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Relationships between memory inconsistency for traumatic events following 9/11 and PTSD in disaster restoration workers

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ABSTRACT

The present study examined the relationships between memories for a single incident traumatic event – the 9/11 attack on the World Trade Center (WTC) – and posttraumatic stress disorder (PTSD). 2641 disaster restoration workers deployed at the WTC site in the aftermath of the attack were evaluated longitudinally, one year apart, for PTSD, using clinical interviews. Their recollection of the traumatic events was also assessed at these times. The results showed that recall of traumatic events amplified over time and that increased endorsement of traumas at Time 2 was associated with more severe PTSD symptoms. It was also shown that, of all the exposure variables targeted, memory of the perception of life threat and of seeing human remains were differentially associated with PTSD symptoms. Implications of the results are also discussed.

The DSM-IV criteria for posttraumatic stress disorder (PTSD) require exposure to a potentially traumatizing event (Criterion A1) accompanied by feelings of fear, horror, and helplessness (Criterion A2) (American Psychiatric Association, 1994) for a diagnosis to be made. However, although the severity of the exposure and the emotional response to it predict the development of PTSD (Brewin, Andrews, & Valentine, 2000; Difede, Roberts, Jayasinghe, & Leck, 2006; Tucker, Pfefferbaum, Nixon, & Dickson, 2000; van Giezen, Arensman, Spinhoven, & Wolters, 2005), researchers currently debate the accuracy of memory of traumatic events. One view is that memories for traumatic events are stable and indelible; others contend that, like other memories, memory for traumatic events is subject to alteration (van Giezen et al., 2005). Animal studies have shown that neurotransmitters released during exposure to aversive stimuli can lead to the formation of "indelible" conditioned fear associations and responses (LeDoux, 1996; McGaugh, 2003; Pitman, 1989). However, more recent research suggests that, when reactivated by cues, memories undergo a dynamic process of reconsolidation during which they becomes vulnerable to change (Nader, Schafe, & LeDoux, 2000a, 2000b). Not all memories are equal, however: some authors have shown that negative memories tend to be more stable than positive memories over time (Porter & Peace, 2007). Human subjects research also suggests that fabricated details can be incorporated into memory and believed to be true even in the face of contradictory facts (Loftus & Kaufman, 1992; Loftus & Ketcham, 1991). The ongoing debate has relevance for the diagnosis of PTSD, which is typically made on the basis of the patient's report of trauma exposure, as well as elucidating the etiology of PTSD. Therefore, the purpose of the present study was to examine the relationships between change in retrospective reports of potentially traumatizing events and PTSD.

Although there is an extensive literature on trauma memories (van Giezen et al., 2005), only a few studies have examined the relationship between PTSD and changes in the report of exposure to the events that constituted Criterion A1 of the index trauma for the PTSD diagnosis. One small study (Schwarz, Kowalski, & McNally, 1993) of staff members who witnessed a school shooting assessed exposure 6 and 18 months after the shooting, using a continuous rating scale. For recall of sense of life threat, changes in exposure scores at follow up were associated with Time 1 re-experiencing symptoms and Time 2 avoidance symptoms and arousal symptoms; increased endorsement of exposure to objective events was associated with more severe avoidance and arousal symptoms at Time 1, and greater re-experiencing and avoidance at Time 2. Another small early study (Wyshak, 1994) ($N = 29$) found an association between less severe PTSD symptoms and changed reports of exposure assessed one week later, but the author did not distinguish between increased and decreased endorsement.

Some studies report a memory "amplification" effect in which subjects endorse a greater number of traumatic events at follow up. One study (Southwick, Morgan, Nicolaou, & Charney, 1997) of 59 Gulf War veterans assessed one month after returning from

