

Enhanced Priming for Trauma-Related Words Predicts Posttraumatic Stress Disorder

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There is preliminary evidence that enhanced priming for trauma-related cues plays a role in posttraumatic stress disorder (PTSD). A prospective study of 119 motor vehicle accident survivors investigated whether priming for trauma-related stimuli predicts PTSD. Participants completed a modified word-stem completion test comprising accident-related, traffic-related, general threat, and neutral words at 2 weeks post-trauma. Priming for accident-related words predicted PTSD at 6 months follow-up, even when initial symptom levels of PTSD and depression and priming for other words were controlled. The results are in line with the hypothesis that enhanced priming for traumatic material contributes to the development of chronic PTSD.

Keywords: priming, implicit memory, information processing, PTSD, trauma

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Even though many trauma survivors show symptoms of post-traumatic stress disorder (PTSD) in the first months after trauma, many recover spontaneously (McFarlane, 2000), and others show a delayed onset of PTSD symptoms (Andrews, Brewin, Philpott, & Stewart, 2007). This indicates that very early symptoms may not differentiate well between normal adaptation and psychopathology. There is evidence that self-reported symptoms lead to an overestimation of PTSD risk (e.g., Engelhard et al., 2007). This raises the question of whether early assessment of mechanisms of psychopathology may help increase the accuracy of the prediction of chronic PTSD.

One potential mechanism of interest is priming. Priming is a type of implicit memory that is characterized by the facilitated identification of perceptual objects as the result of a prior encounter with these items (Schacter, 1992). Priming may influence the development of PTSD in two ways. First, people may vary in the degree to which stimuli that are present *during* trauma are primed. Heightened perceptual priming for stimuli encountered during trauma may increase the risk that PTSD develops, as priming results in a lowered perceptual threshold and a processing advantage for similar stimuli, with the consequence that such stimuli are

more likely to be noticed than other stimuli in the environment and trigger trauma memories through unintentional, cue-driven memory retrieval (Ehlers & Clark, 2000). This hypothesis has received some support in experimental analogue studies that showed greater perceptual priming for neutral visual stimuli that were embedded in traumatic picture stories compared with neutral stimuli embedded in neutral stories. The degree of priming for stimuli presented in a traumatic context predicted the number of intrusive memories participants reported in the following weeks (e.g., Arntz, de Groot, & Kindt, 2005; Ehlers, Michael, Chen, Payne, & Shan, 2006; Michael & Ehlers, 2007).

Second, *post-trauma* priming of trauma-related cues may be involved in the development of chronic PTSD. Some trauma survivors may show greater priming for trauma-related cues they encounter in the aftermath of traumas than do other survivors. The enhanced priming would lead to processing advantages for these stimuli and thus extend the range of trauma-related cues that are preferentially processed and may serve as generalized potential triggers for PTSD-related symptoms, such as intrusive memories, negative affect, or rumination about the trauma. Clinical observations have highlighted the broad range of cues that trigger trauma memories in chronic PTSD (e.g., Ehlers & Clark, 2000). There is some evidence for enhanced posttrauma priming of trauma-related stimuli (abbreviated as PT-PTS in the following) in PTSD. In several cross-sectional studies using a range of different paradigms (e.g., word-stem completion test; perceptual word identification paradigm; white noise paradigm; visual clarity rating task), trauma survivors with PTSD showed greater PT-PTS compared with priming for neutral stimuli, whereas trauma survivors without PTSD did not show differential priming (Amir, Leiner, & Bomyea, 2010; Amir, McNally, & Wiegartz, 1996; Michael, Ehlers, & Halligan, 2005). However, results from other studies did not find enhanced PT-PTS in PTSD (Golier, Yehuda, Lupien, & Harvey, 2003; McNally & Amir, 1996; Paunovi, Lundh, & Öst, 2002).

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The inconsistency of results may in part be due to differences in the sensitivity of the paradigms used to assess priming.

