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RESEARCH ARTICLE

A Deese-Roediger-McDermott study of trauma memory among employees of New York City companies affected by the September 11, 2001, attacks

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BACKGROUND: Posttraumatic stress disorder (PTSD) has been found to be associated with abnormalities in memory function. This relationship has not previously been studied using the Deese-Roediger-McDermott (DRM) false memory paradigm in disaster-exposed populations.

METHODS: Three years after the September 11, 2001 (9/11) attacks, 281 participants from a volunteer sample of 379, recruited from 8 companies directly affected by the attacks, completed an interview about their disaster experience, a structured diagnostic interview, and the DRM paradigm.

RESULTS: It was hypothesized that participants with PTSD would demonstrate more associative errors, termed *false alarms to critical lures*, compared to those without PTSD. This hypothesis was not supported; the only predictor of false alarms to critical lures was direct 9/11 trauma exposure.

CONCLUSIONS: The finding that 9/11 trauma exposure was associated with false alarms to critical lures suggests that neural processing of trauma-exposure memory may involve associative elements of overgeneralization coupled with insufficient inhibition of responses to related but harmless stimuli. Future research will be needed to differentiate psychopathology, such as PTSD, from physiological fight-or-flight responses to trauma.

INTRODUCTION

Intrusive memories of a traumatic event (group B criteria for posttraumatic stress disorder [PTSD] in DSM-5) represent 1 of the 4 main defining symptom groups for the diagnosis of PTSD.[1] Memory functions are central to the emotional processing of trauma; abnormalities in these processes

TABLE 1
Deese-Roediger-McDermott paradigm terms used in this study

Term	Definition
Critical lure	Word on the written list that was not on the recited lists but was related to the words on the recited lists
Unrelated lure	Word on the written list that was not on the recited lists and was unrelated to the words on the recited lists
Hit	Correct selection of any of the 8 words as having been among the recited words
False alarm	Incorrect selection of a word that was not on the recited word lists

are presumed to contribute to generation of PTSD.[2,3] The amygdala, hippocampus, and medial prefrontal cortex are involved in the development, maintenance, and elimination of fear memories through interrelated processes involving fear activation, encoding and storage of contextual memory, inhibitory feedback, and modification of trauma responses.[4] Abnormalities in these structures and their functions have been implicated in the development and maintenance of posttraumatic symptoms and PTSD.[4,5] A model of PTSD advanced by Ehlers and Clark [6] identified difficulties in cognitive processing of the trauma with overgeneralization of the trauma memories and loss of specificity to the context of the trauma event. Consequently, ordinary sensory cues elicit associations to the overgeneralized memory, leading to incorrect interpretation of those cues as signaling danger, even in safe environments. Responses to these overgeneralized trauma memories lack the appropriate inhibitory feedback that normally would modulate them.

A robust paradigm for investigation of memory, originally developed by Deese in 1959[7] and subsequently modified by Roediger and McDermott in 1995,[8] examines memory functions and errors. The Deese-Roediger-McDermott (DRM) paradigm therefore is a useful technique for studying memory function in PTSD. The DRM assesses memory for semantically related and unrelated intrusions in an immediate test of the content of presented word lists. For example, participants who hear a list of words such as *bed*, *rest*, *awake*, *tired*, and *dream* (and 10 more words) falsely recall the word *sleep*, which was not presented. In their 1995 study, Roediger and McDermott[8] found that participants incorrectly recognized a novel word that was semantically related to the words on the list as being part of the original list (termed a *false alarm to a critical lure*) at almost the same rate as the words that were actually present in the list (termed a *hit*) (TABLE 1). They obtained false-alarm rates to critical lures that were about as high as the hit rates. Findings from this and subsequent research further indicated that associative processes may be involved with these errors in memory.[8,9]

The DRM paradigm has had some application beyond study of normal subjects in laboratory settings,[10] but these have produced inconsistent findings in relation to PTSD and trauma exposure.[11] Three studies found PTSD to be positively associated with false alarms among trauma-exposed groups,[12-14] and 3 studies found no significant relationship.[11,15,16] Additionally, 1 study found trauma exposure to be positively associated with false alarms[16] and another study found no significant relationship.[11]

This article presents findings from a study of survivors of the September 11, 2001 (9/11) attacks on the World Trade Center (WTC) towers in New York City using the DRM paradigm to examine associations of memory with disaster trauma exposure and PTSD. What distinguishes this memory study from previous research is that it examined disaster survivors using structured diagnostic interviews to fully assess diagnostic criteria for PTSD in relation to the 9/11 attacks, and it carefully examined 9/11 disaster trauma exposures according to DSM-IV-TR criteria for PTSD.[17] Other distinctive features of this study are the application of the DRM paradigm to examine associated memory functions and the use of neutral (not emotional or trauma-related) words in the DRM paradigm.