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their tour of duty and two years later found that the severity of PTSD symptoms at follow up was positively correlated with the number of non-endorsements changed to endorsements, suggesting an "amplification" of trauma memories. Another study (King et al., 2000) of 2942 Gulf War veterans assessed within five days of their return to the U.S. and at 18–24 months follow up also found a general tendency for increases in the number of the stressors endorsed at Time 2, and small (but significant) correlations between increased report of stressor exposure and higher PTSD symptoms at both time points. A third study (Wessely et al., 2003) with 2370 United Kingdom veterans of the Gulf War and Bosnian conflict found increased endorsements of exposure at three year follow up in the Gulf War cohort only. Increased and decreased endorsements were associated with worsened and improved perception of health status, respectively; but there was no significant association between change in endorsement and PTSD symptoms. However, PTSD was assessed by four questionnaire items rather than with the more reliable standardized self report instruments used in other studies (King et al., 2000; Southwick et al., 1997). Yet another study, done on Dutch Iraq War veterans, documented that people with higher levels of PTSD and neuroticism, lower levels of extraversion and fewer prior missions were more prone to increased memory reporting over time (Engelhard, van den Hout, & McNally, 2008).

Researchers have suggested that amplification of trauma memories could occur as a result of re-experiencing symptoms (King et al., 2000; Southwick et al., 1997), and one study (Roemer, Litz, Orsillo, Erlich, & Friedman, 1998) provided some support for this hypothesis. Roemer et al. (1998) assessed 460 veterans within one year of their return from Somalia and one to three years, and also found a significant increase in the number of endorsed events over time. More critically, the number of events endorsed at Time 2 was significantly correlated with PTSD re-experiencing symptoms, but not with other types of PTSD symptoms or symptoms of depression or anxiety. A smaller study (Bramsen, Dirkzwager, van Esch, & van der Ploeg, 2001) with 137 Dutch peacekeepers assessed by mail survey three years after their return from Cambodia and again one year later failed to replicate this effect, finding no increase in endorsements of exposure at follow up, and no significant correlation between PTSD symptoms and the number of events endorsed at follow up, although the authors noted that value of beta was the same as that in the Roemer et al. study (1998). However a recent study (Koenen, Stellman, Dohrenwend, Sommer, & Stellman, 2007) of 1462 Vietnam vets assessed by mail survey in 1984 and again in 1998 found that increased re-experiencing symptoms at Time 2 were significantly correlated with increased endorsement. Moreover, the presence of PTSD at both assessments or at follow up was associated with greater endorsement of exposure at follow up, whereas recovery from PTSD was associated with decreased exposure scores, and veterans who never had PTSD showed no change in exposure scores.

The overall findings suggest that retrospective reports of potentially traumatizing events may engender an amplification effect, such that subjects tend to endorse experiencing a greater number of events at follow up, and there is some evidence that this might be associated re-experiencing symptoms. However, the current research is limited by a predominance of veteran samples exposed to combat trauma, and by the assessment of PTSD symptoms and exposure with self report instruments. The present study addresses these limitations by using standardized interviews to assess both PTSD and exposure variables in a novel civilian sample, a large cohort of disaster restoration workers exposed to the 9/11/01 World Trade Center (WTC) attack and its aftermath. We examined whether change in the report of exposure was associated with PTSD severity at follow up; and the specificity of the effect to a particular PTSD symptom cluster.

1. Method

1.1. Participants

Participants were 2641 disaster restoration workers deployed to the WTC site during or after the 9/11/01 attack. During their efforts to restore the area to enable businesses and residents to return, the workers were exposed to potentially traumatizing events such as discovering human remains and having to quickly evacuate unsafe structures to avoid collapses. Participants were evaluated as a part of an annual screening program for WTC disaster restoration workers; the Weill-Cornell Medical College IRB approved use of the data for research. The present study includes data collected at Time 1, 05/02–09/04, and Time 2, one year later, 01/03–01/05. The mean number of months between evaluations was 11.60 (S.D. 2.17).

1.2. Instruments

The *Clinician-Administered PTSD scale* (CAPS – Blake et al., 1995; Weathers, Ruscio, & Keane, 1999) is a widely used PTSD interview that yields a categorical diagnosis, and a total PTSD symptom score, calculated by summing frequency and intensity scores for each symptom; and scores for each of the three symptom clusters: re-experiencing (intrusions, nightmares flashbacks, distress and physiological reactions to reminders); avoidance/numbing (avoidance of reminders of the trauma, anhedonia, withdrawal, emotional numbing, amnesia, feelings of foreshortened future); and hyperarousal (insomnia, anger, concentration problems, hypervigilance, exaggerated startle responses).