In the only prospective study of the role of PT-PTS in PTSD to date, Michael et al. (2005) used a word-stem completion task designed to increase task sensitivity and found that assault survivors who had PTSD at 8 weeks posttrauma showed greater priming for assault words, but not for general threat or neutral words, than did those without PTSD. Priming for assault words also predicted PTSD symptom severity 6 months later. The new version of the task presented target words in the encoding phase as well as matched neutral words with the same word-stem and frequency. Target and matched neutral words are thought to compete for processing resources in the subsequent test phase, which may make the task more sensitive to differences in cognitive processing.

Even though Michael et al.'s (2005) study used a prospective design, the results are not fully conclusive about the role of PT-PTS in the development of chronic PTSD, as the first assessment took place when participants had already developed the disorder. Thus, this study could not rule out the alternative hypothesis that PT-PTS may be an epiphenomenon of having PTSD, rather than a process involved in its development. Second, Michael et al.'s study tested assault survivors, and it remains unclear whether the results generalize to other trauma. The present study was designed to investigate the relationship between PT-PTS at 2 weeks posttrauma and the development of PTSD in motor vehicle accident survivors, using an adapted version of Michael et al.'s paradigm. On the basis of the earlier findings, we expected that priming for accident-related words, but not for traffic-related, general threat, and neutral words, would predict PTSD assessed at follow-up (Hypothesis 1). In addition, the study aimed to investigate whether PT-PTS may be useful in the early identification of trauma survivors at risk of chronic PTSD. This idea was tested in two ways. First, given that early symptom reports have been found to overestimate PTSD risk, we expected that priming for accident-related words at 2 weeks still predicts chronic PTSD at 6 months when early symptoms are controlled (Hypothesis 2). Second, we expected that among a high-risk group of trauma survivors, operationalized as initially meeting *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., *DSM-IV*; American Psychiatric Association, 1994) symptom criteria for acute stress disorder or PTSD, priming for accident-related words still predicts chronic PTSD (Hypothesis 3).

Method

Participants

Participants were drawn from a sample of 147 motor vehicle accident survivors who were treated for their injuries at the emergency department of a metropolitan hospital. The current article reports on 119 participants who completed the word-stem completion test and had complete data on all measures included in the current analyses (67.2% male, 32.8% female; M age = 35.56 years, SD = 9.92). Forty-three participants (36.1%) were defined as a high-risk group, as they met *DSM-IV* symptom criteria for PTSD (Clusters B, C, and D) at 2 weeks, including 17 participants (14.3%) who additionally met diagnostic criteria for acute stress disorder (ASD). Sixteen participants (13.4%) met diagnostic cri-

teria for PTSD at 6 months follow-up. The mean injury severity score in the sample was 2.15 (SD = 2.45, min = 0, max = 13). Detailed information about the sample and the recruitment is given elsewhere (Ehring, Ehlers, & Glucksman, 2008). Most participants (78.2%) had experienced other potentially traumatizing events in the past, and 46.2% had experienced an earlier accident. However, only three participants had PTSD related to these earlier events. Excluding these participants from the analyses did not change the results.

Word-Stem Completion Test

Word lists. Lists of words from four categories were generated: accident-related (e.g., crash, horror), traffic-related (e.g., gear, motorway), general threat (e.g., tumor, torture), and neutral words (e.g., teapot, curtains). To control for word-categorization effects, neutral words were all related to the category "household." The word list was generated as follows: First, 13 therapists and researchers specializing in PTSD generated accident- and traffic-related words whose Brown verbal frequency was determined from the MRC Psycholinguistic Database.¹ In addition, the words had to meet the following two conditions: (a) There was a neutral word with the same word stem and the same verbal frequency (to be used as the matched word in the encoding phase), and (b) there was another neutral word with the same word stem and a higher frequency. All words meeting these criteria were rated by the same 13 experts on separate 9-point Likert-type scales as to how well they represented (a) the category of accident-related words and (b) the category of traffic-related words. The words with the highest ranks and unique word stems were chosen. Then general threat and neutral household words were generated that matched the accident-related and traffic-related words in word frequency. Although accident-related and general threat words were both associated with threat, they were also clearly distinct, as general threat words were chosen not to have any link to motor vehicle accidents. For each target word, a neutral match word was chosen with the same frequency and the same word stem as the target word. The target words (and their match words) in each word category were then divided into two parallel sets.

