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Enhanced Priming for Trauma-Related Material in Posttraumatic Stress Disorder

Tanja Michael, Anke Ehlers, and Sarah L. Halligan
University of Oxford

Intrusive reexperiencing in posttraumatic stress disorder (PTSD) has been linked to perceptual priming for trauma-related material. A prospective longitudinal study ($N = 69$) investigated perceptual priming for trauma-related, general threat, and neutral words in assault survivors with and without PTSD, using a new version of the word-stem completion task. Survivors with PTSD showed enhanced priming for trauma-related words. Furthermore, priming for trauma-related words measured soon after the trauma was associated with subsequent PTSD severity at 3, 6, and 9 months. The enhanced priming effect was specific to trauma-related words. Enhanced perceptual priming for traumatic material appears to be one of the cognitive processes operating in PTSD.

Keywords: posttraumatic stress disorder, reexperiencing, implicit memory, information processing, priming

Trauma survivors with posttraumatic stress disorder (PTSD) involuntarily reexperience aspects of the traumatic event (American Psychiatric Association, 1994). Reexperiencing includes the original sensory impressions and emotions that the individual experienced at the time of the trauma. For example, a man who had a head-on car crash at night kept seeing headlights coming toward him. To the trauma survivor, the reexperiencing symptoms appear to come out of the blue (as retrieval is unintentional). However, clinical observations suggest that reexperiencing is triggered by a remarkably wide range of external or internal triggers, including semantic cues, such as TV or newspaper reports about similar events, and stimuli without semantic connection to the trauma that were spatiotemporally linked with the event (Ehlers & Clark, 2000; Ehlers, Hackmann, & Michael, 2004; Southwick et al., 1993).

PTSD researchers have suggested a range of nonintentional or unconscious memory processes as possible explanations for reexperiencing symptoms in PTSD. For example, Brewin, Dalgleish, and Joseph (1996) suggested that intrusive memories are analogical recreations of the trauma, which result from extensive nonconscious processing of the trauma. Cognitive psychology research on implicit memory has influenced models of intrusive memories (e.g., Bower & Sivers, 1998; Siegel, 1995). *Implicit memory* refers to the fact that people's behavior, cognition, and emotions can be influenced by a past experience in the absence of any awareness of remembering. In the laboratory, implicit memory can be measured as a facilitation or change in test performance that is attributable to information or skills acquired during a prior study episode, even though participants are not required to recollect the study episode intentionally or consciously (Schacter, Chiu, & Ochsner, 1993).

Besides their unintentional retrieval, other clinical features of intrusive trauma memories parallel those of implicit memory processes studied in cognitive psychology. When reexperiencing the intrusive sensations and emotions from the trauma, people with PTSD may have no awareness that they are responding to a memory (lack of autonoetic awareness) and may respond as if they were experiencing intrusive sensation at present (Ehlers & Clark, 2000; van der Kolk & Fisler, 1995). Ehlers et al. (2004) described the case of a patient with PTSD who had been attacked by a bull. When the patient saw a license plate with the letters "MOO" at a gas station, she reexperienced the impending attack and sprayed another customer with diesel fuel. At this time she was totally unaware that what she was experiencing involved material from memory. In a less dramatic form, the lack of time perspective also appears to apply to other forms of reexperiencing, including intrusive images such as that of headlights approaching, or distress in response to reminders. Ehlers and Clark (2000) observed that reexperiencing even includes "affect without recollection," that is, individuals with PTSD may reexperience sensations or emotions that were associated with the traumatic event without recollection of the event itself.

As implicit memory does not relate to one unified memory system but rather to a range of memory processes, Ehlers and Clark (2000) specified two aspects of implicit memory that help explain reexperiencing symptoms in PTSD. First, they proposed strong stimulus–stimulus and stimulus–response associations for stimuli that were encountered during the trauma (see also Foa, Steketee, & Rothbaum, 1989; Keane, Zimering, & Caddell, 1985). Second, they proposed that traumatic experiences lead to enhanced perceptual priming for stimuli associated with the traumatic event. They assumed that this strong priming effect contributes to reexperiencing symptoms, as cues that bear similarity with those encountered during the trauma have a processing advantage and can

Tanja Michael, Anke Ehlers, and Sarah L. Halligan, Department of Psychiatry, University of Oxford, Oxford, England.

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Correspondence concerning this article should be addressed to Anke Ehlers, who is now at the Department of Psychology, Institute of Psychiatry, PO77, De Crespigny Park, London SE5 8AF, United Kingdom. E-mail: a.ehlers@iop.kcl.ac.uk

thus trigger unintentional intrusive memories. For example, a patch of bright sunlight on a lawn may trigger involuntary pictures of headlights approaching.