The *WTC Exposure Questionnaire* is a clinician-administered instrument that was developed for the screening program to assess aspects of exposure shown in the disaster literature to predict PTSD as well as those unique to working at the WTC site. Eleven exposure variables were examined: witnessed people jumping from the towers; saw human remains ("bodies, body bags, or body parts"); concerned (during the attacks) about someone who was at the WTC; knew someone injured in the attack; knew someone killed in the attack; attended funerals or memorial services; assisted people affected by the attack, displaced from residence, had to be evacuated for safety while working at the site; perceived life danger while working at the site; and being disturbed by the smell while working at the site. Items were scored dichotomously (endorsement = 1; non-endorsement = 0).

1.3. Data analyses

The first step in the analyses was to run paired *t*-tests to examine differences in memory reports between Times 1 and 2. Following previous research (Southwick et al., 1997), a *memory change* score was calculated by subtracting the number of exposure variables endorsed at Time 2 from the number of exposure variables endorsed at Time 1. Thus, the memory change score took negative values for endorsing more variables at Time 2 ("remembering"), and positive values for endorsing fewer variables at Time 2 ("forgetting"). For example, if an individual endorsed 5 variables at Times 1 and 3 variables at Time 2, the memory change score would be 2.

To examine the associations between change in the reports of traumatic events and PTSD symptoms at follow, we first examined zero-order correlations between memory change score and CAPS total scores and scores for each of the three PTSD symptom clusters. This was followed by two stepwise regression analyses, one examining whether the three PTSD symptom clusters at Time 1 predicted memory change scores, and another examining whether the three PTSD symptom clusters at Time 2 predicted

Table 1
Demographic characteristics.

Characteristics of sample ($N = 2641$)	
Age, *M* (S.D.)	45.03 (9.33)
Gender	
Male	96.9%
Female	3.1%
Race	
Caucasian	65.1%
African American	17.8%
Hispanic	13.6%
Asian	1.3%
Other	2.3%
Education	
Some or no high-school	2.1%
High-school graduate	45.7%
Some college or training	34.6%
College graduate	13.5%
More than college	4.1%
Marital status	
Cohabitating	3.7%
Separated or divorced	8.2%
Married	71.4%
Widowed	.6%
Single	16.1%

memory change scores. We chose stepwise regression because of a lack of definitive evidence in support of a particular order of entry for the PTSD symptom clusters.

To examine which of the exposure variables at Time 1 had an effect on total CAPS scores at Time 2, we conducted a mixed Group × Time ANOVA for each of the 11 exposure variables, followed by planned Tukey's HSD tests (for significant interactions) to examine simple effects. The Group variable had four levels, based on endorsements at Times 1 and 2: (1) yes–yes (endorsed exposure to the variable at both interviews); (2) no–no (denied exposure at both interviews); (3) no–yes (endorsed exposure at Time 2 only, i.e., "remembering group"); and (4) yes–no (endorsed exposure at Time 1 only, i.e., "forgetting group").

2. Results

Demographic variables are presented in Table 1. As shown, the sample was middle-aged, predominantly male, Caucasian, married, and had at least a high-school education.

2.1. Endorsement of exposure

Table 2 presents the percentage of people who changed their report of the 11 exposure variables. The memory change score was normally distributed, with a mean of −1.19 (S.D. = 1.85). The majority (62.9%) increased the number of variables endorsed at Time 2; 17% decreased the number of variables endorsed, and 20.1% endorsed the same number of variables at both interview. The total memory score changed significantly between Time 1 and Time 2 ($t = -30.92$, d.f. = 2322, $p = .001$), and a greater number of variables were endorsed at Time 2, mean (S.D.) = 1.90 (1.60), vs. Time 1, mean (S.D.) = 3.10 (1.92).

