Early Heart Rate Responses to Standardized Trauma-Related Pictures Predict Posttraumatic Stress Disorder: A Prospective Study

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Objective: To investigate whether chronic posttraumatic stress disorder can be predicted by heart rate responses (HRR) and skin conductance responses (SCR) to standardized trauma-related pictures at 1 month after trauma has ocurred. Trauma survivors with PTSD report heightened physiological responses to a wide range of stimuli. It has been suggested that associative learning and stimulus generalization play a key role in the development of these symptoms. Some studies have found that trauma survivors with PTSD show greater physiological responses to individualized trauma reminders in the initial weeks after trauma than those without PTSD. **Methods:** Survivors of motor vehicle accidents or physical assaults (n = 166) watched standardized trauma-related, generally threatening, and neutral pictures at 1 month post trauma, as their HRR and SCR were recorded. PTSD symptoms were assessed with structured clinical interviews at 1 month and 6 months; self-reports of fear responses and dissociation during trauma were obtained soon after the trauma. **Results:** At 1 month, trauma survivors with PTSD showed greater HRR to trauma-related pictures than those without PTSD, but not to general threat or neutral pictures. HRR to trauma-related pictures predicted PTSD severity at 1 month and 6 months, and were related to fear and dissociation during trauma. SCR were not related to PTSD. **Conclusion:** HRR to standardized trauma reminders at 1 month after the trauma differentiate between trauma survivors with and without PTSD, and predict chronic PTSD. Results are consistent with a role of associative learning in PTSD and suggest that early stimulus generalization may be an indicator of risk for chronic PTSD. **Key words:** posttraumatic stress disorder, psychophysiology, prospective study, associative learning, dissociation, anxiety.

PTSD = posttraumatic stress disorder; **HRR** = heart rate responses; **SCR** = skin conductance responses; **PSSI** = PTSD Symptom Scale—Interview Version; **PDS** = Posttraumatic Diagnostic Scale; **MVA** = motor vehicle accident.

INTRODUCTION

People with posttraumatic stress disorder (PTSD) report heightened physiological responses to internal or external cues that symbolize or resemble an aspect of the trauma (1). Clinical observations suggest that these responses can be triggered by a wide range of stimuli. Furthermore, clinical observations suggest that people with PTSD may react with emotional and physiological arousal to situations that have little similarity with the trauma but overlap in particular sensory impressions (e.g., a similar color, smell, or sound) (2).

Models of PTSD draw on associative learning mechanisms to explain this heightened physiological and emotional reactivity (2–6). It has been suggested that, during trauma, fear responses become associated with stimuli that are present at the time and subsequently generalize more broadly to stimuli and situations that resemble the original trauma (4,5).

One way of investigating the role of associative learning in PTSD is to measure physiological responses to trauma reminders. Several studies have demonstrated a heightened physiological reactivity in trauma survivors with PTSD compared with traumatized and nontraumatized controls (7–9). This is consistent with the notion that learned fear responses acquired during trauma contribute to PTSD.

There has been a longstanding interest in trauma research whether psychophysiological responses are useful in diagnosing PTSD and in identifying people at risk of chronic PTSD soon after trauma (7). Psychophysiological measures may provide useful additional information to the widely used self-report measures. In Pole's meta-analysis (9), psychophysiological responses to standardized trauma cues identified PTSD with a mean sensitivity of 0.77 and a mean specificity of 0.91. Responses to idiographic trauma cues identified PTSD with a mean specificity of 0.65 and mean specificity of 0.83.

However, most of the studies to date were cross-sectional comparisons of survivors of very distant traumas, such as combat or sexual abuse in childhood (10,11). This limits the conclusiveness of the results for the development of PTSD, as the heightened physiological reactivity may be a consequence of chronic PTSD, rather than a factor contributing to its development. It is, thus, unclear whether the reasonable sensitivity and specificity observed in these studies also apply toward the early identification of trauma survivors at risk of chronic PTSD. This question is of considerable interest, as many survivors recover on their own (12), and it is unclear how best to identify those who need intervention.

Few studies to date have investigated physiological responses to trauma reminders soon after trauma. Elsesser et al. (13) found that patients with chronic PTSD and recent trauma survivors who met the criteria for acute stress disorder at 6 weeks after the trauma showed heart rate acceleration to individualized trauma-related pictures, whereas nontraumatized controls and survivors without acute stress disorder showed heart rate deceleration. The groups did not differ in heart rate responses (HRR) to generally threatening or neutral pictures. Blanchard et al. (14) studied survivors of motor vehicle accidents (MVA) at about 2.5 months after the trauma and found that HRR to audiotaped individualized scripts describing the participants' accident, but not responses to other stressors, distinguished survivors with PTSD from those

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Received for publication July 28, 2009; revision received October 30, 2009.

The study was funded, in part, by Grant 069777 from the Wellcome Trust (A.E.). Oliver Suendermann was supported by a scholarship from the German National Academic Foundation.