The present studies investigated the hypothesis of enhanced perceptual priming in PTSD with a widely used implicit memory paradigm, word stem completion. The word stem completion task measures priming for words that are processed in an initial encoding phase when participants are unaware that their memory for the words will be tested later. In a subsequent priming task, participants are presented with the initial letters (stems) of the words previously encoded and simply asked to complete them with the first word that comes to their mind. Even though participants are not asked to think back to the encoding phase, the words of the encoding phase seem to pop into their minds to a greater extent than they would without previous exposure. Participants tend to use more words from the encoding phase than people who have not encoded these words previously, thereby expressing implicit memory for these words (Baddeley, 1997; Graf, Squire, & Mandler, 1984). This parallels the involuntary triggering of pictures (e.g., headlights) or other sensory impressions (e.g., sound of a gunfire) from a trauma in PTSD if matching cues are present.

The word stem completion task has been used to study cognitive processes underlying emotional disorders. For example, it was used to test whether generalized anxiety disorder (GAD) is characterized by an implicit memory bias for threat-related information. Some studies have supported this hypothesis (e.g., Eysenck & Byrne, 1994; Mathews, Mogg, May, & Eysenck, 1989), but others have failed to find an implicit memory effect in GAD (Mathews, Mogg, Kentish, & Eysenck, 1995; Mogg, Gardiner, Stavrou, & Golombok, 1992). In PTSD, McNally and Amir (1996) investigated perceptual priming for trauma-related information with a perceptual word identification paradigm. They asked Vietnam combat veterans with and without PTSD to view a series of trauma-related, positive, and neutral words. Subsequently these "old" words and "new" distractor words were presented for 100 ms and immediately replaced by a visual mask, and participants were asked to identify the words. Although McNally and Amir found a general priming effect (i.e., more old than new words were identified), the priming effect was, against expectations, not enhanced for the trauma words in the PTSD group. A subsequent study by Amir, McNally, and Wiegartz (1996) used a white-noise paradigm to investigate priming for trauma-related sentences and found evidence for enhanced priming in Vietnam veterans with PTSD compared to those without PTSD for one out of three noise levels only.

It might be possible that the inconsistent findings in the GAD studies and the negative or inconsistent results in the PTSD studies are due to the fact that experimental words are only a weak approximation of real-life anxiety stimuli. However, the inconsistencies could also be due to methodological problems, that is, the tasks might not be sensitive enough to reveal the effect in all studies. In order to create a more sensitive implicit memory task, we created a new version of the word stem completion task. In this version, the target words are presented in the encoding phase together with matched neutral words that have the same word stem and frequency. Thus, when the word stem is presented later in the test phase, the priming for the target word and the priming for the neutral match word compete with each other. This competition might make the task more sensitive. For example, research into attentional bias for anxiety-related words has shown that attentional bias is only observable when stimuli are processed under competitive conditions (MacLeod & Mathews, 1991; Mathews & Mackintosh, 1998; Mogg, Mathews, Eysenck, & May, 1991).

The present study used the new version of the word stem completion task in a sample of assault survivors in a prospective longitudinal investigation. Participants encoded assault-related words, general threat words, and neutral words, as well as neutral match words for each category in an alleged concentration task. Perceptual priming for these words was tested by presenting word stems that had been primed by both a target and a matched neutral word (e.g., *for*—for *forced* and *formal*). We expected that (a) assault survivors with PTSD would show more priming for assault-related words than would survivors without PTSD and (b) priming for assault-related words would be associated with subsequent PTSD severity.

Method

Participants

The sample comprised 69 assault victims (38 men, 31 women). Participants had experienced either common assault, actual bodily harm, grievous bodily harm, sexual assault, or rape less than 3 months before entering the study. Their ages ranged from 18 to 74 years ($M = 40.36$, $SD = 14.80$). People whose assault occurred before the age of 16, those whose assault occurred in the context of ongoing domestic violence, and those with a history of psychosis or with current substance abuse were excluded from the study. People with poor knowledge of English[1] were also excluded. Recruitment was conducted in collaboration with Victim Support (VS), a United Kingdom–wide charity that receives addresses of all victims of crime from the police and contacts each victim offering help and support. Several local VS offices in South England and Wales agreed to send out information flyers about the study to assault survivors in their database. Unfortunately, time constraints did not allow the VS offices to record the exact number of flyers they sent out. Survivors who were interested in participating contacted the investigators and received more information about the study. People who decided to participate gave written consent and were interviewed at their home or their local VS office. Participants who were seen at the VS office were reimbursed for their travel expenses (which varied from one participant to another, depending on the actual cost incurred). The distribution of study information by the VS offices made it possible to access a wide range of assault survivors but precluded accurate monitoring of the response rate (the overall response rate appeared low)

[1] Three people were excluded from the study because of insufficient knowledge of English. This was indexed by not being able to think of a possible word completion for four or more of the word stems presented in the priming task. This relatively strict criterion was necessary in order to obtain valid results. The priming task relies on the spontaneous response to the word stems and thus requires language fluency. The participants were asked to reply spontaneously and quickly and to continue with the next trial if no word popped into their mind. People who were fluent in English gave fast answers, even though there was no formal time limit, and gave an answer to nearly all the word stems. The incapability to produce a response to more than a few word stems indicates low fluency in English and thus required exclusion.

and did not allow us to establish the representativeness of our sample.