2.2. Change in endorsement of exposure variables and PTSD

The correlation between the memory change score and Time 2 total CAPS score and PTSD symptom cluster scores was significant (total CAPS score: $r = -.16$, $p = .001$; re-experiencing: $r = -.20$, $p = .001$; avoidance/numbing: $r = -.11$, $p = .001$; hyperarousal: $r = -.15$, $p = .001$), suggesting that an increase in the number of endorsed variables at Time 2 was associated with more severe PTSD symptoms at follow up. The same results were found for Time 1 PTSD symptom clusters (total CAPS score: $r = -.16$, $p = .001$; re-experiencing: $r = -.09$, $p = .001$; avoidance/numbing: $r = -.06$, $p = .01$; hyperarousal: $r = -.12$, $p = .001$).

The results of the regression analyses are shown in Table 3.

Time 1 CAPS scores: More severe Time 1 hyperarousal symptoms predicted an increase in the number of endorsed stressors at Time 2, whereas more severe Time 1 avoidance/numbing symptoms predicted a *decrease* in the number of endorsed stressors; re-experiencing symptoms were not significant predictors.

Table 2
Change in endorsement of exposure variables.

Group	Exposure event	No–no	Yes–no (forgetting group)	Yes–yes	No–yes (remembering group)	Change
1	Knowing someone at the WTC	44.2	13.5	26.2	16.1	29.6
2	Knowing someone injured	93.2	2.8	.7	3.3	6.1
3	Knowing people killed	54.2	7.8	25.1	12.9	20.7
4	Attending funerals	55.8	17.3	6.0	20.9	38.2
5	Assisting people affected by the disaster	92.5	2.6	.9	4.0	6.6
6	Being displaced from residence	99.0	.5	.0	.5	1
7	Perception of life threat	54.2	12.3	17.7	15.8	28.1
8	Having to evacuate	55.6	8.7	26.9	8.8	17.5
9	Seeing bodies/body bags/parts	29.5	10.8	47.2	12.5	23.3
10	Seeing people jump	96.2	.4	.5	2.9	3.3
11	Being disturbed by smell at the site	34.4	4.9	15	45.7	50.6

Table 3
Regression analyses: PTSD symptoms and change in exposure endorsements, Time 1 and Time 2.

Model	Predictor	Beta[a]	*p*	Partial *r*	Model R^2	Std. error of the estimate	Significant R^2 change
Model for CAPS scores at Time 1							
1	Hyperarousal	−.172	.000	−.119	.015	1.821	
2	Avoidance/numbing	+.066	.030	+.046	.018	1.820	
Variables excluded	Re-experiencing	−.043	.140	−.031			
Model for CAPS scores at Time 2							
1	Re-experiencing	−.198	.000	−.198	.039	1.824	.000
2	Avoidance/numbing	+.049	.087	+.036			
Variables excluded	Hyperarousal	−.037	.185	−.028			

[a] Standardized coefficients.

Time 2 CAPS scores: The only significant predictor of change in endorsements was re-experiencing symptoms; more severe symptoms at Time 2 were associated with increased endorsements.

2.3. Effects of specific exposure variables on PTSD at Time 2

The Group × Time interactions were significant for only two of the 11 stressor variables, "Perceived life threat" (F (2179) = 7.25, p = .001) and "Seeing bodies, body bags/parts" (F (1574) = 2.75, p = .05). Tukey's HSD tests found that for these two variables all participants had a significant decrease in CAPS scores at Time 2, except for the group that endorsed exposure to a greater number of stressors at Time 2 (i.e., the "remembering" group) (all Tukey HSD's for both variables $\geq$3.07, $p \leq .01$ for the "no–no", "forgetting", and "yes–yes" groups, respectively) and 1.11 for "perceived life threat" (p = ns), and 1.31 for "seeing bodies, body bags/parts" (p = ns) for the "remembering" group.