Disclosure: The authors have no potential conflicts of interest.

DOI: 10.1097/PSY.0b013e3181d07db8

0033-3174/10/7203-0301

without PTSD and nontraumatized controls. These results are in line with the notion that, in the initial months after trauma, PTSD is characterized by strong learned fear responses to reminders of the trauma.

There is also preliminary evidence that HRR to trauma reminders can be used to predict the chronicity of PTSD. Elsesser et al. (15) followed up 35 recent trauma survivors from their 2004 study and found that greater HRR to the individualized trauma-related pictures predicted PTSD symptoms 3 months later. Blanchard et al. (14) found that heart rate (HR) acceleration to individualized MVA scripts predicted chronicity of PTSD at 1 year in 48 participants who had PTSD at the initial assessment. Kleim and colleagues (16) found that HRR to guided imagery of the trauma at 2 weeks predicted PTSD severity at 6 months after the trauma in female, but not male, assault survivors.

These studies are of possible clinical relevance, as they suggest that early psychophysiological responses may be useful in identifying trauma survivors at risk of chronic PTSD. So far, the studies that investigated whether early physiological responses to trauma reminders predict PTSD used idiographic trauma reminders that were selected because of their personal relevance to the participants, mainly script-driven imagery of one's trauma (14,16) or idiographic pictures selected for their personal relevance to each participant (13). This raises the question of whether HRR to standardized sets of trauma reminders would also be predictive of chronic PTSD. If associative learning theories of PTSD are correct, then one would expect stimulus generalization soon after the trauma to contribute to the chronicity of PTSD. The present study was designed to investigate whether HRR to standardized trauma-related pictures can be used to identify people who will develop chronic PTSD. This question is of potential practical interest as many trauma survivors recover from initial symptoms of PTSD (12) and screening tools that allow the identification of those at risk of chronic PTSD are needed for the efficient allocation of scarce treatment resources. Currently, such screening relies on self-report symptom measures (17), as studies have shown that initial symptom severity is a relatively good predictor of chronic PTSD (18). It was, therefore, of particular interest to investigate whether HRR to standardized trauma pictures predict chronic PTSD over and above what could be predicted from self-reported symptoms at 1 month after the trauma. The present prospective study assessed trauma survivors at 1 month and 6 months. The study built on two earlier studies, suggesting that recent trauma survivors with PTSD and patients with chronic PTSD, may show heightened HRR to standardized trauma-related pictures compared with those without PTSD (19,20). In contrast, however, Blanchard et al. (14,21) found that HRR to guided imagery of a standard MVA script or videotapes of car crashes did not distinguish between survivors with and without PTSD.

The present study also explored whether skin conductance responses (SCR) to trauma reminders are related to PTSD. Previous studies (9) have suggested that HRR are particularly sensitive in detecting response differences between people with and without PTSD. In studies of early responses after trauma, HRR also showed the most robust findings. In the study by Elsesser et al. (13), startle responses did not show an interaction between group and picture type. Similarly, in the study by Blanchard et al. (14), electromyogram and blood pressure responses did not distinguish between the PTSD and no PTSD groups. SCR were chosen for this study because SCR are widely used as a measure of conditioned emotional responses in laboratory studies (22) and because SCR have been shown to differentiate between people with chronic PTSD and controls in some, but not all, idiographic trauma cue studies (9). The study by Elsesser et al. (13) did not find any differences in SCR between participants with and without PTSD (Dr. Karin Elsesser, personal communication, September 18, 2009).

Finally, the present study examined whether HRR to trauma reminders are related to the participants' emotional and cognitive responses during the trauma, in particular, to the degree of peritraumatic fear and dissociation. These responses have been shown to predict PTSD (23–25). The literature on conditioning (26,27) suggested that stronger emotional arousal during trauma leads to stronger conditioned emotional responses. Peritraumatic dissociation is thought to decrease focal attention and to promote a perceptual processing style that is characteristic of PTSD (28,29). Ehlers, Hackmann, and Michael (30) proposed that perceptual processing during trauma facilitates memory processes that rely on perceptual operations, such as associative learning.

In sum, the present study investigated the following hypotheses:

Hypothesis 1: Participants with PTSD show greater HRR to trauma-related pictures than participants without PTSD, but not to generally threatening or neutral pictures.

Hypothesis 2: Greater HRR to trauma-related pictures at 1 month predict greater PTSD symptom severity at 6 months.

Hypothesis 3: Peritraumatic dissociation and fear during trauma predict greater HRR to trauma-related pictures at 1 month.

Furthermore, the study explored whether SCR to standardized trauma cues are associated with PTSD, as the previous findings on this response are mixed.