Participants with and without PTSD were compared on several measures that may affect word stem completion rates (see Table 1). Participants with and without PTSD at initial assessment did not differ in sex, $\chi^2(N = 69) = 0.116$, $p = .734$; age, $t(67) = 0.469$, $p = .641$; or ethnic origin, Fisher's exact test ($N = 69$) $p = .359$. The no-PTSD group had higher educational attainment than the PTSD group, $\chi^2(N = 64) = 8.195$, $p = .042$. The groups did not differ in alcohol use, U ($N = 69$) $= 536.00$, $p = .775$, or recreational drug use, Fisher's exact test $= 1.0$. There was no difference between the groups with respect to assault severity, $t(67) = 0.927$, $p = .357$. There was a trend for the assaults of the PTSD group to have occurred somewhat longer ago than those of the no-PTSD group, $t(67) = 1.808$, $p = .075$. This trend should not compromise the validity of group differences on the word stem task because the priming effect for trauma-related material would be expected to decrease with time and, thus, decrease the expected group difference rather than enhance it. There was no difference between the groups in type of assault, Fisher's exact test ($N = 69$), $p = .139$. As expected, the PTSD group reported more severe PTSD symptoms, $t(67) = 11.207$, $p < .001$; depressive symptoms, $t(32.929) = 7.070$, $p < .001$; and trait anxiety, $t(62) = 6.409$, $p < .001$. Sixty-one participants took part in a 3-month follow-up, 67 in a 6-month follow-up, and 60 in a 9-month follow-up.

Table 1
Participants and Assault Characteristics

Variable	*PTSD* ($N = 26$)	*No PTSD* ($N = 43$)
Sex		
Female	11	20
Male	15	23
Age (mean)	39.7	41.5
Ethnic origin (%)		
Caucasian	88	95
Non-Caucasian	12	5
Education (%)		
No exams	13	10
GCSE-O levels	42	20
A levels	38	30
Degree or above	8	40
Alcohol units per week		
M	14.8	10.9
Mdn	8.5	6.0
Recreational drug use (%)		
No current drug use	81	81
Current drug use	19	19
Type of assault (%)		
Physical	92	100
Sexual	8	0
Time since assault (mean, weeks)	8.7	7.4
Severity of assault		
M	5.0	4.7
PDS score (PTSD severity)	29.8	9.8
BDI score (depression)	17.2	5.4
STAI score (trait anxiety)	55.9	38.7

Note. PTSD = posttraumatic stress disorder; GCSE-O levels = General Certificate of Secondary Education-Ordinary levels; A levels = qualification for university entrance; PDS = Posttraumatic Stress Diagnostic Scale; BDI = Beck Depression Inventory; STAI = State–Trait Anxiety Inventory.

Measures

Posttraumatic Stress Diagnostic Scale (PDS)

PTSD symptoms were assessed with the PDS (Foa, Cashman, Jaycox, & Perry, 1997). The PDS asks participants to rate how much they were bothered by each of the PTSD symptoms specified in the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., *DSM–IV*; American Psychiatric Association, 1994), ranging from 0 (*never*) to 3 (*5 times per week or more/nearly always*). Participants answered the questions with respect to the assault with which the study was concerned. The PDS yields a sum score measuring the overall severity of PTSD symptoms. In addition, the presence–absence of PTSD was determined by assessing whether a participant endorsed the minimum number of symptoms (with at least "1") required by *DSM–IV*. Several studies have supported the reliability and validity of the scale (Foa et al., 1997). The PDS shows good agreement with the Structured Clinical Interview for *DSM–IV* (Foa et al., 1997). In order to ensure that the PTSD group were experiencing at least moderate symptom severity, a minimum symptom score of 11 was required for a diagnosis. (The actual minimum score in the PTSD group was 13.) The manual for the PDS states that 11 is the lower boundary for moderate PTSD symptom severity (Foa, 1995). In addition, symptoms were required to be in line with PDS scoring criteria, that is, to cause at least two specific problems in functioning (e.g., work) or to affect the overall level of functioning in all areas of life.

Participants who were interviewed within the 1st month post-assault received a positive diagnosis if they met all diagnostic criteria except E, which requires that the duration of disturbance be more than 1 month.[2] Participants completed the follow-up PDS at 3, 6, and 9 months after the first interview. Twenty-six participants (38%) were classified as having PTSD at the initial interview.

General Information Questionnaire and Semistructured Interview

A questionnaire assessed demographic characteristics. A semi-structured interview, similar to the one used by Dunmore, Clark, and Ehlers (1999, 2001) assessed the nature and severity of the assault as well as psychiatric history and current psychiatric status. Severity of the assaults was computed as a composite measure by combining the participants' scores on each of the following measures of severity: number of assailants, duration of assault, use of verbal threat, extent of resultant injuries, and weapon use (Dunmore et al., 1999, 2001).

