Heart Rate Responsivity to Script-Driven Imagery in Posttraumatic Stress Disorder: Specificity of Response and Effects of Psychotherapy

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Objective: Previous psychophysiological studies of posttraumatic stress disorder (PTSD) have found heightened physiological responsivity to trauma-specific stimuli, but mostly in combat veterans with high comorbidity rates and with psychiatric medication. Our aim was to investigate psychophysiological responses in two new populations while excluding those confounding influences and to assess the effects of psychotherapy on such responses. **Methods:** Thirty-nine subjects with PTSD (24 civilian outpatients and 15 police officers) and 15 trauma-exposed, non-PTSD control subjects underwent psychophysiological assessment while listening to neutral, stressful, and trauma scripts. Psychophysiological measures were heart rate (HR) and blood pressure in combination with subjective anxiety ratings. In a randomized clinical trial, 20 of the civilians were then assigned to treatment or waitlist groups. Psychophysiological assessment was repeated on them after the treatment stage. **Results:** Both civilians and police with PTSD showed significantly higher HR responses to trauma scripts than the control subjects. After successful psychotherapy with the civilians, HR responsivity to the trauma scripts was significantly reduced, and it correlated positively with PTSD clinical symptoms. **Conclusions:** We confirmed previous findings of heightened psychophysiological responses in PTSD for two new populations while minimizing comorbidity and medication as confounding factors. Successful psychotherapy normalized HR response to trauma imagery. **Key words:** posttraumatic stress disorder, psychophysiology, script-driven imagery, randomized clinical trial, psychotherapy.

BEP = brief eclectic psychotherapy; **DBP** = diastolic blood pressure; **EMDR** = eye movement desensitization and reprocessing; **EMG** = electromyographic; **HR** = heart rate; **M** = mean; **MANOVA** = multivariate analysis of variance; **PLES** = Police Life Event Scale; **PTSD** = posttraumatic stress disorder; **SBP** = systolic blood pressure; **SCID** = Structured Clinical Interview for DSM-IV; **SD** = standard deviation; **SI-PTSD** = Structured Interview for Posttraumatic Stress Disorder; **STAI** = State-Trait Anxiety Inventory; **TG** = treatment group; **WG** = waitlist group.

INTRODUCTION

Posttraumatic stress disorder (PTSD) arises from exposure to a traumatic event and manifests itself in intrusive memories of the trauma, avoidance of stimuli associated with the event, and a constant state of increased arousal (1). Studies of the psychophysiological aspects of PTSD have used the script-driven imagery technique developed by Lang and colleagues (2) to provoke PTSD symptoms and the concomitant increases in autonomic and muscular activity. They reported heightened physiological responses during personalized trauma-related imagery (3–5), thus confirming one of the defining features of PTSD in the Diagnostic and Statistical Manual (DSM)—"physiological reactivity on exposure to internal or external cues that symbolize or resemble an aspect of the traumatic event" (PTSD criterion B.5) (1). Studies investigating physiological responsivity to specifically trauma-related cues have reported sensitivities and specificities in the ranges of 60% to 90% and 80% to 100% (6).

Previous studies have been limited by a focus on specific populations such as combat veterans (3–5,7–14), victims of child abuse (15), motor vehicle accidents (16,17), patients with breast cancer (18), or preschool children (19). The results in many studies could also have been affected by high comorbidity rates (10,20–23) or by the use of psychiatric medication (10,22,23). The first aim of our study was to provide a controlled comparison of psychophysiological responsivity in PTSD populations not studied before—a range of civilian outpatients and police officers—while minimizing any confounding effects of comorbidity and psychiatric medication.

If a heightened physiological responsivity is associated with PTSD, one might expect a normalization of this response after successful treatment of PTSD. Some studies that have assessed treatment responses have indeed reported diminished psychophysiological reactions to trauma-related imagery after treatment (17,24–27). These studies, however, were mostly case reports or noncontrolled studies in which habituation to the scripts over time could have also explained the reduction (6). Some studies were randomized trials and have also reported diminished psychophysiological reactions after treatment (28–31). However, these studies are limited because of: 1) no inclusion of a traumatized control group without PTSD at the pretest stage and no use of different scripts with neutral, stressful, and trauma narratives, which is necessary to assess the specific physiological reactions to traumatic reminders; and 2) most of these studies compared different treatments with an overall decreased effect on physiological reactions after treatment and did not include a control or waiting-list condition (28,30,31), except for one study (29) that also found decreased physiological reactions in the control condition. The

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authors, therefore, concluded that these physiological findings reflected an apparent habituation effect and were not differentially affected by treatment. The second aim of our study was to investigate the effects of psychotherapy on the psychophysiological responsivity in a randomized, controlled trial. We examined whether psychophysiological responses to trauma-specific or other imagery are mitigated in psychotherapy compared with a waiting-list condition and whether any such reductions in response specifically correspond to changes in PTSD symptomatology at the posttest stage, ie, not an effect of habituation.