A series of analyses of variance (ANOVAs) tested whether the words in the different categories and sets were parallel. There were no main effects or interactions of word category (accident, traffic, general threat, household), word set, and word type (target vs. match) in verbal frequency, number of letters, or number of syllables (all F s < 1.2, all p s > .34). The word lists were further tested in a pilot study with 42 volunteers who had not experienced an accident or any other traumatic event in their lives (47.6% male, 52.4% female; M age = 33.76 years, SD = 10.78). No main effects or interactions of word category, word set or word type emerged regarding the time it took participants to pronounce the words or word familiarity (all F s < 2, all p s > .13). However, as expected, a significant Word Category \times Word Type interaction was found for ratings of pleasantness, $F(3, 112) = 28.52$, $p < .001$. Follow-up tests showed that for target words, accident-related, and general-threat words were rated as significantly more unpleasant than traffic-related and household words, whereas no significant

¹ http://www.psych.rl.ac.uk/MRC_Psych_Db.html

differences for word type were found for the match words. The final list of words used in this study is available in the online supplemental materials.

Encoding phase. In the encoding phase, the words were presented on a 12.1-in. (30.734-cm) portable computer screen, one at a time. Each participant was randomly assigned to one of the two sets and presented with words from this set during the encoding phase. To disguise the fact that the encoding phase was part of a memory test, participants were told that they were completing a concentration task. Each word was preceded by a fixation cross, was presented on the screen for 3 s, and then flashed away automatically. After the word had disappeared, either a yellow or a red dot appeared in random order, and participants were asked to respond to these dots by pressing either a red or a yellow response key, which automatically activated the next trial. Participants were first presented with five practice words. To prevent a primacy effect, the task then started with four buffer words. Target words were then presented in randomized order. Four additional buffer words followed at the end of the task to prevent a recency effect.

Interval. After the encoding task, participants saw 24 neutral still pictures (e.g., landscapes, flowers) from the International Affective Pictures System (Lang, Bradley, & Cuthbert, 1999) on the computer screen, each for 20 s. Participants were informed that this was a break and that no task would be conducted during this interval. However, participants were asked to look at the pictures for the whole 8 min.

Test phase. During the test phase, participants were presented with word-stems on the computer screen. The stems of all words from both sets were included in this task. For four-letter words, the stem consisted of the first two letters; for all other words, it consisted of the first three letters. Participants were asked to complete the stems with the first word that came to mind by saying them out loud. No reference to the encoding phase was made. The word stems were presented on the screen in random order and appeared in the same position, letter size, and color as the words during the encoding phase. Participants completed five practice trials before the main task. Participants' answers were audiotaped and scored after the session. Answers were scored as correct if the word named by the participant corresponded exactly to the target word. All analyses were repeated using lax criteria, i.e., words closely related to the target word were also scored as correct (e.g., "crashed" or "crashes" for target word "crash"). However, this did not change the results. For reasons of brevity, only results following the exact scoring are reported.

Priming index. In line with earlier studies (e.g., Michael et al., 2005), the main analyses were conducted on the priming index, computed as the difference between the completion rates for primed words and the completion rates for unprimed words. This is generally regarded as a better index of priming than the completion rate for primed words alone, as it takes into account the baseline completion rate (Roediger & McDermott, 1993).

Free Recall Task

To compare implicit memory for the encoded words with explicit memory of the words, a free-recall task was conducted following the test phase. Participants were asked to write down as many words from the encoding phase (termed "concentration task") as they could remember. There was no time limit. For each

word category, accuracy of free recall was computed as the proportion of correctly recalled words among the words presented during the encoding phase.