METHODS

Sample

Participants were recruited from assault or MVA survivors who were treated for their injuries in the emergency department of a large urban teaching hospital during the period of August 2006 and February 2008. To be eligible for the study, participants had to meet the trauma (A) criterion of Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV) (1), and understand and speak English fluently enough to be able to answer interview questions and fill in questionnaires. Participants with current psychosis and substance dependence, as well as those who could not remember the event (e.g., due to a head injury), were excluded. A total of 213 trauma survivors were recruited shortly after their trauma and attended the research session. Of these, 15 (n = 4 with PTSD, 11 without PTSD) had to be excluded before analysis for the following reasons: use of medication that may affect HR, such as β blockers or tricyclic antidepressants ($n = 7$); participant fell

TABLE 1. Sample and Trauma Characteristics

Variables	Diagnosis at 1 Mo			Statistic for Comparison Between PTSD and No PTSD Groups	
	Total (n = 166)	PTSD (n = 56)	No PTSD (n = 110)		
Sex				χ^2 (1) = 3.98	p = .06
Female	57	25	32		
Male	109	31	78		
Age	35.5 (10.8)	34.8 (11.6)	34.6 (10.0)	t (164) = 0.13	p = .90
Type of trauma				χ^2 (2) = 7.13	p = .01
Assault	71	32	39		
Motor vehicle accident	95	24	71		
Ethnic origin				χ^2 (1) = 0.31	p = .62
Caucasian	92	29	63		
Non-Caucasian	73	26	47		
Years of education	15.4 (6.5)	13.3 (3.8)	16.3 (7.2)	t (123) = 2.37	p = .02
Alcohol (units/week)	12.4 (16.3)	11.4 (16.8)	12.8 (16.2)	t (125) = 0.43	p = .67
Tobacco dependency (%)	32.6	44.4	27.1	χ^2 (1) = 4.2	p = .05
Time since trauma (days)	37.5 (9.9)	38.5 (10.1)	36.9 (9.8)	t (164) = 0.97	p = .33
Dissociation (during trauma)	7.4 (5.9)	10.7 (5.7)	5.8 (5.3)	t (155) = 5.3	p < .001
Fear (during trauma)	6.6 (3.6)	7.8 (3.8)	5.9 (3.4)	t (155) = 3.1	p = .001
Injury severity score (ISS)	1.9 (2.1)	1.9 (1.7)	2.0 (2.3)	t (133) = 0.35	p = .72
PDS Score (1 mo)	16.1 (10.8)	26.0 (9.2)	11.1 (7.7)	t (164) = 11.03	p < .001
BDI Score (at 1 mo)	9.8 (8.7)	17.8 (9.1)	5.8 (4.9)	t (164) = 11.1	p < .001
PSSI Score (at 6 mos)	7.8 (9.8)	28 (9.1)	4.6 (4.7)	t (129) = 16.7	p < .001

PTSD = posttraumatic stress disorder; ISS = Injury Severity Score; PDS = Posttraumatic Stress Diagnostic Scale; BDI = Beck Depression Inventory; PSSI = PTSD Symptom Scale Interview.

asleep during the experiment (n = 2); movement artifacts (n = 5); and experiment stopped early due to distress (n = 1). Data from 22 participants (n = 4 with PTSD, 18 without PTSD) were missing due to technical and recording problems. Therefore, the final sample size comprised 166 trauma survivors (n = 56 with PTSD, 110 without PTSD). A total of 131 participants (79%) took part in the follow-up interview 6 months post trauma. Participants who dropped out did not differ from participants who completed the follow-up on sex, age, ethnic group, PTSD diagnosis and symptom severity, depressive symptoms, and tobacco and alcohol consumption (p_{min} = .21 to p_{max} = .58). If participants still had PTSD at the 6 month follow-up (or earlier if the participant was very distressed or at risk), we liaised with their family doctors to arrange treatment. Two participants received an effective psychological treatment for PTSD before the 6-month follow-up; their pretreatment scores were used for data analysis.

Table 1 shows sample characteristics. Participants with and without PTSD did not differ in sex, age, ethnic group, alcohol consumption, time since the trauma at research session, and injury severity. Participants with PTSD had lower educational attainment, were more likely to be smokers, and were more likely to have been injured in an assault than the no PTSD group. As expected, the PTSD group reported more severe PTSD and depressive symptoms, and more dissociation and fear during trauma, than the no PTSD group.

MATERIALS

Participants viewed a series of pictures (Table 2); 14 pictures were related to the participants' trauma (i.e., assault-related pictures, such as a person being threatened with a gun, for assault survivors; and accident-related pictures, such as a crashed car, for MVA survivors); 12 pictures were generally threatening pictures (e.g., a spider on someone's shoulder), and 12 were neutral pictures (e.g., children playing soccer).[1] The order of presentation was randomized for each individual, with the restriction that pictures of the same category were never presented consecutively to minimize habituation effects. Each picture was presented for 6 seconds followed by an interstimulus interval, which varied randomly between 9 seconds and 12 seconds. During picture presentation, the participant's HR and skin conductance were continuously recorded. After picture presentation, participants watched the trauma-related pictures again and rated how relevant each picture was for their personal trauma, using a scale from 0 (not at all relevant) to 4 (very much relevant).