We hypothesized that 1) both the civilian outpatients and the PTSD police officers would show heightened psychophysiological responses specifically to the trauma scripts in comparison to the controls; 2) psychotherapeutic treatment would normalize such responses and these responses did not only reflect a habituation effect; and 3) posttreatment psychophysiological responses to trauma scripts would correlate positively with the posttreatment PTSD clinical symptom picture.

The first part of our study compares our civilian and police PTSD samples with a non-PTSD, trauma-exposed control group in terms of baseline conditions; psychophysiological responses to neutral, stressful, and trauma-specific scripts; and physiological recovery after the scripts. The second part reports on a randomized, controlled trial involving the civilian outpatients, which assesses the effects of psychotherapy in terms of clinical and psychophysiological variables.

METHODS

Sample and Clinical Assessment

The study was carried out at the Department of Psychiatry, Academic Medical Centre, University of Amsterdam. Thirty-nine patients with PTSD were included in the first part. The 24 civilian outpatients with PTSD had been referred by their general practitioners or occupational physicians to the outpatient clinic run by the Department of Psychiatry, and the 15 police officers with PTSD had been referred by their occupational physicians. The 15 control subjects were police officers who had responded to an advertisement in police papers; all reported exposure to traumatic events satisfied the stressor A(1) criterion for PTSD diagnosis, but none had developed PTSD. The study was approved by the Institutional Medical Ethics Committee of the Academic Medical Centre. Before entering the study, all participants received study information and signed informed consent statements.

The diagnosis of PTSD, based on the DSM-IV criteria, was made with the Structured Interview for Posttraumatic Stress Disorder (SI-PTSD) (32). For the Dutch version of the SI-PTSD, we found a Cronbach's alpha of 0.93 and a Cohen's kappa of 0.88, which can be considered acceptable (33). Besides assessing PTSD, the SI-PTSD elicits information about the presence or absence of the three symptom clusters (reexperiencing, avoidance, and hyperarousal) and scales their severity in both a current and a lifetime perspective. The Structured Clinical Interview for DSM-IV (SCID) (34) was administered to assess comorbidity, the intensity of any major depression (mild to severe), and the severity of any excessive alcohol intake. Three of the 24 civilians and three of the 15 police officers with PTSD currently exhibited a mild secondary (onset after PTSD) first episode of major depression. Although some overlap existed between the PTSD and depressive symptoms, no antidepressive medication was needed. PTSD was the primary diagnosis on which the psychotherapy for the civilians would focus. All participants also completed the List of Traumatic Events and the Police Life Event Scale (PLES) (trauma history), two semistructured interviews recording numbers and severity of traumatic experiences in the past (35,36). An added question about the perceived adverse effects of each specific event was rated on a five-point scale (1 = no effects; 5 = very strong effects). The events listed satisfied the stressor A(1) criterion for PTSD diagnosis. A background questionnaire was also administered to collect information about education.

Exclusion criteria included any major lifetime or current medical or psychiatric diagnosis: organic mental disorder, head trauma with loss of consciousness, mental retardation, seizures, neurological disorders, schizophrenia, psychotic disorders, bipolar disorder, moderate to severe depressive disorder, panic disorder, phobia, obsessive compulsive disorder, or dissociative disorder. Candidates with lifetime or current alcohol or drug abuse or dependence, or use of psychiatric medication, were also excluded.

Procedure

All selected participants visited the Department of Psychiatry for psychophysiological assessment. The 24 civilian PTSD outpatients were then assigned randomly to a treatment or waitlist group. A colleague who had done no assessments used a computer program to randomly assign the patients to each condition in a block design. The researchers were blind to group assignment. The PTSD police officers and the traumatized non-PTSD control subjects were examined at the pretest stage only. After termination of the treatment stage 4 months later, all the civilians in both the treatment and waitlist groups were tested a second time with the List of Traumatic Events, SI-PTSD, and SCID. Within 1 week afterward, a second psychophysiological assessment was carried out.