Word Stem Completion Test

Word lists. Three groups of 12 target words were chosen for the word stem completion test: assault-related words (e.g., *victim*, *tortured*, *battered*), general threat words (e.g., *cancer*, *rejection*, *debts*), and neutral words (e.g., *wheat*, *connection*, *introduction*). For each of these target words, a (neutral) match word existed with

[2] Nine of the participants (13%) were interviewed before 1 month had elapsed so that the duration criterion for a *DSM–IV* diagnosis of PTSD could not be established. If these participants were excluded, the group difference in priming for assault-related words remained significant, $t(58) = 2.292$, $p = .026$.

the same frequency and the same initial letters as the target word (the first two letters were the same for words with four letters, and the first three letters were the same for words with more than four letters). The word list was generated in a series of steps: A number of experts (therapists working with anxiety disorder patients, including PTSD, specialists in information processing and anxiety) generated a pool of words relevant to assault and PTSD and a pool of general threat words. We then checked how frequently the words are used in verbal language as derived from the London–Lund corpus of English conversations (see Brown, 1984, for a complete description of this measure). Second, we checked whether a match word existed that had the same stem and the same frequency and whether at least one other word existed that had the same stem but a higher frequency. Experts rated the assault-related and general threat words (and their match words, which had to be neutral) according to how well each represented the categories (trauma words relevant for assault survivors, general threat words). The words with the highest ranks were chosen for the study and divided into two parallel sets (matched for frequency across word categories and set). Each participant was presented with one of the sets (either Set 1 or Set 2) during the encoding phase and with the stems for both sets during the test phase. This procedure made it possible to measure whether the words that were previously encoded had a higher completion rate than the words that were not encoded. Finally, the neutral target word group was generated. We presented the experts with a pool of neutral target and match words. Words that were not perceived by the experts as neutral were removed from the pool. The final selection of the words guaranteed that we had a neutral target word group that was matched in word frequency to the assault and general threat word groups and that could be divided in two parallel sets.

The final word list is presented in the Appendix. An analysis of variance (ANOVA) confirmed that no statistical differences in word frequencies existed between the different word categories (assault related, general threat, neutral), the different word types (target words, match words), and the sets within the categories. All effects were far from significant: word category, $F(2, 9) = 0.412$, $p = .674$; word type, $F(1, 10) = 1.176$, $p = .304$; set, $F(1, 10) = 0.466$, $p = .511$; Word Category $\times$ Set, $F(2, 9) = 0.448$, $p = .652$; Word Type $\times$ Set, $F(1, 10) = 1.178$, $p = .304$; Word Category $\times$ Word Type, $F(2, 9) = 0.187$, $p = .833$; and Word Category $\times$ Word Type $\times$ Set, $F(2, 9) = 0.596$, $p = .571$.

As a test of the suitability of the chosen words for the encoding phase of the paradigm (which required reading the words out loud), a pilot study ($N = 21$) investigated how easy it was to pronounce them. Participants in this pilot study were required to read out the words as soon as they appeared on a computer screen. The next trial was started automatically in response to the voice. It was therefore possible to compare the times people needed to start pronouncing the words. The dependent variable (reaction time) was measured under the influence of word category (assault related, general threat, neutral), set (Set 1, Set 2) and word type (target words, match words). A repeated measures ANOVA showed that none of the three factors had an influence on reaction time. There were no interactions of the factors with each other.

Encoding task. During the encoding task, half the participants processed Set 1 of each word category (target words and match words) and the other half of participants processed Set 2 of each category. Participants were not told to memorize the words. Instead, they were told that they were completing a "concentration task," which purportedly examined whether the assault had a negative effect on concentration. The words were presented for 10 s in a successive order on a portable 12.1 in. (30.7-cm) computer screen and then flashed away automatically. The order of word presentation followed a variable randomization procedure, that is, it was different for each participant. After the word disappeared, a yellow or red dot appeared either below or above the location where the word had been. The participants were instructed to read the words aloud as soon as they appeared and to vigilantly watch the screen until the dot appeared, as they needed to react as quickly and accurately as possible toward the dot by pressing either a yellow or red marked button on the keyboard. The next word appeared automatically on the screen after the participants had responded to the dot. After the encoding task, there was a 20-min interval during which participants performed an unrelated task.

Priming task. Participants were presented with the word stems of all words from the word list (both sets) and asked to complete them with the first word that came into their minds. No reference to the encoding ("concentration") task was made. The word stems were presented in successive order on the screen of the portable computer; the order of word stem presentation was determined by a variable randomization procedure. The word stems appeared in the same position, letter size, and color on the screen as the words of the encoding task. The participants told the investigator the words that came spontaneously into their minds, and the investigator wrote the answers down. The participants started the next trial by pressing the space bar.

Additional material. Five practice words were used at the beginning of the encoding task (*association*, *phoned*, *loudly*, *able*, *habitual*) to accustom the participants to the use of the computer. To prevent a primacy effect, we presented four buffer words (*principled*, *recruited*, *resurrection*, *temperature*) before the experimental words. To prevent a recency effect, we presented a further four buffer words (*brigade*, *cabinet*, *liberal*, *mountain*) after the experimental words. The practice and buffer words were neutral and had different word stems than the experimental words. The word stems of the practice words were used as practice trials in the priming task, and the word stems of the buffer words were presented before and after the experimental word stems. The word stem completion test was not repeated at the follow-ups.

