the memory trade-off score, we next conducted an analysis of corrected recognition scores that considered all scene valences and scene component types separately. This was a Type (item, background) \times Valence (positive, negative, neutral) \times Group (PTSD, Trauma, Non-Trauma) ANCOVA with the Beck Depression Inventory and Rey–O Complex Figure Test Delayed score used as covariates (see **Figure 3**). This analysis revealed a main effect of type [$F_{(1, 72)} = 25.66, p < 0.001, PES = 0.263$]. This main effect was qualified by a type \times valence interaction [$F_{(2, 72)} = 4.80, p < 0.05; PES = 0.063$], and a marginal type \times valence \times group interaction [$F_{(2, 72)} = 2.25, p < 0.07; PES = 0.059$]. This marginal three-way interaction remained present when other mood and cognitive scores were used as covariates, and it reached significance ($p < 0.05$) when no covariates were used. As indicated by the Bonferroni *post hoc* tests, the PTSD group and the Non-trauma Exposed group showed a similar pattern of results such that there was better memory for items than backgrounds for positive and negative pictures, while there was not a significant item-background discrepancy for neutral pictures. In contrast, the Trauma group exhibited a significant difference in memory for items as compared to backgrounds for positive, negative, and neutral pictures. When comparing each

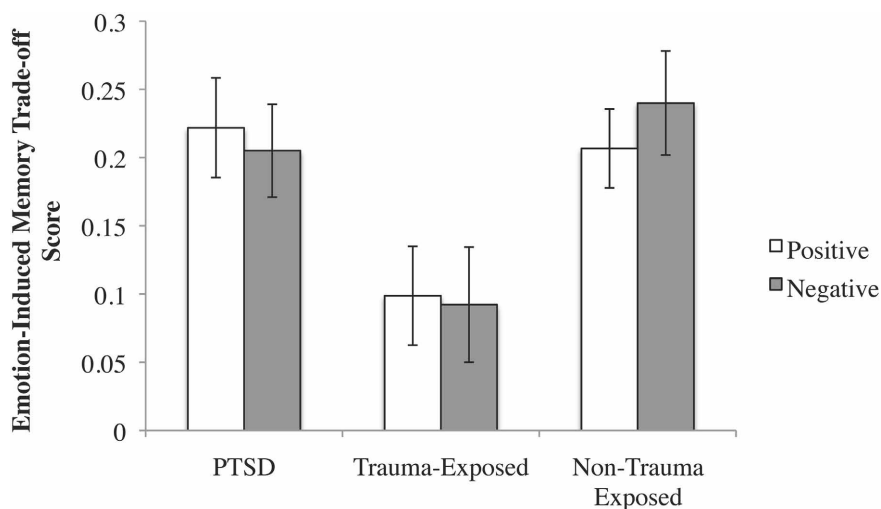
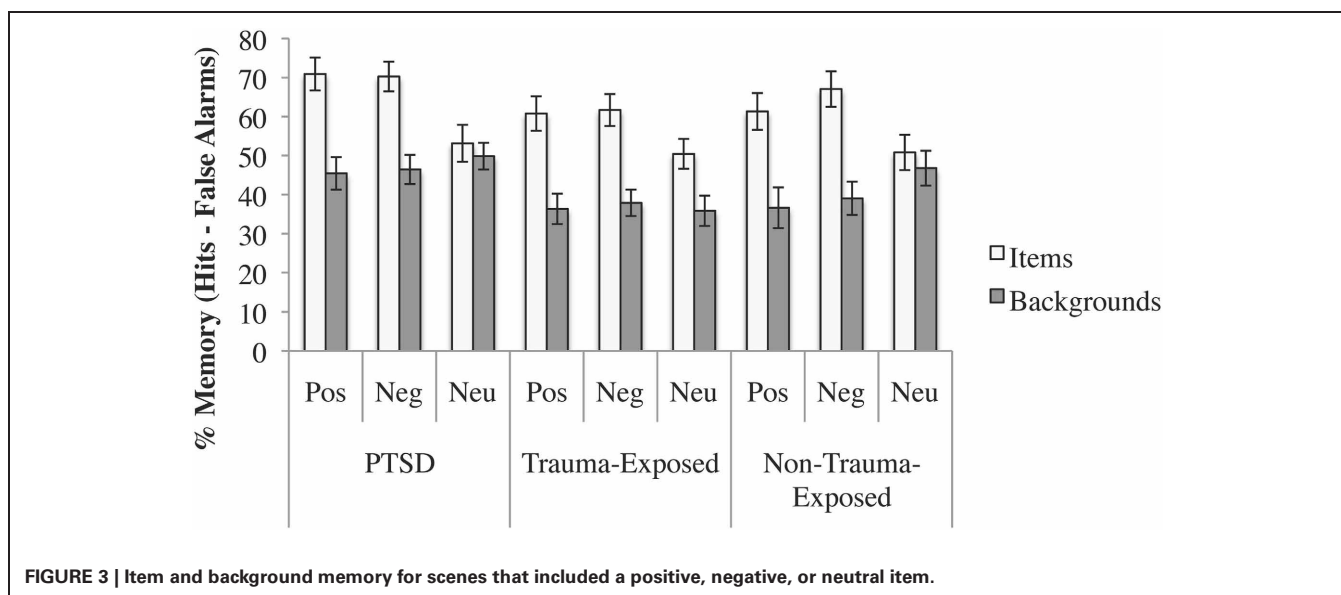