Psychophysiological Assessment

We asked all 54 participants to relate two past personal experiences—one stressful but nontraumatic event and one traumatic event that satisfied DSM-IV criterion A for PTSD—and we used these to create scripts as described in the literature (4). For the patients with PTSD, we created the trauma script using the event thought to have caused PTSD; in the traumatized control group, we asked for the traumatic event that had had the greatest impact on their lives. The trauma scripts for most participants, both civilian and police, involved interpersonal violence. The neutral script (brushing your teeth) was the same for every participant, and the stressful script was based on the personally experienced nontraumatic event. During the psychophysiological assessment, the scripts were played back to each participant one at a time in the following order: neutral, stressful, and trauma. They listened to the scripts and were instructed to imagine each event as vividly as possible, as though they were actually reexperiencing it.

Physiological Responsivity

Physiological variables were collected 2 minutes before (baseline phase), during (imagery phase of 2 minutes), and 4 minutes after (recovery phase) the playing of each script. Physiological variables consisted of heart rate (HR), systolic blood pressure (SBP), and diastolic blood pressure (DBP) measured with a Boso Carat (oscillometric) device on the left arm.

Psychological Responsivity

All participants completed a State-Trait Anxiety Inventory (STAI) (37) after listening to each script to determine their subjective psychological anxiety score in relation to that script.

Psychotherapy

Details of our psychotherapeutic procedure have been published previously (38,39) and are described here only briefly. The treatment described in the manual consisted of Brief Eclectic Psychotherapy (BEP) with 16 weekly individual sessions of 45 to 60 minutes each. As Brewin (40) has noted, psychotherapy for PTSD generally requires two elements: 1) detailed, repeated exposure to traumatic information; and 2) modification of maladaptive beliefs about events, behaviors, or symptoms. BEP addresses both these elements.

The psychotherapists working on the present study were clinically experienced psychiatry residents, and they received supervision every 2 weeks from two senior psychiatrists (I.VE.C. and B.P.R.G.). All sessions were audiotaped. A rating system covering the elements of BEP described here was

developed to analyze treatment integrity. Treatment integrity was approximately 75%, with a kappa >0.81, indicating good adherence to the protocol.

Statistical Analysis

Statistical analysis was performed with SPSS 11.0 for Windows (SPSS, Chicago, IL). Demographic and clinical PTSD variables, and STAI scores were analyzed to compare the two PTSD groups and the traumatized control group, as well as the treatment and waitlist subgroups, using chi-squared tests for categorical variables and multivariate analysis of variance (MANOVA) for continuous variables. In connection to each script, three values were calculated for each physiological variable: 1) the baseline mean, 2) the mean response score, and 3) the mean recovery score. Response scores were calculated by subtracting the baseline mean from the imagery phase mean and recovery scores by subtracting the recovery phase mean from the imagery phase mean. Multivariate analysis of variance was used to compare the baseline means, response scores, and recovery scores on each script for the civilian and police PTSD groups and the control group, as well as for the civilian treatment and waitlist subgroups, analyzing HR, SBP, and DBP simultaneously as dependent variables. At the posttest stage, after the treatment group received psychotherapy, the effects of the therapy were measured by again analyzing the PTSD clinical variables, STAI scores, and physiological variables with MANOVA using the pretest measurements as covariates. Correlations of the posttreatment PTSD total scores with the HR response and STAI scores in reaction to especially the trauma scripts were obtained using Pearson product-moment correlation coefficients (two-tailed) with a significance level of 5% ($\alpha = 0.05$).

RESULTS

Pretest Comparisons Across Groups

Demographic and Clinical Variables for the Two Posttraumatic Stress Disorder Groups and the Traumatized Control Group

Thirty-nine subjects with PTSD (24 civilians and 15 police officers) and 15 trauma-exposed control subjects were assessed in the first part of the study. Table 1 shows the demographic and clinical variables for the total sample.

No statistical differences were found among the two PTSD groups and control group in terms of age, gender, education, or smoking. Consistent with their diagnoses, both PTSD groups had higher PTSD total scores as well as higher reexperiencing, avoidance, and hyperarousal scores than the controls. No statistical differences were found for comorbid mild major depression (see Table 1).