Based on previous literature linking impaired memory functions to PTSD,[2-5] as well as a model of PTSD implicating impaired cognitive processing and overgeneralization of trauma memories,[6] it was hypothesized that false alarms to critical lures would be significantly associated with PTSD and not with trauma exposure, both of which were examined in this study.

METHODS

A previous publication from this study[18] provides details of the research methods and descriptive characteristics of the sample. Approval for the study was obtained

in advance from the institutional review boards at the academic institutions participating in the research, and informed consent was obtained in advance from all participants. Approximately 3 years (median, 35 months) after the 9/11 attacks, a volunteer sample of 379 study participants was recruited from members of 8 participating companies (3 companies in the WTC towers and 1 nearby agency, 3 companies that provided 9/11 disaster recovery services, and an airline that lost personnel and property in the attacks) in a study of the mental health effects of the 9/11 attacks on survivors.

The sample was administered a fully structured diagnostic interview that provided predisaster and postdisaster diagnoses relative to the time of the 9/11 attacks (Diagnostic Interview Schedule for DSM-IV)[19] and a systematic assessment of specific disaster-related experiences (Disaster Supplement).[20] The 9/11 exposure variables for this study were developed using explicit criteria for defining qualifying traumatic exposures for the diagnosis of PTSD in DSM-IV-TR, which include experiences of actual or threatened physical injury or death to the individual, directly witnessing people being injured or killed, and endangerment/injury/death of a close associate in the attacks. Variables representing direct exposures were developed from objective data from personal reports of exact geographical location and its proximity to the disaster (ie, inside the WTC towers or within 1 city block between the time that the first plane struck the towers and the second tower collapsed) and specific reports of physical injury or threat of immediate physical danger in the disaster. More detail on the development of these exposure variables has been provided previously.[18]

The version of the DRM word-recognition paradigm used in this study utilizes 4 lists of words (**TABLE 2**) originally validated by Roediger and McDermott.[8] Words on these 4 lists were each strongly associated with another word that was not part of the list, eg, the word list "sour, candy, sugar, bitter, good, taste,..." did not include the word *sweet*. Before administration of the paradigm, the interviewer informed the participant that a word memory test would be administered, in which the participant would be read 4 lists of words and then asked to identify the words when presented on a written list. Then the interviewer sequentially recited the 4 lists of 15 words each at the rate of about 1 to 1.5 seconds/word. Immediately following the interviewer's oral presentation of the 4 lists, a written list of 24 words was provided, and participants were asked to circle the words they remembered having heard on the lists recited by the interviewer. The written list included 2 words from each of the 4 lists recited by the interviewer (eg, *sour*). A participant's correct selection of any of these 8 words as having been among the recited words is referred to as a *hit*; selection of a word that was not on the recited word lists is termed a *false alarm* (**TABLE 3**).

TABLE 2
Four lists recited to the participants and their associated critical lure

List	Critical lure
Sour, candy, sugar, bitter, good, taste, tooth, nice, honey, soda, chocolate, heart, cake, tart, pie	Sweet
Bed, rest, awake, tired, dream, wake, snooze, blanket, doze, slumber, snore, nap, peace, yawn, drowsy	Sleep
Table, sit, legs, seat, couch, desk, recliner, sofa, wood, cushion, swivel, stool, sitting, rocking, bench	Chair
Mug, saucer, tea, measuring, coaster, lid, handle, coffee, straw, goblet, soup, stein, drink, plastic, sip	Cup

False alarms reflect incorrect selection of 2 types of words on the written word list that were not on the recited lists: *unrelated lures* (12 words) and *critical lures* (4 words). *Unrelated lures* are words incorrectly selected on the recognition test that were not on the recited lists and were unrelated to the words on those lists (eg, *mountain*), reflecting general memory errors or *false alarms to unrelated lures*. *Critical lures* are words incorrectly selected on the recognition test that were not on the recited lists but were related to the words on those lists (eg, the word *sweet*, as described above), as determined by extensive prior research on word association probabilities.[7,21] The 4 false critical lures (1 for each list) for this study were *sweet*, *sleep*, *chair*, and *cup*. The proportions of responses chosen for each word category (hits and false alarms to unrelated lures and to critical lures) were calculated by dividing the number of participant-identified words in each category by the total number of words in the category.