FIGURE 2 | The emotion-induced memory trade-off score [(memory for emotional item—memory for neutral item)—(memory for background paired with emotional item—memory for background paired with neutral item)] for the three groups. White bars indicate memory for scenes that

included positive (pleasant) items. Gray bars indicate memory for scenes that included negative (unpleasant) items. There was a larger memory trade-off for both the PTSD and the Non-Trauma Exposed group as compared to the Trauma-Exposed group.



valence there were no group differences in item memory. There was only one group difference in background memory, with better memory in the PTSD group and the Non-trauma Exposed group as compared to the Trauma group for backgrounds that had been paired with neutral items (see **Figure 3**). There were no interactions with any of the covariates.

In order to make sure that the pattern of results for the Trauma group were not driven by the presence of a prior history of PTSD, two subsequent Type (item, background) \times Valence (positive, negative, neutral) ANCOVAs were run with just the participants in the Trauma group. These analyses also included the Beck Depression Inventory and Rey–O Complex Figure Test Delayed score as covariates. The first analysis included only those who previously had PTSD ($N = 14$). This analysis revealed no main effects or interactions (all $F < 1.4$, $p > 0.2$). The second analysis included those who never had PTSD ($N = 13$). This analysis revealed only a main effect of type [$F_{(1, 10)} = 5.17$, $p < 0.05$, $PES = 0.341$] such that there was greater item memory than background memory. Critically, there was no valence \times type interaction for either group. Similarly, when past PTSD was run as a between subjects factor in a valence \times type \times past PTSD ANCOVA, there were no interactions with past PTSD (all $F < 1.2$, $p > 0.2$) and no interaction between valence and item type ($F < 0.25$, $p > 0.6$); the only significant effect was that of type [$F_{(1, 23)} = 6.924$, $p < 0.05$, $PES = 0.231$].

The prior analyses were run with the corrected memory data (hits—false alarms). However, hits and false alarms are listed separately in **Table 3**. When a Type (item, background) \times Valence (positive, negative, neutral) \times Group (PTSD, Trauma, Non-trauma) ANCOVA (with the Beck Depression Inventory and Rey–O Complex Figure Test Delayed score used as covariates) was run on the hit rates, there was the same pattern as when the corrected scores were used: a main effect of type [$F_{(1, 72)} = 37.19$, $p < 0.001$, $PES = 0.107$] qualified by a type \times valence interaction [$F_{(2, 72)} = 8.67$, $p < 0.001$; $PES = 0.063$], and a type \times valence \times group interaction [$F_{(2, 72)} = 2.80$, $p < 0.05$; $PES = 0.072$]. When

this ANCOVA was run for the false alarms, there was only a marginal effect of group [$F_{(2, 72)} = 2.76$, $p < 0.07$; $PES = 0.072$] such that there were fewer false alarms for the PTSD group than for the trauma-exposed and non-trauma exposed groups.

DISCUSSION

The current study sought to examine changes in memory for emotional information in individuals who currently meet diagnostic criteria for PTSD and trauma-exposed individuals who do not currently have PTSD. Looking at both item and background memory in the emotion-induced memory trade-off paradigm, this investigation focused on three central questions: (1) What is the effect of PTSD on memory for positive, negative, and neutral items? (2) What is the effect of PTSD on the emotion-induced memory trade-off? (3) What is the effect of trauma-exposure on the emotion-induced memory trade-off? First, we found that there are no group differences in memory for emotional items. For all groups emotional items (positive and negative) are better remembered than neutral items. Second, we found that people with PTSD did not have a larger memory trade-off when compared with control participants who had not experienced trauma; however, people with PTSD did have a larger memory trade-off when compared to trauma-exposed controls. A closer examination of the differences in item and background memory revealed that while the PTSD and non-trauma exposed control group had significant differences in item memory as compared to background memory for emotional items, there was no difference between item and background memory for neutral items. The decreased memory trade-off in the trauma-exposed controls was driven by a significant item-background difference between both the emotional and the neutral items. Thus, in answer to the third question, trauma exposure in the absence of PTSD does seem to change the memory trade-off, resulting in a mnemonic focus on the item within a scene regardless of whether that item is emotional or neutral. We expand on each of these points below.