Pretest Psychophysiological Responsivity in Civilians With Posttraumatic Stress Disorder as Compared With Traumatized Controls

Table 2 shows the psychophysiological variables of the two PTSD groups and the control group.

Psychological Responsivity

The STAI (subjective anxiety) scores in reaction to each of the three scripts at pretest were significantly higher in the civilians with PTSD than in the traumatized control subjects (multivariate tests: $F[1] = 23.81$, $p < .001$; tests of between-subjects effects: neutral: $F[1] = 27.17$, $p < .001$; stressful: $F[1] = 36.05$, $p < .001$; trauma: $F[1] = 53.73$, $p < .001$).

Physiological Responsivity

The multivariate tests results for the physiological variables were $F(1) = 2.39$, $p = .058$). The tests of between-subjects effects were as follows: In terms of baseline (prescript) means on the physiological variables, only the HR before the trauma script ($F[1] = 4.69$, $p = .037$) was significantly higher in the PTSD group than in the controls. In terms of response scores, the increase in HR during the trauma script ($F[1] = 5.64$, $p = .023$) was also significantly greater in the PTSD group, but not during the neutral and stressful scripts. In terms of recovery scores, there were no significant differences on physiological variables between PTSD and control subjects after any of the scripts.

Although three PTSD subjects had a secondary first episode of mild major depression as compared with none of the control subjects, MANOVA revealed no significant differences within the PTSD group between depressed and nondepressed subjects in terms of physiological responsivity.

TABLE 1. Demographic and Clinical Characteristics of Two Posttraumatic Stress Disorder (PTSD) Groups versus a Control Group ($n = 54$)

Variable	PTSD Civilian Outpatients ($n = 24$)	PTSD Police Officers ($n = 15$)	Control Subjects ($n = 15$)	$F(2)/\chi^2$	
				df	p^a
Age in years, mean (SD)	38.9 (9.4)	36.2 (11.3)	37.2 (9.9)	0.36	0.70
Education in years, mean (SD)	12.4 (2.9)	11.6 (2.7)	11.3 (2.5)	0.84	0.44
Duration of PTSD symptoms in years, mean (SD)	4.4 (6.9)	2.8 (4.3)	0 (0)	3.32	0.04
PTSD total score, mean (SD)	11.2 (1.9)	9.9 (1.9)	0.1 (0.5)	236.25	<0.001
Reexperiencing score, mean (SD)	3.7 (0.9)	3.1 (1.2)	0 (0)	87.4	<0.001
Avoidance score, mean (SD)	3.7 (0.9)	3.5 (0.5)	0 (0)	161.71	<0.001
Hyperarousal score, mean (SD)	3.8 (1.0)	3.3 (0.9)	0.1 (0.5)	95.00	<0.001
Gender, N (%)				1.08	0.58
Male	11 (45.8)	9 (60)	9 (60)		
Female	13 (54.2)	6 (40)	6 (40)		
Mild major depression, N (%)	3 (12.5)	3 (20)	0 (0)	3.12	0.21
Smoking, N (%)	7 (29.2)	7 (46.7)	6 (40)	5.46	0.24

[a] Multivariate analyses of variance for continuous variables and chi-squared test for categorical variables.
SD = standard deviation.

TABLE 2. Psychophysiological Responsivity to Script-Driven Imagery in Two Posttraumatic Stress Disorder (PTSD) Groups and a Control Group (n = 54)