The research interviews lasted 2 hours on average (mean [SD] = 120 [47.1] minutes; median = 120 minutes). The DRM word-recognition paradigm was administered immediately after the interviews, and 98 participants opted not to participate in the memory test or did not complete it. A total of 281 participants

TABLE 3
Written test in its original order as presented to participants after recitation of the 4 lists and designation of items as either correct answer, unrelated lure, or critical lure

Test item	Designation
Tea	Correct answer
Smell	Unrelated lure
Tough	Unrelated lure
Sleep	Critical lure
Chair	Critical lure
Smooth	Unrelated lure
Hill	Unrelated lure
Sniff	Unrelated lure
Rough	Unrelated lure
Sugar	Correct answer
Mountain	Unrelated lure
Sing	Unrelated lure
Tired	Correct answer
Music	Unrelated lure
Sour	Correct answer
Climb	Unrelated lure
Nose	Unrelated lure
Sweet	Critical lure
Mug	Correct answer
Bed	Correct answer
Seat	Correct answer
Note	Unrelated lure
Table	Correct answer
Cup	Critical lure

completed both the clinical interview and the memory test. The group with complete data was not different from the rest of the sample with regard to sex; age; race; current marital status; direct exposure to 9/11 trauma; minimum distance from the towers during the attacks; employment in an company located in the WTC towers on 9/11; postdisaster diagnosis of 9/11-related PTSD, major depression, or alcohol use disorder after the disaster; or diagnosis of any lifetime predisaster psychiatric disorder ($P > .05$ in all comparisons). Those with complete data had more years of education (mean [SD] = 16.8 [3.1] vs mean [SD] = 15.9 [2.9]; $t = 2.31$, $df = 374$, $P = .022$) than those with incomplete data.

SAS version 9.2 (SAS Institute, Inc.) was used for data analysis. Descriptive data are presented as raw numbers, proportions, means, standard deviations, medians, and ranges. Comparisons between 2 dichotomous variables were made using chi-square tests, substituting Fisher exact tests for expected cell sizes <5. Comparisons between dichotomous and numerical variables were conducted using Student *t* tests, using the Satterthwaite method for instances of unequal variances. Multivariate regression models were tested for rates of 3 DRM categories (hits, false alarms to unrelated lures, and false alarms to critical lures—each serving as a dependent variable for 1 model), controlling for several independent covariates entered into the model simultaneously that included demographic variables (sex, age, ethnicity, education, marital status, income, and 9/11 workplace in WTC towers), duration of interview, and direct exposure to danger in the 9/11 attacks. Statistical significance was set as alpha = .05.

RESULTS

The characteristics of the study participants (N = 281) on demographic, disaster exposure, and psychiatric diagnosis variables are presented in **TABLE 4**. The sample was about one-half male and predominantly white. Most were college graduates and about one-half were currently married. The median age was 44 years and the median income was $64,800 (in 2004). Postdisaster major depression, diagnosed in nearly one-third of the sample, was more prevalent than 9/11-related PTSD. The lifetime pre-9/11 prevalence of psychopathology was 41%.

Approximately one-half of the sample worked in a company located in the WTC towers on 9/11. One-fourth were directly exposed to 9/11 disaster trauma and 7% were injured. More than one-fourth directly witnessed injury or death. Fourteen percent had a close associate who was directly exposed to the attacks. Participants in this sample were located over a wide range of distances from the WTC towers during the attacks, with a median distance of about 3.5 miles.