Questionnaire and Interview Measures

Diagnoses. The Acute Stress Disorder Scale (ASDS; Bryant & Harvey, 2000) was conducted as an interview at the 2-week assessment. The presence of PTSD at 6-month follow-up was assessed using the Structured Clinical Interview for *DSM-IV* (SCID; First, Spitzer, Gibbon, & Williams, 1996). Interrater reliabilities for the ASDS and SCID interviews were high (ASD $\kappa = 0.93$; PTSD $\kappa = 0.82$; $N = 56$ randomly chosen interviews from this and a related study, two raters).

Symptom severities. PTSD symptom severity was assessed using the Posttraumatic Diagnostic Scale (PDS; Foa, Cashman, Jaycox, & Perry, 1997), a validated and widely used self-report measure of PTSD symptom severity. The Beck Depression Inventory (BDI; Beck, Rush, Shaw, & Emery, 1979), a standardized questionnaire of established reliability and validity, assessed the severity of depressive symptoms.

Procedure

The study was approved by the local ethics committees, and participants gave written informed consent. At approximately 2 weeks post-trauma, participants attended a research session that comprised the word-stem completion test, the ASDS interview, and the symptom-severity measures. It also contained some additional tasks and questionnaires unrelated to the analyses presented here (see Ehring et al., 2008). At 6-month follow-up, the SCID was carried out via telephone by the same interviewer, and participants completed the symptom measures again. Participants completed a few further questionnaires at 1 and 3 months that have been reported elsewhere (Ehring et al., 2008). Participants received a reimbursement of £50.

Data Analysis

Hypotheses were tested with hierarchical logistic regression analyses. Priming indices for general threat, neutral, and traffic-related words were entered in Step 1, followed by the priming index for accident-related words in Step 2 and symptom scores at 2 weeks in Step 3. The PDS and BDI were square-root transformed to normalize distributions. Standardized scores for each variable were used in these analyses to obtain odds ratios. One-tailed levels of significance are given for correlations with the priming index for accident-related words as the direction of the effect was predicted.

Results

General Priming Effect

A repeated-measure ANOVA with the between-subject factor word set encoded (Set 1 vs. Set 2) and the within-subject factor word set completed (Set 1 vs. Set 2) tested whether primed words showed a higher completion rate than unprimed words. There were no significant main effects for word set encoded, $F(1, 117) = 3.42$,

$p = .07$, $\eta_p^2 = .03$, or word set completed, $F(1, 117) = 0.56$, $p = .46$, $\eta_p^2 = .01$; but the expected significant interaction, $F(1, 117) = 88.42$, $p < .001$, $\eta_p^2 = .43$. Planned follow-up tests showed that consistent with a general priming effect, participants who had encoded Set 1 showed significantly higher completion rates for words from this set ($M = 0.16$, $SD = 0.06$) than for words from Set 2 ($M = 0.09$, $SD = 0.05$), $t(65) = 7.83$, $p < .001$, whereas participants who had encoded Set 2 showed significantly higher completion rates for words from Set 2 ($M = 0.14$, $SD = 0.06$) than for words from Set 1 ($M = 0.08$, $SD = 0.05$), $t(52) = -5.62$, $p < .001$.

Group Differences

Participants with and without PTSD at 6 months did not differ significantly regarding age, sex, or years spent in education (all $ps > .14$). However, participants with PTSD showed significantly lower injury severity scores than those without PTSD ($M = 1.36$, $SD = 1.22$ vs. $M = 2.27$, $SD = 2.56$), $t(34.31) = 2.18$, $p < .05$. Controlling for injury severity scores did not change the results in any of the analyses reported below. In addition, as to be expected, participants with PTSD at 6 months showed significantly higher levels of PTSD symptoms at 2 weeks ($M = 29.31$, $SD = 12.92$ vs. $M = 9.89$, $SD = 9.15$), $t(17.41) = 5.79$, $p < .001$, and depression ($M = 19.19$, $SD = 12.50$ vs. $M = 7.05$, $SD = 5.89$), $t(16.05) = 3.82$, $p < .001$.