	PTSD Civilian Outpatients (n = 24)			PTSD Police Officers (n = 15)			Non-PTSD Traumatized Controls (n = 15)		
	Baseline Mean	Response Score	Recovery Score	Baseline Mean	Response Score	Recovery Score	Baseline Mean	Response Score	Recovery Score
Neutral script									
HR	70.3 (9.8)	2 (5.7)	0.6 (3.5)	67 (10.7)	1.2 (2.3)	−0.75 (2.2)	63.8 (14)	3.2 (3.4)	1.2 (3)
SBP	124.7 (13.7)	−3.2 (7.2)	2.2 (5.3)	124.9 (14)	−0.3 (12)	2.5 (4.3)	130.8 (17.3)	−3.2 (5.3)	3.9 (2.9)
DBP	76.7 (9.6)	−1.2 (4.2)	0.3 (8.3)	79.1 (12.5)	−1.5 (2.6)	2.3 (4.9)	76.3 (12.3)	−1.3 (2.7)	2.7 (3.3)
STAI		40.5 (9.8)***			36.2 (11.5)**			26.2 (5.1)	
Stressful script									
HR	71.5 (10.5)	3.7 (5.6)	2.3 (5.5)	68.7 (13)	1.3 (4.5)	0 (2.5)	64.4 (13.5)	1.8 (2.7)	0.9 (2.3)
SBP	124.6 (11.7)	−2.3 (7)	1.9 (5.8)	126.9 (15.5)	0.3 (6.2)	6.2 (5.6)	129.4 (18.9)	−3.2 (6.4)	4.2 (3.3)
DBP	77.6 (8.3)	−0.6 (4.3)	1.7 (8.3)	78.7 (11)	0.6 (6.1)	4 (7.2)	75.8 (13)	−0.3 (3.3)	3.1 (2)
STAI		49.6 (10.4)***			42.5 (12.7)**			31.8 (6.1)	
Trauma script									
HR	72 (9.8)*	8.2 (10.3)*	4.6 (9.4)	69 (12.7)	5.3 (5.3)*	2.3 (4.7)	63.8 (13.9)	1.7 (2.6)	1.5 (3.4)
SBP	124.8 (15.7)	5 (14.1)	5.8 (11.8)	126.7 (17.4)	2.1 (7.3)*	4.6 (6.8)	125.8 (17.2)	−2.6 (4.4)	1 (3.2)
DBP	78.3 (12.3)	6.8 (20.5)	6.9 (16)	77.9 (12.7)	5.3 (10.1)*	6.8 (9)	75.1 (12.7)	−1.1 (2)	2.6 (2.4)
STAI		60.3 (10.9)***			53.9 (15.7)‡			34 (10.8)	

* $p < .05$; ** $p < .01$; *** $p < .001$.

Response score indicates imagery score minus baseline mean; recovery score, imagery score minus recovery score; HR, heart rate; SBP, systolic blood pressure; DBP, diastolic blood pressure; STAI, State-Trait Anxiety Inventory. Values are mean group scores (standard deviation).

Psychophysiological Responsivity in Police Officers With Posttraumatic Stress Disorder as Compared With Traumatized Controls

Psychological Responsivity

STAI scores in reaction to each of the three scripts were likewise significantly higher for the police officers with PTSD than for the control subjects (multivariate tests: $F[1] = 5.51$, $p = .005$; tests of between-subjects effects: neutral: $F[1] = 9.45$, $p = .005$; stressful: $F[1] = 8.67$, $p = .006$; trauma: $F[1] = 16.38$, $p < .001$) (Table 2).

Physiological Responsivity

The multivariate tests results for the physiological variables were $F(1) = 0.70$, $p = .75$. The tests of between-subjects effects were as follows: In terms of the baseline means on the physiological variables, no significant differences were apparent between PTSD police officers and non-PTSD controls before any of the scripts. Response scores for HR ($F[1] = 5.44$, $p = .027$), for SBP ($F[1] = 4.46$, $p = .044$), and for DBP ($F[1] = 5.86$, $p = .022$) were significantly higher in the PTSD group in reaction to the trauma script than for the controls, whereas no significant differences appeared on the neutral and stressful scripts. In terms of recovery scores, no significant physiological differences were found between PTSD and control groups after any of the scripts.

Here, too, three PTSD subjects had secondary first-episode mild major depression as compared with none of the controls, but MANOVA again revealed no significant differences between depressed and nondepressed subjects in the PTSD group in terms of physiological responsivity.

Treatment Effects in the Civilian Outpatients

Demographic and Clinical Variables in the Treatment and Waitlist Groups

Our statistical analysis of the treatment effects was carried out on the net PTSD trial sample ($N = 20$) comparing the treatment subgroup ($N = 9$) to the waitlisted subgroup ($N = 11$). Figure 1 shows a flow diagram of patients with PTSD who were included, randomly assigned, received treatment, and analyzed for the primary outcome.

At the pretest stage, no statistical differences were evident between the two subgroups on any of the demographic or clinical variables (not in the table).