The proportions of DRM paradigm words judged by participants as having been on the presented word lists were calculated separately for correctly recognized words, unrelated lures, and critical lures. The mean (SD) hit rate for correctly recognized words was 0.79 (0.19). Nearly one-fourth (24%) of the sample recognized all

TABLE 4
Sample characteristics

	% (n/N)	Mean (SD)	Median	Range
Demographics				
Sex, male	47% (133/281)			
Age, years		44.6 (11.1)	44	23 to 84
Ethnicity[a]				
White	72% (202/281)			
Black	15% (41/281)			
Hispanic	7% (20/281)			
Asian	5% (13/281)			
Other	2% (5/281)			
Education				
Years of education (GED = 12)		16.8 (3.1)	16	10 to 29
College graduate	70% (197/281)			
Current marital status				
Married	51% (144/281)			
Not married	49% (137/281)			
Annual income[b]		$79,000 ($54,000)	$64,800	$0 to ≥$200,000
Worked in WTC towers	48% (135/281)			
Psychiatric disorders				
Pre-9/11 psychiatric disorder	41% (116/281)			
Postdisaster 9/11-related PTSD	14% (38/281)			
Post-9/11 major depression	31% (85/278)			
9/11 disaster exposure				
Directly exposed to 9/11 trauma	26% (73/281)			
Directly witnessed injury/death/carnage	27% (77/281)			
Close associate exposed to 9/11 trauma	14% (39/279)			
Closest proximity to WTC during 9/11 attacks, miles		53.7 (245.4)	3.5	0 to 2937

[a]Subgroup percentages add to >100% because of rounding.
[b]N = 248 because of missing data on this variable.

GED: general equivalency diploma; PTSD: posttraumatic stress disorder; WTC: World Trade Center.

8 words from the recited lists. The unrelated lures elicited a mean (SD) false alarm rate of 0.11 (0.14). Forty-three percent of the sample did not select any of the 12 unrelated lures. The mean (SD) false alarm rate for the critical lures was 0.84 (0.23); 61% of participants incorrectly selected all 4 critical lures and only 1% correctly selected none of the 4 critical lures. Thus, a substantial DRM false recognition effect was observed, with the false alarm rate for critical lures (0.84) approximately the same (or even slightly higher) than the hit rate for words actually heard (0.79).

The associations of demographic, psychiatric, and disaster-exposure variables with words correctly recognized as having been on the recited lists, unrelated lures, and critical lures are presented in **TABLE 5**. In separate bivariate analyses, younger age, having a close associate who was exposed to 9/11 trauma, and longer interview duration were associated with a significantly higher hit rate; being currently married, employment in a WTC company on 9/11, and being in close proximity to the WTC towers during the attacks were associated with a

significantly lower hit rate. Sex, racial/ethnic group, years of education, income, psychiatric disorders, direct exposure to 9/11 trauma, and direct witnessing of the disaster were not associated with hit rates. In additional separate bivariate analyses, false alarms to unrelated lures were significantly associated with racial/ethnic minority group membership and a higher number of years of education but not with any of the other variables tested. False alarms to critical lures were significantly associated only with employment in a WTC company on 9/11, direct exposure to 9/11 trauma, and having a close associate who was exposed to 9/11 trauma. However, false alarms to critical lures were not significantly associated with 9/11-related PTSD.

TABLE 6 presents results from 3 multivariate regression models constructed to predict correct identification of words correctly recognized as having been heard on the lists (hits), incorrect selection of unrelated lures, and false alarms to critical lures (1 dependent variable for each of 3 models) from other variables (independent variables listed in **TABLE 6**) entered into the model simultaneously. Because psychiatric disorders were not associated with any of the 3 categories of responses (hits, false alarms to unrelated lures, and false alarms to critical lures) in bivariate analyses (**TABLE 5**), they were not included in the multiple regression models. In the model predicting correctly identified hits, only younger age and longer interview duration were predictive independent of the effects of all the other variables in the model. In the model predicting false alarms to unrelated lures, only fewer years of education was predictive independent of the effects of all the other variables. In the model predicting false alarms to critical lures, only direct exposure to 9/11 danger remained significantly predictive.

DISCUSSION

This study was the first to apply the DRM memory paradigm to a sample of disaster survivors assessed with structured diagnostic interviews specific to the disaster to allow precise categorization of psychiatric disorders and trauma exposures. This study's disaster sample represented both groups with and without direct exposure to 9/11 trauma and groups with and without 9/11-related PTSD, permitting examination of the association of DRM memory variables with trauma exposure and with PTSD.

As in other DRM studies, the false alarm rate for critical lures (84%) was close to the hit rate for the correctly recognized words from the recited list (79%), revealing a robust illusion of memory.[8,10] Findings that younger participants correctly identified more words and that lower educational attainment predicted errors on unrelated lures support notions that age is negatively associated with recollection and that greater education protects against general memory errors. The duration of the interview immediately preceding the memory paradigm test was positively associated with correct identification of recited words but not with false alarms to critical lures or unrelated lures. It may be that individuals with longer interviews were more diligent and thoughtful in their responses, which was further reflected in their attention to the word lists, resulting in more accurate recollection of the recited words.