Hypothesis 1: Priming for Accident-Related Words, But Not for Traffic-Related, General Threat, and Neutral Words, Predicts PTSD Assessed at Follow-Up

The priming index for accident-related words was not related to ASD ($r_{pbis} = .02$) or PTSD high risk ($r_{pbis} = .07$) at 2 weeks. There was a small association with self-reported PTSD severity (PDS; $r = .15$, $p < .05$, one-tailed, for both time points) but not with depression severity (BDI; $r = .09$ and $r = .11$, respectively). Table 1 shows the results of the logistic regression analysis predicting PTSD at 6 months. As expected, priming indices for traffic-related, general threat, and neutral words entered in Step 1 did not predict PTSD at 6 months. However, priming for accident-related words entered in Step 2 predicted PTSD at 6 months over and above priming indices for other word categories.

Hypotheses 2 and 3: Priming for Accident-Related Words Predicts Chronic PTSD Over and Above Initial Symptoms in the Total Sample and in High-Risk Participants

As expected, priming for accident-related words predicted PTSD at 6 months over and above symptoms at 2 weeks and the priming indices for other word categories in the total sample (see Table 2) and among the 43 high-risk participants (see Table 3).

Free-Recall Test

The proportion of words recalled per category showed no significant interactions between ASD or PTSD and word type in mixed-model ANOVAs (all $Fs < 1.2$, $ps > .34$).

Discussion

In line with Hypothesis 1, the current study showed that greater priming for accident-related words at 2 weeks post-trauma predicts the development of chronic PTSD. This effect was specific to accident-related words as there were no differences in priming for general threat, traffic-related and neutral words. Furthermore, only the implicit memory test (word-stem completion) showed the expected group differences, whereas there was no relationship between PTSD and explicit memory for the encoded words as assessed with the free-recall task. Furthermore, in line with Hypothesis 2, priming for accident-related words predicted chronic PTSD over and above initial symptom levels.

It is interesting that priming for accident-related words was not related to ASD or PTSD symptom criteria at 2 weeks. This shows that enhanced priming for trauma-related stimuli is not merely an epiphenomenon or consequence of experiencing PTSD symptoms. Rather, it appears to be a psychopathological process that distinguishes between people who show transient symptoms after trauma and those who develop chronic PTSD. In line with this interpretation and Hypothesis 3, priming for accident-related words predicted chronic PTSD among a high-risk group who met ASD or PTSD symptom criteria at 2 weeks.

The present results extend those of Michael et al.'s (2005) in several ways. First, they established that enhanced PT-PTS precedes the development of PTSD. Second, they showed that

Table 1
Results of Logistic Regression Analyses Predicting PTSD Diagnoses at 6 Months From Priming Indices in the Total Sample ($N = 119$)

Predictor	χ^2 (step), Nagelkerke R^2 (model)	Wald	OR
Step 1: Priming for other words	$\chi^2(3, N = 119) = 3.90, R^2 = .07$		
Traffic words		3.63	1.77
General threat words		0.09	1.11
Neutral words		0.71	0.74
Step 2: Priming accident-related words	$\chi^2(1, N = 119) = 10.04^{**}, R^2 = .23$		
Traffic words		2.53	1.62
General threat words		0.02	0.95
Neutral words		1.16	0.66
Accident words		8.05^{**}	2.98

Note. OR = odds ratio.
** $p < .001$.

Table 2
Results of Logistic Regression Analyses Predicting PTSD Diagnoses at 6 Months From Symptoms at 2 Weeks and Priming Indices in the Total Sample (N = 119)