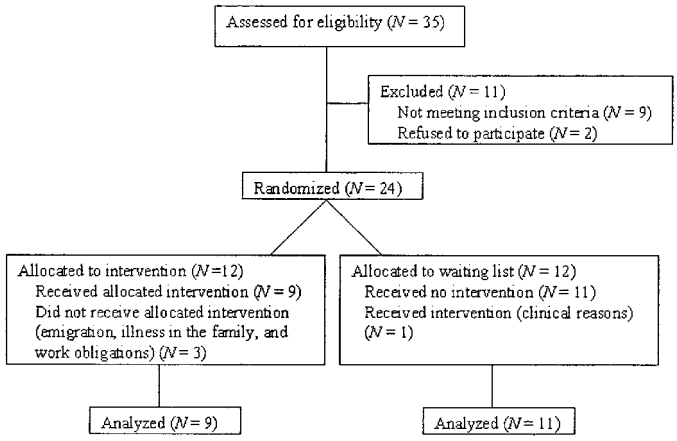

Figure 1. Flow diagram of patients with posttraumatic stress disorder who were included, randomly assigned, received treatment, and analyzed for the primary outcome.

After treatment, the condition of the patients in the treatment group had improved on all PTSD clinical variables (multivariate tests: $F[1] = 4.79$, $p = 0.018$; tests of between-subjects effects: PTSD total score: $F[1] = 13.80$, $p = .002$; reexperiencing: $F[1] = 12.33$, $p = .003$; avoidance: $F[1] = 7.43$, $p = .016$; hyperarousal: $F[1] = 16.47$, $p = .001$) in comparison to the waitlist group.

Psychophysiological Changes After the Treatment Period in the Treatment and Waitlist Groups

Table 3 summarizes the pretest–posttest comparison of the two groups in terms of psychophysiological responses to the scripts (for purposes of clarity, only the STAI and the physiological response scores are shown; statistics refer to the entire set of variables).

Psychological Responsivity

At the pretest stage, no significant differences between the treatment and waitlist groups were evident in terms of STAI scores or physiological measures. After treatment, the STAI scores were significantly lower in the treatment group after the stressful and trauma scripts (multivariate tests: $F[1] = 1.66$, $p = .22$; tests of between-subjects effects: stressful: $F[1] = 4.43$, $p = .053$; trauma: $F[1] = 4.82$, $p = .044$).

Physiological Responsivity

The multivariate tests results for the physiological variables after treatment were $F(1) = 3.94$, $p = .38$. The tests of between-subjects effects were as follows: Significant reductions relative to the waitlist group occurred in DBP baseline means (stressful: $F[1] = 4.59$, $p = .046$). Especially for the trauma scripts, significant reductions relative to the waitlist group also occurred in SBP baseline mean (trauma: $F[1] = 5.43$, $p = .032$), mean HR response score (trauma: $F[1] = 4.61$, $p = .046$), and mean DBP recovery score (trauma: $F[1] = 4.78$, $p = .042$). Figure 2 shows the HR responses to the trauma scripts in the two PTSD groups and the non-PTSD control group at pretest, and the effects of psychotherapy at posttest in the treatment group as compared with the waitlist group.

Correlations Between Heart Rate Responses and Posttraumatic Stress Disorder Severity at the Posttest Stage

After the treatment group had received psychotherapy, the PTSD total scores in the combined treatment and waitlist groups were positively and linearly correlated with the HR responses to the trauma script ($r = 0.56$, $p = .01$), as well as with the STAI scores after the stressful and trauma scripts (stressful: $r = 0.67$, $p = .001$; trauma: $r = 0.79$, $p < .001$). No significant correlations were found between PTSD total scores and HR responses to the neutral and stressful scripts.

DISCUSSION

In comparing psychophysiological responsiveness in patients with PTSD and trauma-exposed controls, we found higher HR responses specifically to the trauma scripts in both PTSD groups as compared with the controls, whereas no differences occurred across groups in response to the neutral and stressful scripts. Baseline HR was higher for the civilians with PTSD before the trauma script, and blood pressure was higher for the PTSD police officers during it. We thus con-

TABLE 3. Effects of Psychotherapy on Psychophysiological Responsivity to Different Scripts in Civilian Outpatients with Posttraumatic Stress Disorder ($n = 24$)