3. Discussion

The present study offers support to the notion that memory for traumatic events is malleable and subject to change. Indeed, we found that recall of both objective traumatic events (saw human remains) and subjective events (perceived life danger) changed over time. The greatest memory inconsistency was for a subjective event: "Being disturbed by the smell at the WYC site", for which 51% of the sample changed their reports from 'yes' to 'no' or from 'no' to 'yes' at Time 2. Of the 11 exposure variables assessed, only perceived life danger while working at the site and exposure to human remains emerged as being differentially associated with PTSD symptoms. Consistent with previous findings (Schwarz et al., 1993; Southwick et al., 1997), this study revealed an association in change in report of life threat and exposure to objective events and PTSD. Participants who changed their initial non-endorsement to endorsement for these two variables did not show a decline in PTSD symptoms at follow up, unlike the other endorsement groups (no change, or change from endorsement to non-endorsement). The association between perceived life danger at the time of initial exposure and later PTSD symptom severity supports the validity of the DSM-IV diagnostic criterion A2 (Criterion A2) (American Psychiatric Association, 1994). This finding and the finding that the discovery of human remains was also associated with PTSD symptom severity at follow up are also consistent with research linking the both objective severity of initial exposure and the emotional response to it to the development of PTSD (Brewin et al., 2000; Difede et al., 2006; Tucker et al., 2000). Although seeing human remains, however unpleasant, does not constitute a direct threat to life, the association between this variable and PTSD suggests that horror, as much as terror, is traumatogenic.

This study also replicated the memory amplification effect (King et al., 2000; Roemer et al., 1998; Southwick et al., 1997) in a civilian sample exposed to a single incident trauma assessed with a structured clinical interview; the majority of workers endorsed more exposure variables at follow up. We also found a significant association between increased endorsement and more severe PTSD symptoms at follow up. Multiple regression analyses revealed that each type of PTSD symptom cluster exerted a unique effect. Consistent with previous findings (Schwarz et al., 1993), more severe Time 1 hyperarousal symptoms were associated with an increase in endorsements at follow up; whereas in contrast to previous findings (Schwarz et al., 1993), more severe Time 1 avoidance and numbing symptoms were associated with a decrease in endorsements at follow up. This finding suggests that some of the "forgetting" that occurs could be related to early avoidance of thoughts, conversations, and other trauma-related stimuli, and is also consistent with the finding that the initial severity of PTSD avoidance/numbing symptoms predicted a decrease in the number of initially endorsed lifetime traumatic events at follow up (Ouimette, Read, & Brown, 2005). This study also replicated the finding of an association between increased endorsement at follow up and the severity of concurrent re-experiencing symptoms (Koenen et al., 2007; Roemer et al., 1998), supporting the hypothesis that such symptoms contribute to the memory amplification effect (King et al., 2000; Southwick et al., 1997).

Although the results of the study documented significant associations between memory and psychopathology, several caveats are in order. First, the nature of this study was mainly correlational, so a clear direction of causality cannot be pinpointed with certainty and more prospective studies are needed to elucidate the nature of the phenomenon. Second, because of the unprecedented nature of the index trauma (WTC attack), exposure to potentially traumatizing events was assessed with an instrument created for this study rather than an existing instrument with known psychometric properties. Third, the sample was assessed several months to one year after initial exposure, which could have influenced the recollections of exposure as well. Lastly, the study is specific to September 11th WTC attack, a tragic and unique event that was covered extensively in the media, not only initially, but repeatedly through ongoing news stories, movies, and memorials. The effects of this ongoing media coverage on the sample's change in endorsements is unknown and would require more experimental control of exposure to reminders of the traumatic event to fully understand. One way of elucidating the reasons for the discrepancies over time, and which can be the object of future research, could be to show the subjects their data from the different time points and to ask them for their opinion on why the reports changed (e.g., forgetting, changing personal criteria/definitions of what counts as being disturbed by the smell, etc.). Additionally, future research should also address the issue of conflating alteration in features of a single traumatic event versus endorsing (of failing to endorse) exposure to an entirely new event. These might be different kinds of memory problems, in that getting a detail wrong about a single event may differ from creating a false memory of the entire event.

In conclusion, the results of this study suggest that a memory amplification effect occurs in civilian as well as veteran samples, and that it can be associated with single incident traumas as well as combat exposure. Moreover, the collected findings suggest that report of trauma exposure appears to be most consistently related to concurrent re-experiencing symptoms, which calls into question the directionality of the association between PTSD symptoms and the intensity of exposure and peri-traumatic emotional responses. Future prospective longitudinal studies that can assess trauma survivors more immediately after exposure, as well as the development of externally valid laboratory analogues which with to study trauma memories could help to increase our understanding the relationship between trauma exposure, recollections of trauma memories, and PTSD.

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