Free-Recall Task

After the priming task, participants were asked to write down as many words as they could remember from the "concentration task" (encoding task). They were told that this was to investigate whether a possible negative effect of the assault on concentration would also lead to memory problems. The inclusion of the free-recall task allowed us to compare explicit (free recall) and implicit memory (word stem completions) for the words and to check whether there was dissociation between the two tests.

Further Measures

Participants completed a number of other questionnaires, including the Beck Depression Inventory (BDI; Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) and the State–Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), and interview questions, and they gave a narrative account of the

trauma. The results are presented elsewhere (Halligan, Michael, Clark, & Ehlers, 2003). It is highly unlikely that the other tasks influenced the results of the present study because of low similarity of the tasks and a clear separation between investigation phases. Patients had a 15-min break before doing the encoding part of the word stem completion test.

Procedure

Participants completed the BDI in the week prior to the interview. The PDS and STAI measures were completed during the interview session. Participants were greeted by the experimenter and signed an informed consent form. They were then asked to complete the PDS and some questionnaires about their cognitive processing during the trauma (results reported in Halligan et al., 2003). They then gave a narrative of their assault, and described the nature of their intrusive memories. After a 15-min break, the encoding task was administered. The priming task and free-recall task followed after a 20-min time period, during which the interviewer asked participants about the ruminative thoughts the participant may have had and other consequences of the assault.[3] Participants filled in the PDS again 3, 6, and 9 months after the initial assessment.

Data Analysis

Scoring of Word Stem Completions

In the primed condition (words seen in the encoding phase), words were scored as correct if they corresponded exactly to one of the previously encoded target words. The primed score expresses the proportion of completed target words, that is, the number of completed words that were the same as those seen during encoding, divided by the number of word stems that could have been completed with target words.[4] In the unprimed condition (no previous exposure to words), scoring depended on an exact match between a participant's completion choice and the corresponding word from the word set that was not encoded by that participant. Thus, the unprimed score represents a baseline level of completion rate found in the absence of previous exposure to the words.

The task was also analyzed using a lax scoring criterion; that is, words that were closely related to the target words (e.g., *torture* instead of *tortured*) were scored as correct. This analysis yielded analogous results to the analysis using the exact scoring criterion and is, for reasons of brevity, not reported.

Priming Index

In order to gain a measure of priming that takes into account the baseline completion rate, the completion probabilities for the unprimed words were subtracted from the completion probabilities for the primed words. This difference score between primed and unprimed words was the main dependent variable and is referred to in subsequent text as *priming*.

Statistical Analysis

Differences in priming between the groups were tested using the SPSS-10 General Linear Modeling (GLM) procedure, with word category (assault-related, general threat, neutral) as the within-subject variable and diagnostic group (PTSD, no PTSD) as the between-subject variable. Greenhouse–Geisser coefficients were used for significance testing. We expected priming for assault-related words to be higher for participants with PTSD than for participants without PTSD. No difference in priming between the groups was expected for neutral and general threat words. This pattern of results should show up in a significant interaction between diagnostic group and word category, and a significant group difference for assault-related words only.

We further examined associations between priming and PTSD severity using Pearson's product–moment correlation coefficient (scatter plots confirmed the assumption of a linear relationship between these variables). Significance levels for correlations are two-tailed with the exception of the correlation between priming for assault-related words and PTSD symptoms for which we had a directional hypothesis.

Analysis of Free-Recall Test

Accuracy of free recall was measured as the proportion of correctly recalled words, that is, the number of correctly recalled words divided by the number of words that were presented during the encoding phase. The data were positively skewed and logarithmically transformed for statistical analysis.[5] The GLM analysis compared the performance of the two diagnostic groups (the between-subjects factor) in the three word categories (the within-subject factor). We predicted that there would be a dissociation between the results of the priming and those of the free-recall tests (e.g., Jacoby, Toth, & Yonelinas, 1993; Mitchell & Brown, 1988) and did not expect group effects or interactions for the free-recall test.

Results

Priming Task

Group Differences

The results are shown in Table 2. As expected, there was a significant Word Category × Diagnostic Group interaction, $F(1.669, 111.819) = 5.124$, $p = .011$. The subsequent planned

[3] Twenty-eight of the participants did not report ruminative thoughts, and in these cases, the interviewer engaged them in a conversation of the same duration relating to the consequences of their assault. The topic of conversation did not influence the results of the word stem completion test. A GLM analysis, with word category as a within-subjects factor and topic of conversation (rumination vs. other consequences of assault) as a between-subjects factor, showed no main effect for topic of conversation, $F(1, 67) = 0.526$, $p = .471$, and, most important, no interaction between word category and topic, $F(2, 108) = 0.158$, $p = .854$.