In this study, the only predictor of false alarms to critical lures was direct exposure to 9/11 trauma, which was positively associated. Direct exposure to 9/11 trauma was not associated with hits or with false alarms to unrelated or critical lures in the multivariate models. PTSD was not associated with false alarm rates to critical lures. No associations were found between PTSD or other psychopathology and DRM memory variables.

These results are consistent with suggestions that neural processing of trauma exposure in the creation and maintenance of fear memory may involve overgeneralization in cognitive processing coupled with insufficient inhibition of responses to related but harmless stimuli. The study's finding that false alarms to critical lures were associated with disaster exposure but not with PTSD suggests that overgeneralization and disinhibition may be normative functions of the brain as part of the physiological fight-or-flight response, rather than pathological processes. Individuals exposed to a life-threatening trauma may become overly vigilant to potential danger cues and react before the situation can be processed to determine whether danger is really present. The rapidity of the reaction in a threatening context may be lifesaving, but similar, unnecessary reactions to related stimuli in harmless situations may be an inherent part of normative response to trauma.

Other research[22-29] has demonstrated that although intrusive memories and hyperarousal are common after trauma exposure, they are not by themselves indicative of psychopathology in the absence of avoidance and

TABLE 5
Association of demographic, psychiatric, and disaster exposure variables with hits, unrelated lures, and critical lures

		Hits[a]		Unrelated lures		Critical lures	
		Mean (SD)	*P* (R)	Mean (SD)	*P* (R)	Mean (SD)	*P* (R)
Demographic/interview characteristics							
Sex							
Male		0.79 (0.18)	NS	0.12 (0.15)	NS	0.85 (0.22)	NS
Female		0.80 (0.19)		0.10 (.013)		0.84 (0.24)	
Age			**.036** (–0.13)		NS		NS
Race/ethnicity							
White		0.79 (0.19)	NS	0.10 (0.13)	**.049**	0.85 (0.23)	NS
Other		0.80 (0.19)		0.14 (0.16)		0.84 (0.24)	
Years of education			NS		**.005** (–.17)		NS
Marital status							
Married		0.77 (0.20)	**.018**	0.12 (0.15)	NS	0.83 (0.25)	NS
Not married		0.82 (0.16)		0.11 (0.13)		0.86 (0.25)	
Income		0.79 (0.19)	NS		NS		NS
WTC company worker	Yes	0.76 (0.22)	**.001**	0.11 (0.13)	NS	0.89 (0.18)	**.002**
	No	0.83 (0.14)		0.12 (0.15)		0.80 (0.26)	
Duration of interview (minutes)			**.012** (0.16)		NS		NS
Psychiatric diagnosis							
Pre-9/11 diagnosis	Yes	0.79 (0.18)	NS	0.10 (0.12)	NS	0.87 (0.23)	NS
	No	0.80 (0.19)		0.12 (0.16)		0.83 (0.23)	
Postdisaster 9/11-related PTSD	Yes	0.81 (0.16)	NS	0.10 (0.14)	NS	0.89 (0.22)	NS
	No	0.79 (0.19)		0.11 (0.14)		0.84 (0.23)	
Post-9/11 MDD	Yes	0.80 (0.20)	NS	0.11 (0.12)	NS	0.86 (0.22)	NS
	No	0.79 (0.18)		0.12 (0.15)		0.84 (0.23)	
Exposure							
Directly exposed to 9/11 trauma	Yes	0.83 (0.17)	NS	0.11 (0.14)	NS	0.92 (0.15)	**<.001**
	No	0.78 (0.19)		0.11 (0.14)		0.82 (0.25)	
Directly witnessed injury/ death/carnage	Yes	0.81 (0.18)	NS	0.12 (0.13)	NS	0.88 (0.21)	NS
	No	0.79 (0.19)		0.11 (0.14)		0.83 (0.02)	
Close associate directly exposed to 9/11 trauma	Yes	0.87 (0.13)	**.002**	0.12 (0.13)	NS	0.92 (0.16)	**.004**
	No	0.79 (0.19)		0.11 (0.13)		0.83 (0.24)	
Distance from the WTC towers (miles)			**.047** (–0.12)		NS		NS

[a]Hits: words correctly recognized from the recited lists.