Predictor	χ^2 (step), Nagelkerke R^2 (model)	Wald	OR
Step 1: Symptoms at 2 weeks	$\chi^2(2, N = 119) = 33.47^{**}, R^2 = .45$		
PDS		8.72**	4.77
BDI		0.88	1.52
Step 2: Priming for other words	$\chi^2(3, N = 119) = 3.50, R^2 = .49$		
PDS		8.04**	4.93
BDI		1.29	1.73
General threat words		0.10	1.15
Neutral words		0.99	0.65
Traffic words		2.29	1.83
Step 3: Priming accident-related words	$\chi^2(1, N = 119) = 5.30^*, R^2 = .55$		
PDS		6.96**	4.86
BDI		1.67	1.91
General threat words		0.03	1.08
Neutral words		1.70	0.55
Traffic words		1.90	1.80
Accident words		4.75*	2.28

Note. OR = odds ratio; PDS = Posttraumatic Diagnostic Scale (Foa, Cashman, Jaycox, & Perry, 1997); BDI = Beck Depression Inventory (Beck, Rush, Shaw, & Emery, 1979).

* $p < .01$. ** $p < .001$.

PT-PTS predicts chronic PTSD over and above initial symptom levels. The results confirm that the modified word-stem paradigm is sensitive in detecting clinically relevant differences. Overall, the results are in line with the hypothesis that PT-PTS is one of the processes involved in the development of chronic PTSD symptoms. Enhanced PT-PTS may contribute to stimulus generalization of triggers of trauma memories, as it results in a processing advantage for a wide range of trauma-related stimuli that may serve as triggers of trauma memories, negative affect, or rumination. The present study found smaller associations between priming for accident-related words and self-reported PTSD symptoms than previously reported by Michael et al. The earlier assessment

and a smaller proportion of participants with PTSD in the present study may have contributed to this finding.

Although the results of the current study are promising, some limitations bear noting. First, theorists of PTSD have emphasized the role of *perceptual* priming (e.g., Ehlers & Clark, 2000). The current study used words as stimuli and it cannot be ruled out that *semantic*, rather than *perceptual*, priming processes were assessed. In future studies, researchers should therefore consider using pictorial stimuli instead of words. Second, it is possible that explicit memory processes contributed to the findings. Although the results of the free-recall task did not suggest explicit memory effects, recognition memory may nevertheless have contributed to task

Table 3
Results of Logistic Regression Analyses Predicting PTSD Diagnoses at 6 Months From Symptoms at 2 Weeks and Priming Indices in the High-Risk Group (N = 43)

Predictor	χ^2 (step), Nagelkerke R^2 (model)	Wald	OR
Step 1: Symptoms at 2 weeks	$\chi^2(2, N = 43) = 16.54^{**}, R^2 = .45$		
PDS		2.08	3.18
BDI		2.67	2.72
Step 2: Priming for other words	$\chi^2(3, N = 43) = 3.48, R^2 = .52$		
PDS		2.19	3.30
BDI		2.79	2.68
General threat words		0.12	0.98
Neutral words		0.28	0.80
Traffic words		2.70	2.67
Step 3: Priming accident-related words	$\chi^2(1, N = 43) = 6.30^*, R^2 = .64$		
PDS		1.81	5.27
BDI		2.87	4.04
General threat words		0.00	1.02
Neutral words		1.28	0.42
Traffic words		2.62	3.32
Accident words		5.03*	3.32

Note. OR = odds ratio; PDS = Posttraumatic Diagnostic Scale (Foa, Cashman, Jaycox, & Perry, 1997); BDI = Beck Depression Inventory (Beck, Rush, Shaw, & Emery, 1979).

* $p < .01$. ** $p < .001$.

performance, which may point to a role of involuntary explicit memory rather than implicit memory (see McNally, 1998). In addition, it has been argued that no task is process-pure; all tasks are influenced by both explicit and implicit processes to varying degrees (see Jacoby, 1991). Third, although the sample size was substantial, relatively few participants met diagnostic criteria for PTSD. Future studies should increase the power by including a larger group of participants with PTSD. Fourth, the words used in the current study were selected and rated by experts, which may not be entirely consistent with participants' perceived personal relevance and trauma-relevance of the words. Future studies should consider ratings from trauma survivors. Finally, although it is encouraging that the present findings in accident survivors are in line with earlier results on assault survivors, future research should directly test the generalizability of the findings to other trauma populations.

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