[4] The degree of priming for the match words was not pertinent to predictions and was therefore not analyzed. Including the match words in the analysis would have only been important if we had used a forced-choice task. In the present version of the word stem completion task, the participants had many possible response alternatives, some of which had higher word frequencies than the match and target words. For example, even if the words *forced* and *formal* are both primed through earlier presentation, the stem could still be completed with words like *forecast*, *foreign*, or *ford*.

[5] Analysis of the raw data gave the same results.

Table 2
Word Stem Completion Scores and Priming Index for Participants With and Without PTSD

	PTSD		no PTSD	
Word type	*M*	*SD*	*M*	*SD*
Primed words				
Assault related	.32	.40	.12	.20
General anxiety	.13	.16	.14	.17
Neutral	.05	.08	.11	.13
Unprimed words				
Assault related	.11	.14	.08	.11
General threat	.09	.10	.09	.12
Neutral	.04	.09	.04	.08
Priming index (primed minus unprimed words)				
Assault related	.21	.39	.04	.22
General threat	.05	.14	.05	.18
Neutral	.01	.12	.07	.14

Note. PTSD = posttraumatic stress disorder.

comparisons confirmed that the PTSD group showed greater priming for assault-related words than the no-PTSD group, $t(67) = 2.26$, $p = .027$, but did not differ from the no-PTSD group in the completion rates for primed general threat words, $t(67) = 0.022$, $p = .983$. The PTSD group showed an unexpected trend for lower priming for neutral words, $t(67) = 1.927$, $p = .058$.

Association Between Priming and PTSD Severity

The Pearson correlation between priming for assault-related words and concurrent PTSD severity at initial assessment was .357 ($p = .002$), and the Pearson correlation with subsequent PTSD severity was .413 ($p < .001$), .258 ($p = .018$), and .264 ($p = .021$) for the 3-, 6- and 9-month follow-ups, respectively. The relationship between priming for assault-related words and PTSD symptoms was not because of differences in education level, as indicated by partial correlations with PTSD severity at all time points controlling for level of education ($pr = .293$, $p = .010$; $pr = .304$, $p = .011$; $pr = .221$, $p = .044$; and $pr = .268$, $p = .025$ for initial assessment and 3-month, 6-month, and 9-month follow-ups, respectively). To test whether priming for assault-related words predicted PTSD severity at the follow-ups over and above initial PTSD severity, we calculated partial correlations. These were not significant (all ps $> .12$). However, priming for assault-related words tended to predict flashbacks at the 3-month follow-up (but not at the 6- or 9-month follow-ups) over and above what could be predicted from flashbacks at initial assessment ($pr = .23$, $p = .037$).

Priming for *general threat words* was not associated with PTSD severity at initial interview ($r = -.038$, $p = .759$), 3-month follow-up ($r = -.051$, $p = .698$), 6-month follow-up ($r = -.076$, $p = .541$), or 9-month follow-up ($r = -.090$, $p = .493$). Priming for neutral words was not significantly correlated with PTSD severity at initial assessment ($r = -.229$, $p = .058$), 6-month follow-up ($r = -.150$, $p = .227$), and 9-month follow-up ($r = -.076$, $p = .562$). However, there was a significant negative correlation between priming for neutral words and PTSD at the 3-month follow-up ($r = -.286$, $p = .026$). This correlation was no longer significant when level of education was controlled for in a partial correlation analysis ($pr = -.101$, $p = .451$). Priming for neutral words correlated with level of education ($r = .37$, $p = .003$).

Free-Recall Task

The results of the free-recall test are shown in Table 3. As expected, there was no interaction between word category and diagnostic group, $F(1.970, 132.019) = 0.453$, $p = .634$.

Discussion

In line with the clinical observation that people with PTSD show intrusions of trauma-related material when matching cues are present, assault survivors with PTSD showed more priming for assault-related words in a word stem completion test than did traumatized individuals without PTSD. This effect was specific to assault-related words and did not apply to general threat words. For neutral words, there was even a trend in the opposite direction. The explanation for the latter unexpected trend remains unclear. It is possible that the lower educational attainment in the PTSD group played a role. Priming for neutral words correlated positively with education levels, and the correlation between priming for neutral words and PTSD severity at 3 months ceased to be significant when education was partialed out. The lower educational attainment in the PTSD group may reflect the relationship of low intelligence and PTSD observed in previous studies (McNally & Shin, 1995). Of importance, differences in education did not account for greater priming for trauma-related material, as the association between priming for assault-related words and PTSD severity remained significant when level of education was partialed out.