MDD: major depressive disorder; NS: not significant; PTSD: posttraumatic stress disorder; WTC: World Trade Center.

numbing symptoms. These nosologic observations are consistent with this study's findings that trauma exposure is related to the processing of memories, suggesting that these changes alone do not constitute the identifying pathology of PTSD.

One of the strengths of this study was the large sample, which was far larger than the samples in most previous studies using the DRM memory paradigm. Another strength was that the DRM paradigm was applied with a sample of 9/11 survivors that included individuals with

and without trauma exposure in the attacks and individuals with and without PTSD related to the disaster.

The DRM paradigm applied in this study was an add-on to a larger study on mental health effects of disaster. Participants completed the memory paradigm after an approximately 2-hour interview about their 9/11 experiences. Fatigue and emotional arousal could have potentially affected the results. Therefore, minimal memory assessment was performed to decrease the interview burden, resulting in relatively few memory data obtained per participant. The DRM paradigm used in this study was restricted to recognition (ie, data on recall and confidence in endorsement of test words were not collected), and the word lists contained only neutral words and did not test differential effects of trauma-related words.

It is possible that the participants who were predisposed to make associative errors of memory on a word test in this study also could have been those more likely to exaggerate or misrepresent their reports of exposure to the disaster. The degree to which this may have occurred could have contributed to the association found in this study between direct exposure to the disaster and false alarms to critical lures. A study examining reported exposures to 9/11-related trauma among 9/11 WTC recovery workers approximately 7 months after 9/11 and again a year later found that the numbers of reported exposures generally increased in the second interview, consistent with amplification of recall of exposures over time.[30] PTSD was associated with a greater increase in endorsement of exposures. Additionally, DSM-IV group D posttraumatic symptoms were associated with an increase in reported exposures, but DSM-IV group C posttraumatic symptoms were associated with a decrease in reported exposures. That study did not examine the association of 9/11 trauma exposure with reporting of exposures over time. Another study of witnesses of a school shooting,[31] which assessed reported exposures to the disaster at 6 and 18 months afterward, found severity of both group C and D posttraumatic symptoms to be positively associated with increased endorsement of exposures to the disaster with the passage of time.

However, the exposure variable used in this study was developed with explicit criteria based on objective information such as precise geographical location and injury or direct physical threat. Although there is controversy regarding the validity and stability of memories of traumatic public events (ie, "flashbulb" memories), studies have found that memories of where or when a person heard the news about such an event remain consistent and accurate over time.[32,33] It is unlikely that misremembering or misrepresenting experiences of such vivid and unequivocal events occurred uniformly enough in this large sample to result in the statistically significant association found, although this possibility cannot be dismissed.

The time frame in which the current study was conducted (almost 3 years after the disaster) may have failed to capture important findings that may have been manifest in earlier postdisaster time frames. The memory findings of this study so long after the disaster suggest, however, that the effects may be relatively long-standing. This study cannot determine, of course, whether the differences in memory demonstrated in the DRM paradigm are causal or represent pre-existing differences inherent in the likelihood of exposure to 9/11 trauma. However, because disasters in general, and the 9/11 attacks in particular, tend to be relatively nonselective in exposures to trauma,[20,34,35] it is likely that the findings represent effects of the experience of this disaster rather than pre-existing differences in exposure groups.

The primary hypothesis of this study, based on a model of trauma-related cognitive processing and mixed results in previous studies, was not supported. Previous studies lack consensus in memory findings related to trauma and PTSD, which could reflect methodological differences. However, review of that literature does not reveal any consistent methodological element (eg, use of pictures vs words, listening to vs reading the words) in association with the findings. The differences may perhaps lie with other study variables, such as the type of trauma or the characteristics of the study samples.