Table 3 | Hits and false alarms for item and background memory for each group and each valence.

		Group	Mean	SD
ITEMS				
Hits	Positive	PTSD	0.79	0.19
		Trauma-exposed	0.78	0.18
		Non-trauma-exposed	0.79	0.17
	Negative	PTSD	0.80	0.17
		Trauma-exposed	0.81	0.16
		Non-trauma-exposed	0.82	0.16
	Neutral	PTSD	0.61	0.22
		Trauma-exposed	0.66	0.22
		Non-trauma-exposed	0.65	0.21
False alarms	Positive	PTSD	0.08	0.09
		Trauma-exposed	0.17	0.17
		Non-trauma-exposed	0.18	0.22
	Negative	PTSD	0.10	0.11
		Trauma-exposed	0.20	0.18
		Non-trauma-exposed	0.15	0.21
	Neutral	PTSD	0.08	0.08
		Trauma-exposed	0.16	0.18
		Non-trauma-exposed	0.14	0.20
BACKGROUNDS				
Hits	Positive	PTSD	0.58	0.21
		Trauma-exposed	0.58	0.23
		Non-trauma-exposed	0.55	0.23
	Negative	PTSD	0.59	0.19
		Trauma-exposed	0.60	0.21
		Non-trauma-exposed	0.58	0.19
	Neutral	PTSD	0.62	0.19
		Trauma-exposed	0.58	0.24
		Non-trauma-exposed	0.66	0.20
False alarms	Positive	PTSD	0.12	0.10
		Trauma-exposed	0.22	0.19
		Non-trauma-exposed	0.19	0.21
	Negative	PTSD	0.12	0.10
		Trauma-exposed	0.22	0.19
		Non-trauma-exposed	0.19	0.21
	Neutral	PTSD	0.12	0.10
		Trauma-exposed	0.22	0.19
		Non-trauma-exposed	0.19	0.21

WHAT IS THE EFFECT OF PTSD ON MEMORY FOR POSITIVE, NEGATIVE, AND NEUTRAL ITEMS?

There were not significant item memory differences between groups. All groups remembered positive and negative items better than neutral items. The current study found no evidence that PTSD patients remember non-trauma-related negative items particularly well or that they remember positive items particularly poorly. This suggests that for individuals with PTSD, though the memory for information related to the trauma may be enhanced, this does not translate to differences in the general emotion-memory system.

The results revealed no evidence of an effect of PTSD on the bias to endorse emotional items as studied: the item recognition

performance of the PTSD group remained similar to the performance of the other groups even when recognition responses were corrected for incorrect endorsements of unstudied items, and if anything the PTSD group showed *lower* false alarm rates than the other participant groups. Although at least one study found that PTSD may lead to an enhanced response bias for negative information when verbal stimuli are used (Thomaes et al., 2011), this biasing effect has not been found in other studies using verbal stimuli (Thomaes et al., 2009; Tapia et al., 2012). The few studies that have assessed recognition memory using non-traumatic pictorial stimuli have not reported hits and false alarms separately (Dickie et al., 2008; Brohawn et al., 2010), but the present results suggest that PTSD does not always lead to a more liberal response bias for negative stimuli.

WHAT IS THE EFFECT OF PTSD ON THE EMOTION-INDUCED MEMORY TRADE-OFF?

The memory trade-off exhibited in PTSD patients did not differ in magnitude from the trade-off exhibited by the control participants who had never experienced trauma. Thus, in some ways, the memory pattern that the PTSD patients experienced in this study can be considered “normal,” because, just as in the Control group, background memory was traded in favor of item memory only when an emotional item was present and not when a neutral item was present. As mentioned previously, memories of trauma in individuals with PTSD have been described as possessing “tunnel memory.” However, it is still unknown if this effect is enhanced in individuals with PTSD as compared to those without PTSD. The current study cannot speak to “tunnel memory” in the trauma memory. However, the current data suggest that non-trauma memories are not remembered in a unique manner for individuals with PTSD. Though they do exhibit a “tunnel memory” of sorts (e.g., worse memory for backgrounds that are paired with emotional information than neutral information), this is not uniquely exaggerated in PTSD. By contrast, and as we will elaborate upon next, the trauma-exposed individuals without current PTSD consistently showed selective item memory, regardless of the emotionality of the item.