There has been a debate in the literature on the influence of explicit memory on the performance in implicit memory tasks such as the word stem completion test (e.g., Jacoby et al., 1993; Tulving, Schacter, & Stark, 1982). The present study was not designed to address this issue, so we cannot conclude with certainty that a pure implicit memory effect was observed. However, the pattern of findings makes it unlikely that the enhanced priming effect for assault-related words during word stem completion stemmed from the intentional search for words seen in the encoding phase and the use of explicit knowledge: Participants recalled very few words, and there were no group differences in the free-recall test. Further investigations are necessary before final conclusions are drawn, as the order of the priming test and the free-recall test was fixed and the results of the free-recall test suggested a floor effect. Given these limitations, the present results should not be interpreted as showing that there is no explicit memory bias in PTSD, especially

Table 3
Free-Recall Scores for Participants With and Without PTSD

	PTSD		no PTSD	
Word category	*M*	*SD*	*M*	*SD*
Assault related	.02	.05	.04	.09
General threat	.01	.03	.02	.07
Neutral	.02	.05	.02	.05

Note. PTSD = posttraumatic stress disorder.

as some recent studies suggests that such a bias may exist (Buckley, Blanchard, & Neill, 2000; Moradi, Taghavi, Neshat-Doost, Yule, & Dalgleish, 2000).

The results of the study have methodological, theoretical, and possibly some practical implications. First, a methodological aspect of the study was that the introduction of competitive conditions into a word stem completion task led to successful demonstration of an implicit memory bias in PTSD. Previous attempts to measure implicit memory bias in PTSD that did not take this dimension into account have either shown negative or only partially positive findings (Amir et al., 1996; McNally & Amir, 1996). The present version of the word stem completion task created competitive conditions by presenting words that matched the word stems of the target words during the encoding phase, which might have enhanced the sensitivity of the task. The present findings may have wider methodological implications for other studies of memory bias in anxiety disorders, a field characterized by inconsistent findings. It is possible that the introduction of competitive conditions will lead to clearer results, parallel to the research on selective attention to threat in anxiety disorders (e.g., MacLeod & Mathews, 1991; Mathews & Mackintosh, 1998). This hypothesis will have to be tested in further research comparing word stem completion tests with and without competitive conditions.

Second, the bias in perceptual priming for trauma-related material found in the present study supports the suggestion of trauma theorists that memory processes play an important role in PTSD (e.g., Brewin et al., 1996; Foa et al., 1989; McNally, 1998). The hypothesis of enhanced perceptual priming (Ehlers & Clark, 2000) implies that stimuli present during the trauma, regardless of whether they have a meaningful relationship to the trauma or not, have a relative processing advantage when encountered again and can therefore trigger reexperiencing symptoms. Given the nature of perceptual priming, even very short exposure to these stimuli, or degraded perceptual cues (e.g., vaguely similar stimulus configurations), may trigger intrusive memories.

The present study is only an indirect test of the perceptual priming hypothesis of reexperiencing symptoms because it tested priming for words representing the traumatic situation, rather than priming for the original stimuli present at the time (which would be very difficult for practical and ethical reasons). The study suggests that symbolic stimuli that represent the traumatic experience show enhanced priming in individuals with PTSD, that is, they are more likely than other stimuli to pop into the individual's mind when matching triggers are present. This is probably because symbolic stimuli such as words representing the traumatic experience are associated with the event in memory and are thus assigned similar processing priority. The case example of the patient who responded to seeing "MOO" on a license plate with a flashback to being attacked by a bull is in line with this interpretation.

Approximations of a direct test of perceptual priming for stimuli that occur in a traumatic situation are analog studies that expose healthy nontraumatized volunteers to unpleasant material. Such studies have the advantage that the experimenter has full control over the stimulus material. Analog studies from our laboratory have shown that stimuli occurring in a traumatic context were indeed more strongly primed than stimuli occurring in a neutral context. This enhanced priming effect predicted the occurrence of PTSD-like intrusions (Michael & Ehlers, 2004). Thus, there is converging evidence pointing to perceptual priming as one mechanism underlying intrusions in PTSD.

In the present study, priming for assault-related material measured soon after the assault not only was related to concurrent PTSD severity but also predicted subsequent PTSD severity 3, 6, and 9 months later, thereby underlining its theoretical importance in explaining PTSD. However, priming is unlikely to be of practical relevance when predicting persistent PTSD, as it did not predict over and above what could be predicted from initial PTSD severity. The pattern of findings is, nevertheless, consistent with Ehlers and Clark's (2000) model of PTSD that distinguishes between factors explaining the onset and those explaining the maintenance of PTSD symptoms. Perceptual priming is one of three memory mechanisms proposed to lead to the onset of reexperiencing symptoms (see also Ehlers et al., 2004). Maintenance factors are hypothesized to predict PTSD severity at later time points over and above what can be explained from initial PTSD severity. This hypothesis has been supported for several maintenance factors specified in the model (e.g., negative appraisal of initial symptoms, perceived negative responses from others, and dysfunctional cognitive strategies and behaviors such as rumination; Dunmore et al., 2001; Ehlers et al., 1998; Halligan et al., 2003).

In contrast, factors explaining the onset of PTSD symptoms may or may not predict subsequent symptom severity independently of initial severity. In the extreme case that a variable fully explained the onset of initial PTSD symptoms (i.e., showed a correlation of 1.00), partial correlations of the variable with PTSD severity at later time points will be zero if initial PTSD severity is partialed out. The present findings suggest that perceptual priming is related to the onset of PTSD symptoms but may not have direct and separate effects on PTSD severity at follow-up. Nevertheless, it was of theoretical interest that priming at initial assessment predicted flashbacks 3 months later over and above what could be predicted from the frequency of initial flashbacks, as flashbacklike intrusive memories are the PTSD symptom that perceptual priming is specifically meant to help explain (Ehlers & Clark, 2000).