Further research on the associations of memory with trauma exposure and psychopathology among disaster survivors is warranted to clarify the inconsistent findings in the literature. Future studies may benefit by including both neutral and trauma-related word lists among disaster survivor populations to determine whether trauma-related words might yield different results among disaster survivors. The findings of this study also support the importance of differentiating psychopathology such as PTSD from normal physiological fight-or-flight responses to trauma in future studies of memory and neurobiological investigations of trauma and its effects. ■

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TABLE 6
Multivariate regression models predicting rates of 3 DRM categories: Words correctly recognized from the recited lists, false alarm for unrelated lures, and false alarm for critical lures,[a] based on demographic and main exposure variables[b]

	Parameter estimate	Standard error	*t*	*P*
Words correctly recognized from the recited lists (hits)				
Intercept	0.84	0.09	9.10	<.001
Sex	–0.02	0.02	–1.05	.295
Age	0.00	0.01	–2.05	.042
Nonwhite ethnicity	0.00	0.03	0.29	.775
Years of education	0.00	0.00	–0.64	.520
Currently married	–0.04	0.02	–1.53	.128
Income	0.00	0.00	1.28	.203
Worked in WTC company	0.05	0.03	1.82	.071
Directly exposed to 9/11 trauma	–0.03	0.03	–0.92	.358
Duration of interview	0.00	0.00	3.04	.003
False alarm rate for unrelated lures				
Intercept	0.32	0.08	4.23	<.001
Sex	0.01	0.02	0.74	.462
Age	0.00	0.00	–1.39	.166
Nonwhite ethnicity	0.04	0.02	1.64	.102
Years of education	0.00	0.00	–2.60	.010
Currently married	0.00	0.02	0.45	.653
Income	0.00	0.00	–0.34	.738
Worked in WTC company	–0.01	0.02	–0.36	.716
Directly exposed to 9/11 trauma	0.00	0.02	–0.02	.986
Duration of interview	0.00	0.00	–1.28	.202
False alarm rate for critical lures				
Intercept	0.90	0.13	6.83	<.001
Sex	0.04	0.03	1.13	.261
Age	0.00	0.00	–1.27	.204
Nonwhite ethnicity	0.03	0.04	0.71	.481
Years of education	0.00	0.00	0.05	.957
Currently married	–0.05	0.03	–1.51	.133
Income	0.00	0.00	0.31	.756
Worked in WTC company	0.02	0.04	0.57	.567
Directly exposed to 9/11 trauma	0.09	0.04	2.20	.029
Duration of interview	0.00	0.00	–0.39	.694

[a]1 dependent variable for each of 3 models.
[b]Independent variables.

DRM: Deese-Roediger-McDermott; WTC: World Trade Center.