Pictures were selected in a pilot study that tested the suitability of the stimulus material. Healthy volunteers (n = 21; 7 males; mean age, 27.4 years; SD = 4.5) rated the valence and arousal of the pictures on a Likert scale ranging from −10 (extremely unpleasant or relaxing) to +10 (extremely pleasant or arousing). Trauma and general threat pictures were rated as moderately unpleasant to very unpleasant (mean = −6.6, SD = 0.6; and mean = −6.7, SD = 0.6, respectively) and as moderately arousing (mean = 4.8, SD = 1.5; and mean = 4.7, SD = 1.4, respectively); neutral pictures were rated as somewhat pleasant (mean = 3.3, SD = 1.0) and arousing (mean = 1.8, SD = 0.7). Arousal and valence ratings for trauma versus general threat pictures did not differ significantly from each other (p = .30 and p = .19, respectively). As intended, arousal ratings for trauma and general threat pictures were significantly higher than those for neutral pictures (p < .001) and valence ratings were more negative (p < .001).

Apparatus and Physiological Recording

HR, skin conductance, and respiration were recorded, using a Varioport biosignal recording device (Becker Meditec, Karlsruhe, Germany). Electrocardiogram (ECG) electrodes were placed on the manubrium sterni and the left lower rib cage. The reference electrode was attached to the right lower rib cage and the ECG was recorded with a sampling rate of 256 Hz. Electrodermal activity was measured, using a constant voltage system (0.5 V) and a bipolar recording with two Ag/AgCl electrodes filled with a 0.05 M NaCl electrolyte paste. Skin conductance electrodes were placed on the thenar and hypothenar palmar eminences of the nondominant hand and SCR were recorded with a sampling rate of 256 Hz. To check for possible respiration artifacts (sighs, coughs), respiration was recorded with a Pneumotrace II

[1]Pictures were partly drawn from the International Affective Picture System (31), namely, some of the trauma pictures (6560, 6821, 6243, 6510, 6312, 3550), general threat pictures (2692, 9440, 1201, 9921), and neutral pictures (5623). All other pictures were either downloaded from online picture databases, or taken from digitalized movies or photos from magazines to create sets that were comparable in complexity. The picture sets are available from the authors.

Table 2. Content of Pictures

Picture	Assault-Related (for Assault Survivors)	MVA-Related (for MVA Survivors)	General Threat (All Participants)	Neutral (All Participants)
1	Man threatening woman with gun IAPS No: 6560	Ambulance and stretcher	Jet fighter firing missile	Child's room
2	Gang beating up man	Car on dark wet street	Man with bomb IAPS No: 2692	Boy playing with sailing boat
3	Gang stopping car with baseball bat IAPS No: 6821	Cyclist being cut off by car	Junkie with syringe	Ice cream kiosk
4	Man pointing gun IAPS No: 6243	Swerving motorcyclist	Skulls piled up IAPS No: 9440	Man tidying room
5	Masked man with knife IAPS No: 6510	Crashed motorcyclist	Spider on shoulder IAPS No:1201	Surfer in wave IAPS No:5623
6	Gang attacking man	Car crashed into tree	Tanks rolling over street	Man sitting under sun shade
7	Brawl in park	Cyclist in busy traffic	Helicopter over flooded area	Children playing soccer
8	Woman with blood on face	Crashed bicycle	Crashed airplane	Two men chatting in living room
9	Man stalking woman	Car crashed into concrete bollard	Dead bird covered in oil	Boy drying his hair
10	Man being kicked on floor	Collision of car and motorbike	Fire fighter rescuing woman IAPS No: 9921	Camping site
11	Pedestrian in dark street	Car hitting pedestrian	Noose of gallow	Business meeting
12	Man beating other man with elbow	Wrecked motorbike	Starving child	Business meeting
13	Man attacking woman IAPS No: 6312	Injured woman behind steering wheel		
14	Man covered with blood IAPS No: 3550	Injured person lying on street		

MVA = motor vehicle accident; IAPS = International Affective Picture System.

transducer (UFI, Morro Bay, California), which was attached around the participant's upper chest.

Questionnaire Measures and Clinical Interview

PTSD Measures

The PTSD section of the Structured Clinical Interview for the DSM-IV (32) was carried out to diagnose PTSD. PTSD symptom severity was assessed with the Posttraumatic Stress Symptom Scale Interview (PSSI) (33). The interviewer rated each of the PTSD symptoms during the past 2 weeks on a scale from 0 (not at all) to 3 (≥5 times per week/very much). The total PSSI score is the sum of the ratings for the 17 items. Interrater reliability for this sample was $\kappa = 0.96$ for PTSD diagnosis and $\kappa = 0.96$ for PTSD symptom severity. In addition, participants completed the Posttraumatic Stress Diagnostic Scale (PDS) (34) at 1 month post trauma. The PDS is a reliable, validated, and widely used self-report measure in research with traumatized individuals. Participants rate how often they were bothered by each PTSD symptom as defined in the DSM-IV (1) on a scale ranging from 0 (not at all or only one time) to 3 (≥5 times a week/almost always). The total severity score is the sum of all items. For the current sample, the internal consistency of the PDS was $\alpha = 0.93$.