	Pretest Stage TG ($n = 9$)	WG ($n = 11$)	Posttest Stage TG ($n = 9$)	WG ($n = 11$)	$F(1)$	
					df	p^a
Neutral script						
HR	3.9 (4.2)	1.7 (7.2)	1.0 (3.9)	2.3 (3)	0.74	0.40
SBP	0.1 (5.4)	−7 (8)	−1.4 (5)	−2.6 (5)	0.26	0.62
DBP	−0.1 (3.6)	−2.1 (5.2)	−1.4 (4.8)	−2.5 (2.9)	0.41	0.53
STAI	44.7 (9.7)	37.6 (10.3)	38.6 (13.6)	38 (9.1)	3.7	0.073
Stressful script						
HR	5.2 (4.4)	3.6 (5)	1.8 (3)	1.7 (6.3)	0.00	0.98
SBP	−0.6 (8.7)	−2.5 (6.5)	−4.3 (7.7)	0.5 (4.4)	2.97	0.10
DBP	1.2 (5)	−1.3 (3.9)	−0.1 (3.4)	0.0 (2.2)	0.01	0.94
STAI	50.8 (8.3)	49.0 (13.6)	42 (14.7)	52.5 (11.1)	4.43	0.053
Trauma script						
HR	7.4 (7.7)	9.4 (12.2)	0.5 (4.9)	4.7 (3.8)	4.61	0.046[b]
SBP	4.3 (5.2)	6.3 (20.7)	−1.3 (3.3)	−4.8 (8)	1.50	0.24
DBP	3.6 (5.8)	9.5 (29.9)	−1.0 (3.7)	−1.2 (4.8)	0.01	0.91
STAI	58.7 (9.3)	62.7 (13.4)	47.7 (19.8)	62.6 (12)	4.82	0.044

Values are mean response or STAI scores for the group (standard deviation); statistics refer to all categories of the physiological variables.

[a] Multivariate analysis of variance with pretest measurements as covariates.

[b] The patient who could not remain on the waiting list received treatment and benefited from it. By analyzing this patient in the treatment group, the HR responsivity in reaction to the trauma scripts after treatment were significantly more reduced ($F[1] = 6.05$, $p = .024$).

TG = treatment group; WG = waitlist group; HR = heart rate; SBP = systolic blood pressure; DBP = diastolic blood pressure; STAI = State-Trait Anxiety Inventory.

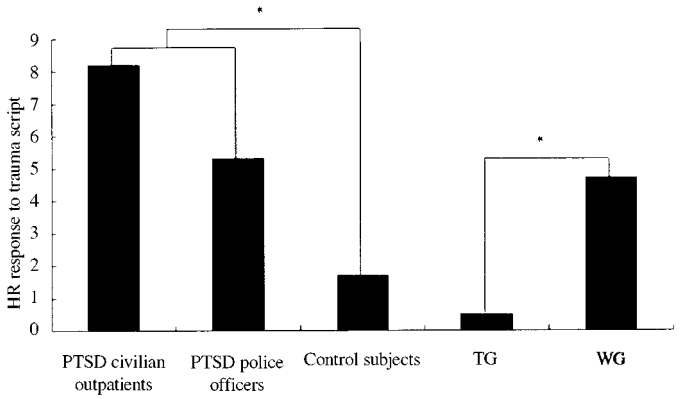

Figure 2. Heart rate responses to trauma scripts in two posttraumatic stress disorder (PTSD) populations and a control group, and the effects of psychotherapy in a randomized controlled trial. TG indicates treatment group posttreatment; WG, waitlist group posttreatment; HR, heart rate. *$p < .05$, **$p < .01$, and ***$p < .001$.

firmed results from previous PTSD studies that reported heightened physiological responsivity to trauma-related cues compared with individuals without PTSD (3,4,5,15), but not in two new populations with low comorbidity and no psychiatric medication. Important to note is that, in our study, subjective anxiety (STAI) scores were significantly elevated for all scripts in both PTSD groups but that HR response was elevated on the trauma script only. Hence, the heightened HR response to trauma cues appears to be a very specific marker of PTSD. Consistent with our findings, Orr and Roth (6) concluded earlier that increased physiological response to trauma imagery is highly indicative of PTSD and suggested that this reflects an elevated sensitivity to unconditioned aversive stimuli. Although these studies were cross-sectional studies in which no causal relationships could be established between psychophysiological responses and PTSD symptoms, two studies with longitudinal designs have also reported elevated HRs in trauma victims who were later to develop PTSD (41,42). Heart rate may therefore also be an effective indicator of *vulnerability* to PTSD, even before it develops.