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REFERENCES

1. Diagnostic and statistical manual of mental disorders. 5th ed. Washington DC: American Psychiatric Association; 2013.
2. Brewin CR. The nature and significance of memory disturbance in posttraumatic stress disorder. Annu Rev Clin Psychol. 2011;7:203-227.
3. van der Kolk BA, Herron N, Hostetler A. The history of trauma in psychiatry. Psychiatr Clin North Am. 1994;17:583-600.
4. Rougemont-Bücking A, Linnman C, Zeffiro TA, et al. Altered processing of contextual information during fear extinction in PTSD: an fMRI study. CNS Neurosci Ther. 2011;17:227-236.
5. Liberzon I, Sripada CS. The functional neuroanatomy of PTSD: a critical review. Prog Brain Res. 2008;167:151-169.
6. Ehlers A, Clark DM. A cognitive model of posttraumatic stress disorder. Behav Res Ther. 2000; 38:319-345.
7. Deese J. On the prediction of occurrence of particular verbal intrusions in immediate recall. J Exp Psychol. 1959;58:17-22.
8. Roediger HL, McDermott KB. Creating false memories: remembering words not presented in lists. J Exp Psychol Learn Mem Cogn. 1995;21:803-814.
9. Roediger HL, Balota DA, Watson JM. Spreading activation and the arousal of false memories. In: Roediger HL, Nairne JS, Neath I, et al, eds. The nature of remembering: essays in honor of Robert G. Crowder. Washington, DC: American Psychological Association Press; 2001:95-115.
10. Gallo DA. False memories and fantastic beliefs: 15 years of the DRM illusion. Mem Cognit. 2010;38:833-848.
11. Hauschildt M, Peters MJ, Jelinek L, et al. Veridical and false memory for scenic material in posttraumatic stress disorder. Conscious Cogn. 2012;21:80-89.
12. Bremner JD, Shobe KK, Kihlstrom JF. False memories in women with self-reported childhood sexual abuse: an empirical study. Psychol Sci. 2000;11:333-337.
13. Brennen T, Dybdahl R, Kapidzić A. Trauma-related and neutral false memories in war-induced posttraumatic stress disorder. Conscious Cogn. 2007;16:877-885.
14. Hayes JP, LaBar KS, McCarthy G, et al. Reduced hippocampal and amygdala activity predicts memory distortions for trauma reminders in combat-related PTSD. J Psychiatr Res. 2011;45:660-669.
15. Jelinek L, Hottenrott B, Randjbar S, et al. Visual false memories in post-traumatic stress disorder (PTSD). J Behav Ther Exp Psychiatry. 2009;40:374-383.
16. Zoellner LA, Foa EB, Brigidi BD, et al. Are trauma victims susceptible to "false memories"? J Abnorm Psychol. 2000;109:517-524.
17. Diagnostic and statistical manual of mental disorders, 4th ed, text rev. Washington, DC: American Psychiatric Association; 2000.
18. North CS, Pollio DE, Smith RP, et al. Trauma exposure and posttraumatic stress disorder among employees of New York City companies affected by the September 11, 2001 attacks on the World Trade Center. Disaster Med Public Health Prep. 2011;(suppl 2):S205-S213.
19. Robins LN, Cottler LB, Compton WM, et al. Diagnostic Interview Schedule for the DSM-IV (DIS-IV). St. Louis, MO: Washington University School of Medicine; 2000.
20. North CS. Assessing the link between disaster exposure and mental illness. In: Cottler LB, ed. Mental health in public health. New York, NY: Oxford University Press; 2011:104-117.
21. Roediger HL 3rd, Watson JM, McDermott KB, et al. Factors that determine false recall: a multiple regression analysis. Psychon Bull Rev. 2001;8:385-407.
22. Breslau N, Reboussin BA, Anthony JC, et al. The structure of posttraumatic stress disorder: latent class analysis in 2 community samples. Arch Gen Psychiatry. 2005;62:1343-1351.
23. Ehlers A, Mayou RA, Bryant B. Psychological predictors of chronic posttraumatic stress disorder after motor vehicle accidents. J Abnorm Psychol. 1998; 107:508-519.
24. Maes M, Delmeire L, Schotte C, et al. Epidemiologic and phenomenological aspects of post-traumatic stress disorder: DSM-III-R diagnosis and diagnostic criteria not validated. Psychiatry Res. 1998;81:179-193.
25. McMillen JC, North CS, Smith EM. What parts of PTSD are normal: intrusion, avoidance, or arousal? Data from the Northridge, California, earthquake. J Trauma Stress. 2000;13:57-75.
26. Norris FH. Epidemiology of trauma: frequency and impact of different potentially traumatic events on different demographic groups. J Consult Clin Psychol. 1992;60:409-418.
27. North CS, Kawasaki A, Spitznagel EL, et al. The course of PTSD, major depression, substance abuse, and somatization after a natural disaster. J Nerv Ment Dis. 2004;192:823-829.
28. North CS, Nixon SJ, Shariat S, et al. Psychiatric disorders among survivors of the Oklahoma City bombing. JAMA. 1999;282:755-762.
29. North CS, Pfefferbaum B, Narayanan P, et al. Comparison of post-disaster psychiatric disorders after terrorist bombings in Nairobi and Oklahoma City. Br J Psychiatry. 2005;186:487-493.
30. Giosan C, Malta L, Jayasinghe N, et al. Relationships between memory inconsistency for traumatic events following 9/11 and PTSD in disaster restoration workers. J Anxiety Disord. 2009;23:557-561.
31. Schwarz ED, Kowalski JM. Malignant memories. Reluctance to utilize mental health services after a disaster. J Nerv Ment Dis. 1992;180:767-772.
32. Hirst W, Phelps EA, Buckner RL, et al. Long-term memory for the terrorist attack of September 11: flashbulb memories, event memories, and the factors that influence their retention. J Exp Psychol Gen. 2009;138:161-176.
33. Rimmele U, Davachi L, Phelps EA. Memory for time and place contributes to enhanced confidence in memories for emotional events. Emotion. 2012;12: 834-846.
34. Hasin DS, Keyes KM, Hatzenbuehler ML, et al. Alcohol consumption and posttraumatic stress after exposure to terrorism: effects of proximity, loss, and psychiatric history. Am J Public Health. 2007;97:2268-2275.
35. North CS. An exploration of causality in the development and timing of disaster-related PTSD. In: Widom CS, ed. Trauma, psychopathology, and violence: causes, correlates, or consequences? New York, NY: Oxford University Press; 2012:219-230.