Depressive Symptoms

Severity of depressive symptoms was assessed with the Beck Depression Inventory (BDI) (35), a standardized questionnaire with established reliability and validity.

Peritraumatic Responses

Participants rated how much fear they experienced during the trauma (three items). Each item was rated on a scale from 0 "not at all" to 4 "very strongly" (36). Dissociation during trauma was assessed with a short version of the State Dissociation Questionnaire α ($\alpha = 0.88$), which comprises five items assessing different aspects of dissociation, such as derealization, depersonalization, detachment, altered time sense, and emotional numbing (37). This measure has shown good reliability and validity in traumatized and nontraumatized samples and predicted PTSD after MVA and assault (38,39). It correlates strongly with the Peritraumatic Dissociation Scale ($r = .79$) (36).

Injury Severity Score (ISS)

ISS is an anatomical scoring system, which is based on the medical hospital notes and provides an overall score of the severity of injuries (40). A trained research nurse experienced in accident and emergency medicine performed the ratings.

Further Measures for Characterization of Sample

Participants completed a General Information Questionnaire (36,37), which assessed demographic and trauma characteristics and the Alcohol, Smoking and Substance Involvement Screening Test (41) to screen for the use of psychoactive substances.

Procedure

The present study used a prospective design. Participants were recruited in two ways: where possible, participants (39%) were recruited in the emergency department on the day of their trauma. Those participants who were admitted to the emergency room when no recruiter was present (61%) received an information sheet about the study and invitation letter 3 to 5 days after their trauma. Participants were assessed at three different time points after their trauma: 1) On recruitment, shortly after the trauma, participants rated their peritraumatic fear and dissociation. ISS ratings were obtained on the basis of hospital notes. 2) Approximately 1 month after the traumatic event, participants attended the research session that involved the picture viewing task, Structured Structured Clinical Interview for DSM-IV, PSSI, PDS, BDI, and General Information Questionnaire. The session also involved filling out other questionnaires that will be reported elsewhere. 3) Six months post trauma, the PSSI was conducted again over the telephone by the same interviewer.

Data Reduction and Statistical Analyses

HRR and SCR data were preprocessed and analyzed with a software package developed by Gamer (42).

Heart Rate Responses

In a first step, R waves were detected from the ECG data. R-R intervals were then converted into HR (in beats/minute) and sampled second by second. For each picture, the prestimulus baseline HR was defined as the HR during the last second before picture onset. HRR were assessed as the relative change from baseline during the 6 seconds of stimulus presentation. For each second of stimulus presentation, the prestimulus baseline HR was subtracted from the HR during that second. Mean HRR were the mean of the HRR during the 6 seconds for each picture of the respective picture type.

Skin Conductance Responses

Raw skin conductance data were downsampled to 64 Hz and smoothed with a Gaussian filter of 16 Hz. The first artifact free SCR amplitude with an onset between 1 second and 3 seconds post stimulus (latency criterion) was measured (inflection to maximum) when exceeding a threshold of 0.02 μS. Finally, SCR amplitudes were log-transformed, using the formula log (X + 1) as recommended by Venables and Christie (43).

Statistical Analyses

In this study, physiological responses were measured repeatedly across time. HRR and SCR data were analyzed with Generalized Estimating Equations (GEE) to take account for the correlation between the temporal measures. Specifically, an exchangeable correlation structure was assumed to account for the within-subject correlation.

GEE provides unbiased estimates of the marginal effects, even if the assumed correlation structure is misspecified (44,45). To safeguard a possible misspecification against the variance/covariance matrix, robust Hubert White sandwich estimators were used to adjust standard errors and, hence, confidence intervals and p values (46). The following factors were included in the GEE model: the between-group factor diagnostic group (PTSD vs. no PTSD), the within-subject factor picture type (trauma, general threat, and neutral), and for the HRR data the within-subject factor second (1 second to 6 seconds after stimulus onset). Furthermore, we included the timing when a stimulus was presented during the experiment as a covariate in the analysis, thus controlling for effects of overall habituation or sensitization during the experiment. The covariate time was coded as the position of the picture in the overall order of presentation. All possible interaction terms were added to the model. Terms which increased the model fit of the HRR/SCR data were retained in the model, and others were excluded (47).