The demonstration of enhanced priming for trauma-related material may also have some practical implications. The implicit memory bias for trauma-related material found in the present study may help in normalizing reexperiencing symptoms in that it offers an explanation of why intrusive trauma memories in PTSD occur. Providing a plausible explanation of intrusions may help in correcting dysfunctional interpretations that contribute to the maintenance of PTSD. For example, Ehlers and Steil (1995) observed that PTSD patients frequently interpret them as a sign of madness or brain injury. Prospective studies with survivors of assault or motor vehicle accidents (Dunmore et al., 2001; Ehlers et al., 1998) have confirmed that such negative appraisals of intrusive memories predict the course of PTSD. Normalization may include explanations that the processing of information under high levels of stress differs from the processing of everyday material. Material associated with a trauma will have a strong implicit memory representation, which is a standard memory function and nothing abnormal. Intrusive memories are caused, at least in part, when environmental triggers activate these implicit representations. The implicit nature of the memory process elucidates why intrusions seem to be coming out of the blue.

The study presented in this article had several strengths and limitations. Among the strength is the use of a traumatized control group. This makes it unlikely that the smaller priming effects for

assault-related words in the no-PTSD group is due to the lower relevance of the material to the participant. Further strengths include the relatively large sample size and the prospective longitudinal design.

A limitation was that the number of words representing each word category was modest, as experimental and match words had to be presented in the encoding phase, and the overall length of the test had to be manageable. The disadvantage was that the overall number of correct answers in both the word stem test and the free-recall test was small. It would be desirable to use an extended word list in future studies. However, the test proved to be sensitive enough to demonstrate the expected group difference, supporting the validity of the findings. Furthermore, although the neutral words were matched to the other words categories for frequency on the frequency count of the London–Lund corpus of English conversation (Brown, 1984), they might have been somewhat less commonly used by our particular sample than words from the other categories, as indicated by somewhat lower priming for neutral words in comparison with the other word categories. This speculation would be compatible with the association of educational attainment and priming for neutral words. However, these limitations would not explain the pattern of results observed in the study.

A second limitation is that the study used words representing the traumatic experience rather than stimuli from the traumatic situation itself as stimulus material. It would be desirable to develop paradigms that allow a direct test of the perceptual priming hypothesis with traumatized people.

A third limitation is that the word stem completion task was conducted as part of a longer session. This raises the issue of whether the previous interviews could have influenced the results. Although we acknowledge that this cannot be ruled out, we think that it is unlikely that the particular pattern of results was due to the previous interviews. All participants had experienced an assault, and assault severity did not explain the pattern of results (there was no group difference in severity). Furthermore, one would not expect the participants' response to the interviews to affect primed and unprimed assault-related word stems differently, and there was no indication of group differences in the completion rates for nonprimed assault-related word stems. However, it would be desirable to replicate the present results in a neutral experimental context.

A fourth limitation is that the representativeness of the sample is unclear. The recruitment through local VS offices ensured that a wide range of assault survivors could be approached, but it did not allow the recording of response rates or comparisons of responders and nonresponders. However, the assault characteristics are comparable to those of other samples, making it unlikely that any particular variable affecting participation led to the particular pattern of results. Nevertheless, it remains to be tested whether the present results generalize to other populations of trauma survivors.

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(*Appendix follows*)

Appendix

Word List for the Word Stem Completion Task

Word type	Target word	Match word
Assault words		
Set 1	*Fear*	*Festival*
	Victim	*Vicar*
	Tortured	*Torrent*
	Forced	*Formal*
	Humiliated	*Humanity*
	Terrified	*Terrain*
Set 2	*Battered*	*Bathed*
	Crushed	*Crust*
	Pain	*Pack*
	Weapon	*Weasel*
	Trapped	*Trading*
	Helpless	*Helmet*
General threat words		
Set 1	*Bomb*	*Bowl*
	Tumour	*Tumble*
	Infection	*Infinite*
	Cheated	*Cheapen*
	Failure	*Faith*
	Drowning	*Drowsy*
Set 2	*Debts*	*Debate*
	Mortuary	*Mortgage*
	Rejection	*Rejuvenate*
	Cancer	*Canal*
	Stroke	*Stripe*
	Widowed	*Widen*
Neutral words		
Set 1	*Invigorated*	*Invalidated*
	Matriculated	*Materialistic*
	Pertinent	*Personnel*
	Connection	*Conference*
	Compile	*Commentate*
	Wheat	*Wheel*
Set 2	*Introduction*	*Interval*
	Correlation	*Corresponding*
	Proposal	*Properly*
	Variance	*Varsity*
	Diminish	*Diminutive*
	Locomotive	*Localisation*

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