It will be interesting for future studies to examine whether a different pattern is revealed when verbal stimuli are used rather than visual stimuli. Prior studies have shown that participants are more likely to remember neutral words from sentences that include an emotional word as opposed to those same words from sentences that contain only neutral words (Kensinger et al., 2002; Medford et al., 2005). Thus, it seems that control participants process the sentence as one entity (rather than as the discrete words that make up the sentence) and thus show a memory benefit for all words within an emotional sentence rather than showing a trade-off. It would be interesting for future research to examine whether PTSD patients would show a memory pattern like control participants or instead would show a trade-off even for these sentence stimuli.

WHAT IS THE EFFECT OF TRAUMA-EXPOSURE IN INDIVIDUALS WITHOUT PTSD ON THE EMOTION-INDUCED MEMORY TRADE-OFF?

Our data suggest that the trauma-exposed group stands apart from the other groups tested, in that these individuals remember

both emotional and neutral items better than their backgrounds. This effect could either be seen as a positive coping mechanism or a negative reaction to stress. Because the trauma-exposed group had a discrepancy in item and background memory for both emotional and neutral information, this may indicate that emotional and neutral stimuli are processed in a similar manner. Perhaps participants who were exposed to trauma but do not currently have PTSD have managed to avoid developing PTSD or were able to recover from it because of an ability to process emotional events in a similar fashion as processing neutral information. On the other hand, this exaggerated trade-off may mirror the effects of stress on memory for contextual information. There is evidence that individuals who are under stress at the time of encoding (via the Trier Social Stress Test manipulation; Kirschbaum et al., 1993) trade off background memory in favor of item memory for neutral as well as emotional scenes (Mattingly et al., 2012). Further, individuals who are stressed exhibit increased amygdala activity for both high and low arousal information (Marle et al., 2009), suggesting that stressed individuals enter a state of “indiscriminate hypervigilance.” Although the trauma-exposed individuals did not report higher state anxiety or rate the scenes differently than the other groups, it is nevertheless possible that they have more global changes in scene processing, such as seen under these stress manipulations, which lead them to exhibit a more focused attentional and mnemonic pattern for both emotional and neutral scenes. In addition, because both of these groups had trauma-exposure, this effect is specific to those who had experienced trauma and do not currently have PTSD. Though it is difficult to know from the current study how the presence of trauma with and without PTSD may change emotional processing, it may be that the PTSD group would be more likely to focus the stress response particularly on their traumatic experience as opposed to a more diffuse focus in the trauma-exposed group. In other words, perhaps those who both have experienced stress/trauma and who have PTSD would mostly show narrowed focus for things related to their trauma specifically, whereas those with stress/trauma but without current PTSD may more generally show a narrowed focus, even to neutral stimuli.

One thing of note is that the trauma-exposed group is impaired on many of the cognitive tests. This could suggest that these individuals’ attention is more narrowed—regardless

of valence—due to limited processing capacity. However, older adults, who have more limited processing capacities than young adults, still show the memory trade-off (Kensinger et al., 2007b; Waring and Kensinger, 2011). In addition, in the current study, lower performance on cognitive tests did not relate to the magnitude of the memory trade-off, and when the cognitive tests were used as covariates, there were no interactions with the covariates. Thus, it is likely not solely a deficit in cognitive capacity which leads to the selective retention of all items (emotional or neutral) in this trauma-exposed group.

SUMMARY OF FINDINGS

The current study provides insight into the pattern of emotional memory in individuals with PTSD and in those who have experienced trauma but do not have PTSD. When only emotional items are considered, there is no difference between any of the groups. Across the board, emotional items (positive and negative) are better remembered than neutral ones. The PTSD group showed no difference in the emotional memory trade-off when compared to the non-trauma-exposed control group. However, the PTSD group did show a larger emotional memory trade-off than the trauma-exposed individuals. The trauma-exposed individuals showed a pattern distinct from the other groups, in that they traded background memory in favor of item memory for all item types, emotional and neutral. This pattern of results suggests that the memory trade-off may be differentially exhibited depending on both the experience of trauma and the presence of PTSD.

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