As the PTSD and no PTSD groups differed in the proportion of participants who had experienced MVA or assault, we tested whether trauma type interacted with any of the factors specified in the GEE model. As this was not the case, data for MVA and assault participants were collapsed. Education, nicotine dependency, sex, and time since the trauma were also entered into the GEE model but dropped as no significant main effects or interactions emerged.

Correlation analyses and hierarchical multiple regression analyses were carried out, using SPSS 15.0 (SPSS, Inc., Chicago, Illinois). Data were tested for normality, using the Kolmogorov Smirnov test and transformed, where appropriate.

A discriminant function analysis with the mean HRR to trauma-related pictures as the independent variable and diagnostic group as the dependent variable was computed to assess how well participants could be classified into the PTSD and no PTSD groups on the basis of their HRR (sensitivity and specificity).

RESULTS

The PTSD and no PTSD groups did not differ in their relevance ratings for the trauma-related pictures: PTSD: mean = 1.5, SD = 1.0; no PTSD: mean = 1.3, SD = 0.9; $F(1,152) = 2.4$, $p = .12$, $\eta^2 = 0.02$.

Heart Rate Reactivity and PTSD

Figure 1 shows the mean HRR to the trauma, general threat, and neutral pictures for the PTSD and no PTSD groups for each of the 6 seconds of stimulus presentation.

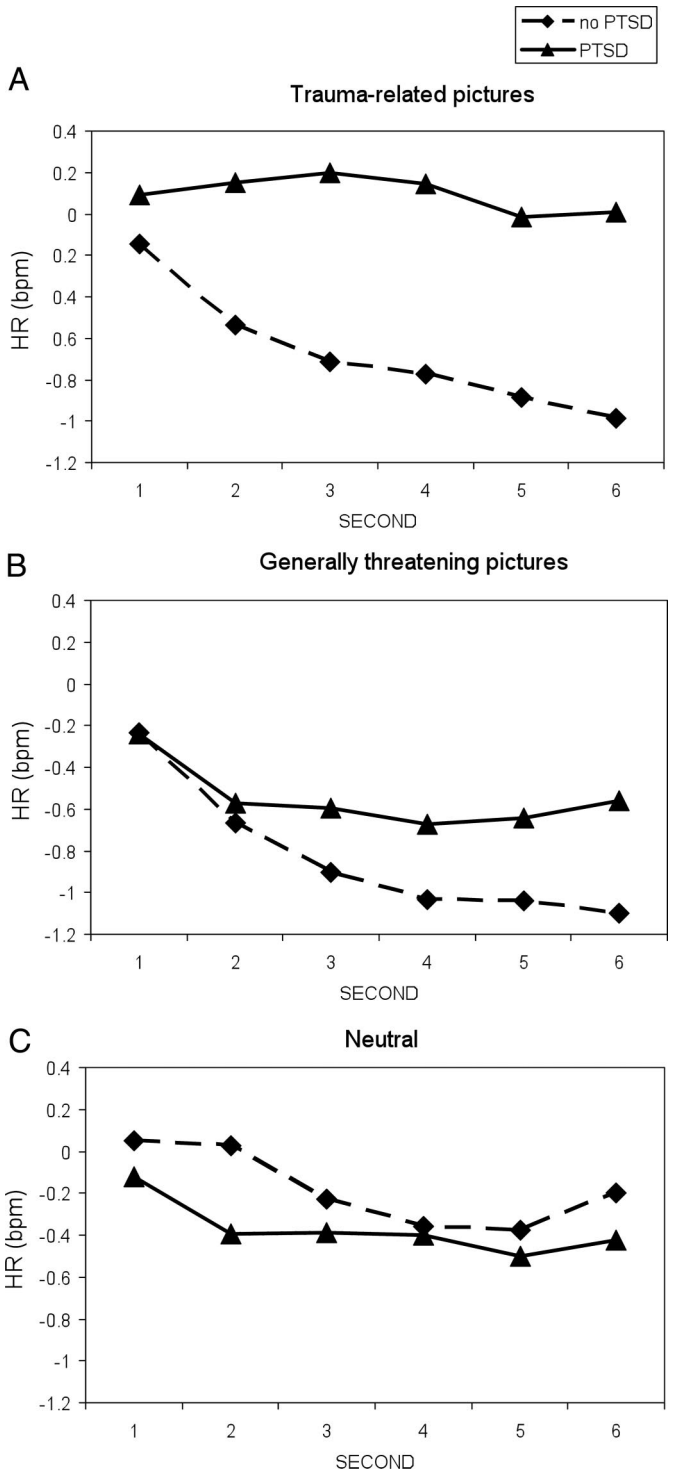

Figure 1. Mean heart rate (HR) responses to trauma-related (*A*), general threat (*B*), and neutral (*C*) pictures for the posttraumatic stress disorder (PTSD) and no PTSD groups in changes from prestimulus baseline (beats/min). The PTSD group showed greater HR responses to the trauma-related pictures than the no PTSD group; but not to general threat or neutral pictures.