Furthermore, we showed that the elevated heart rate response to the trauma script was normalized after successful psychotherapy in the civilian sample. Because all patients in this randomized clinical trial heard the same individual scripts at the pretest and posttest stages, habituation to the scripts probably developed in both the treatment and the waitlist groups. Despite this, HR response to the trauma script significantly decreased in the treatment group relative to the waitlist group. Subjective anxiety scores, which were significantly elevated in PTSD subjects but, unlike HR response, did not differ between scripts at pretest, were now significantly lower on the stressful and trauma scripts in the treatment group. At posttest stage, HR responsivity to the trauma scripts was positively and linearly correlated with the severity of PTSD symptomatology. Several other studies have likewise reported diminished psychophysiological responses to trauma-related imagery after treatment (17,24–27,28–31). In a case report on combat-related PTSD, Keane and Kaloupek (26) found that HR response during recall of the traumatic event was lower after treatment with imaginal flooding than before treatment. Boudewijns and Hyer (24) reported that better adjustment 3 months posttreatment was associated with reduced skin conductance responses during trauma-related imagery. Shalev et al. (27) described in a case report three patients with PTSD treated with systematic desensitization and found a reduction in psychophysiological responses to trauma-related imagery. Cohen et al. (25), although not recording responses to trauma imagery, noted that HR variability at rest was normalized in patients with PTSD treated with a selective serotonin reuptake inhibitor. Because most of these studies were noncontrolled case reports, habituation to the trauma imagery cannot be excluded as an explanation for the reduced heart responsivity after treatment. Our study lends support to their findings and uses a waitlist control group to overcome such habituation effects. Five studies were randomized trials in which psychophysiological reactions were assessed (28–31). Renfrey and Spates (28) investigated three groups who were treated with eye movement desensitization and reprocessing (EMDR) and two modified forms of EMDR, and found an overall effect of decreased HR after treatment. Rogers et al. (30) found a trend toward decreased HR reactivity in both treatment groups in which a single EMDR session was compared with exposure. Wilson et al. (31) described three groups who were treated with EMDR and two modified forms of EMDR and found, in the regular EMDR, an overall slowed HR and the galvanic skin response decreased in a clear "relaxation response." Blanchard et al. (17) showed that cardiovascular reactivity to trauma cues diminished with successful psychosocial treatment of PTSD. Carlson et al. (29) compared EMDR, biofeedback-assisted relaxation, and routine clinical care with each other, and reported that the significant overall pre/post effects obtained in electromyographic (EMG) variables may have reflected a general habituation of arousal responses that was independent of treatment. In our randomized, controlled trial, successful psychotherapy normalized HR responses to trauma imagery, and this finding could not be explained by a habituation effect.

Even when few studies had investigated the effects of treatment for PTSD using psychophysiological outcome measures, hypotheses were formulated on how different treatments might affect those biological correlates. Foa and Kozak (43) suggested that effective exposure-based treatments may intervene to modify a fear network in which associative learning has combined psychophysiological and neuroendocrine responses with situational cues of the traumatic event. Pitman et al. (44) proposed that effective medication may modulate subcortical activation and/or increase the capacity of cortical structures to do so. Our BEP psychotherapy of 16 weekly sessions involved repeated detailed exposure to the traumatic event and subsequent modification of maladaptive beliefs about it, the elements described by Brewin (40). Exposure therapy processes the trauma to modify the affective and cognitive valences associated with the traumatic memories (43,45). This emotional adaptation should lead to decreased

autonomic arousal during exposure (43). Our study seems to confirm this.

We should comment on several limitations of our study. Organizational considerations prevented us from examining the PTSD and non-PTSD police officers at the posttest stage. As a consequence, our trial sample of civilians was relatively small, but we nevertheless obtained significant effects in the randomized, controlled trial. Because we did not play the three scripts to the subjects in a pseudorandom order, they may have learned to anticipate them. Had we varied the sequence, however, the startle response induced by the trauma script might have seriously confounded the results. Although it would have also been informative to record physiological measures like facial electromyogram and skin conductance in addition to HR and BP, increased HR has been the most consistent finding in the PTSD literature so far (3,8,46).

Future studies could use psychophysiological assessment to investigate vulnerability factors for the development of PTSD. Such procedures could have practical implications for personnel selection, especially in such high-risk professions as police work. Other important issues that need investigating are the effects of different types of treatments on the biological correlates identified in PTSD and the role that psychophysiological assessment could play in gauging vulnerability to relapse.

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