The 2 × 3 × 6 GEE model showed main effects for the factor second ($\chi^2(5) = 27.0, p < .001$), and the covariate time ($\chi^2(1) = 10.6, p = .001$), but not for diagnostic group ($\chi^2(1) = 1.08, p = .299$) and picture type ($\chi^2(2) = 4.4, p = .111$). The following interactions were included in the model: "diagnostic group × picture type" ($\chi^2(2) = 12.3, p = .002$), "diagnostic group × second" ($\chi^2(2) = 4.36, p = .037$), "picture type × time" ($\chi^2(2) = 6.90, p = .032$), and "diagnostic group × time" ($\chi^2(1) = 1.70, p = .192$).

Post hoc analyses of the interaction "diagnostic group × picture type" revealed that, in line with the hypothesis, the PTSD group showed greater HRR to trauma pictures than the no PTSD group ($\chi^2(1) = 5.71, p = .017$). There were no such group differences for generally threatening ($\chi^2(1) = 0.74, p = .390$) or neutral pictures ($\chi^2(1) = 0.79, p = .372$). A significant main effect of the covariate time indicated a small increase in HRR across all picture categories over the course of the experiment.

The discriminant function analysis showed that the mean HRR to the trauma-related pictures classified 63.3% of the participants correctly into the PTSD and no PTSD groups. Of the participants who received a PTSD diagnosis, 53% were classified as responsive (sensitivity); and 68% of the individuals without a PTSD diagnosis were classified as nonresponsive (specificity).

The PTSD and no PTSD groups did not differ in prestimulus baseline ($F(1,164) = 0.41, p = .52$), nor was there an interaction between diagnostic group and picture type on baseline HR ($F(2,163) = 1.29, p = .28$) (HR before trauma-related pictures: PTSD: mean = 71.4, SD = 9.1; no PTSD: mean = 70.6, SD = 11.0; before general threat pictures: PTSD: mean = 71.8, SD = 9.2; no PTSD: mean = 70.7, SD = 11.1; before neutral pictures: PTSD: mean = 71.6, SD = 9.3; no PTSD: mean = 70.4, SD = 11.1).

Skin Conductance Responses

Parallel analyses for SCR showed neither significant main effects nor interactions.

Relationship of HRR With Peritraumatic Responses and Subsequent PTSD Symptoms

The mean PSSI score at 6 months post trauma was mean = 7.8, SD = 9.8. In accordance with Hypothesis 2, greater mean HRR to trauma-related pictures at 1 month predicted PTSD symptom severity (PSSI) at 6 months ($r = .27, p < .001$). This correlation remained significant when controlling for self-reported PTSD symptoms (PDS) at 1 month after the trauma ($r = .17, p = .046$), suggesting that HRR to trauma reminders explain variance of chronic PTSD over and above initial symptoms. A multiple regression analysis showed that PDS scores and HRR to trauma pictures at 1 month together explained 28.1% of the variance of PSSI scores at 6-month follow-up, $R = .53$, $F(2,129) = 25.22, p < .001$. Entering other variables that distinguished the PTSD and no PTSD groups in the second step of the multiple regression function (sex, trauma type, level of education, fear, and dissociation during the trauma, BDI) did not significantly add to the prediction, $F_{change}(6,114) = 1.11, p = .36$.

In line with Hypothesis 3, fear and dissociation during trauma significantly predicted mean HRR to trauma-related pictures at 1 month post trauma (both $r = .17, p = .02$).

DISCUSSION

The present study used a prospective design to investigate whether HRR to trauma-related pictures at 1 month after trauma predicts acute and chronic PTSD. In line with the first hypothesis, MVA and assault survivors with PTSD showed greater HRR to trauma-related pictures, but not to generally threatening or neutral pictures than those without PTSD. These results are consistent with previous findings of heightened physiological responding to idiographic trauma reminders in the initial weeks after trauma in civilian trauma survivors with PTSD (13,14).

The present study extends these findings by demonstrating that trauma survivors with PTSD exhibit heightened HRR to standardized trauma-related pictures compared with survivors without PTSD as early as 1 month after the trauma. This result is in line with suggestions that, in PTSD, learned fear responses acquired during the trauma generalize to stimuli that resemble the original traumatic situation so that more and more situations trigger fear and physiological arousal (4,5). Note that both groups of participants rated the trauma pictures as not very relevant to their personal trauma. Nevertheless, the PTSD and no PTSS group differed in their HRR. Whereas the no PTSD group showed the HR deceleration usually observed in healthy participants (48,49), the PTSD group tended to show a more accelerative cardiac response, which is generally seen as a sign of a phobic reaction (50). This suggests that, by 1 month, the PTSD group's fear responses had generalized to general reminders of the trauma that did not have great similarity to their own trauma. Generalization of conditioned fear responses is a well-established phenomenon. Animal studies have shown that conditioned emotional responses progressively generalize to more remote stimuli (51,52).

The present study also demonstrated that HRR to standardized trauma reminders predicted PTSD symptom severity at 6 months after the trauma. This finding extends previous prospective studies showing that HRR to individualized trauma reminders predicts chronicity of PTSD symptoms (15–17). The current findings suggest that the degree of generalization of learned fear responses or the speed with which it takes place may be indicators of risk for chronic PTSD. This has possible applications for the early detection of those at risk of chronic PTSD. Although many trauma survivors initially develop PTSD symptoms, the majority recover in the following months. Thus, measures of risk for chronic PTSD are needed that would allow the identification of those who need early intervention. The present study suggests that HRR may be a useful addition to self-reports, as they predicted over and above self-reported symptom severity at 1 month.

Overall, whereas the absence of relative HR acceleration to standardized trauma reminders was related to the absence of a

PTSD diagnosis, as indicated by a satisfactory specificity of 68%, a more positive HRR was less predictive of PTSD and the sensitivity was only 53%. This indicates that there may be several pathways to chronic PTSD, and generalized fear responses may only be one of them. This pattern of findings is in line with theories of PTSD that suggest several maintenance factors. For example, appraisals leading to feelings of guilt, shame, or anger have also been implicated in chronic PTSD, and participants who score high on these appraisals may not show HRR (2).

The present study also explored electrodermal responding to trauma pictures but the PTSD and no PTSD groups did not differ in their SCR. Previous studies (9) investigating physiological responses to standardized trauma reminders also found that HRR differentiated better between the PTSD and no PTSD groups than SCR and other measures. One possible explanation accounting for the differences between HR and skin conductance measures might be that these response systems require a different degree of contingency awareness about the relationship between triggers (conditioned stimulus) and the trauma (unconditioned stimulus) (53,54). Whereas conditioned HRR do not seem to depend on contingency awareness, conditioned SCR seem to require such awareness (54). Thus, the pattern of HRR results (HR acceleration despite low perceived relevance to one's trauma) seems to fit with clinical observations that patients with PTSD often report that their anxiety and physiological arousal seem to come "out of the blue" (2).

The results for peritraumatic responses are in line with associative learning models of PTSD (4,5). Fear during the trauma predicted greater HRR to trauma-related pictures at 1-month follow-up. High fear during trauma may indicate a strong activation of the sympathetic nervous system and, thus, lead to stronger conditioning of emotional responses, which in turn may increase the risk for PTSD. The finding that dissociation during the trauma also predicted HRR to trauma-related pictures lends some preliminary support to the suggestion that engaging in perceptual processing during trauma promotes associative learning (28). Note that some studies have found a negative relationship between dissociation and HRR to intentional recall of trauma memories in the laboratory (55,56). In these studies, trauma survivors were asked to give a narrative of the trauma as their HR was recorded. Peritraumatic dissociation and PTSD symptoms were related to smaller HR increases during the narrative. Thus, in line with current models of PTSD (2), physiological responses during cue-driven unintentional retrieval of traumatic material (reexperiencing symptoms, response to trauma pictures) may differ from physiological responses during intentional retrieval of trauma memories.

The present study has strengths and limitations. Among its strengths are the prospective design and the large sample size. Furthermore, all trauma survivors were diagnosed with reliable structured clinical interviews. A limitation is that, although this study employed a prospective design, physiological responses to trauma reminders were only recorded at one time point. It would have been desirable to administer the picture viewing task again at follow-up to test whether the heightened HRR to trauma reminders changes with recovery from PTSD and whether those with chronic PTSD show further generalization to other classes of threat stimuli (14,15). Furthermore, arousal and valence ratings for the pictures were not taken in the main study so that possible differences between the PTSD and no PTSD groups could not be assessed; in addition, it would have been interesting to examine the concordance between self-reported arousal and valence with physiological responses to trauma reminders. Finally, HRR only had limited sensitivity, but satisfactory specificity, in identifying participants at risk of chronic PTSD.

In conclusion, we found that trauma survivors with PTSD showed greater HRR to standardized visual trauma reminders at 1 month after the trauma than those without PTSD. HRR were related to fear and dissociation during the trauma. HRR at 1 month predicted PTSD symptom severity at 6 months post trauma, and predicted over and above what could be predicted from self-reported symptoms at 1 month. The results may have practical implications for identifying people at risk of chronic PTSD after trauma. HR responders had an increased risk of chronic PTSD.

We are grateful to Drs. Elsesser and Sartory for providing some of the stimulus material, and to Jonathan Howard for programming the picture viewing task. We thank Emma Briddon, Judith Kalthoff, Linda Horrell, Melanie Walwyn Martin, Franziska Wallott, Marit Hauschildt, Benjamin Boecking, Anne Reitz, Sarah Auerbach, and Laura Pielmaier, and the staff of King's College Hospital's Emergency Department for their help with recruitment, testing, and data entry; and we thank Daniel Stahl for statistical advice.

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