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PREDICTION OF EXPERIMENTAL PAIN SENSITIVITY BY ATTENTION TO PAIN-RELATED STIMULI IN HEALTHY INDIVIDUALS[1, 2]

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Summary.—The aim of the present study was to assess the predictive power of the processing of pain-related information, comprising concepts of hypervigilance to pain, pain catastrophizing, and pain-related anxiety (questionnaires) as well as attentional processes related to pain-related stimuli (dot-probe task) in explaining individual differences in experimental pain sensitivity (pressure/thermal pain threshold). In 160 healthy participants (ages 13–61; 80 females), results of hierarchical multiple regression analyses showed that self-reported hypervigilance contributed significantly to the prediction of pain sensitivity, whereas pain catastrophizing and anxiety did not. However, inconsistent with prediction, the effect was in the opposite direction, indicating that vigilance to pain sensations or stimuli is associated with lower pain sensitivity in healthy individuals. Entering the attentional bias indices from the dot-probe task showed that an increased bias to pain words is related to higher experimental pain sensitivity, which confirms the hypothesis.

Besides physical characteristics of the stimulus and features of the peripheral and central nociception, psychological factors, including attentional and emotional factors in particular, seem to determine individual pain sensitivity. Recent interest has focused on variables describing the processing of pain-related information, e.g., hypervigilance to pain, pain catastrophizing, pain-related anxiety, or fear of pain (Sullivan, Thorn, Rodgers, & Ward, 2004; Lautenbacher, Huber, Kunz, Parthum, Weber, Griessinger, *et al.*, 2009). Positive evidence for the influential role of these factors in pain processing has been provided both by experimental studies, in which these factors were manipulated (Kirwilliam & Derbyshire, 2008), and by correlational studies, which investigated the inter-individual relationships between these factors and pain processing (George, Dannecker, & Robinson, 2006; Lautenbacher, *et al.*, 2009; Lautenbacher, Huber, Schoefer, Kunz, Parthum, Weber, *et al.*, 2010).

Hypervigilance can be understood as an attentional process, including (a) automatic shift toward certain classes of events or kinds of stimuli and (b) difficulty disengaging from them (Crombez, Eccleston, Baeyens,

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& Eelen, 1998; Van Damme, Crombez, & Eccleston, 2002; Van Damme, Crombez, Eccleston, & Roelofs, 2004). Hypervigilance to pain-related stimuli and pain experience was assumed to increase pain experiences (McCracken, 1997; Goubert, Crombez, & Van Damme, 2004; Lautenbacher, *et al.*, 2009) and pain sensitivity (Sullivan, *et al.*, 2004), although there have been examples demonstrating the opposite relationship (Verhoeven, Crombez, Eccleston, Van Ryckeghem, Morley, & Van Damme, 2010).

Two methodological approaches have been established to assess these types of attentional variables, namely self-report questionnaires and experimental tests of attention. Self-reports seem to represent a more explicit form of hypervigilance, as the individual is required to consciously report attentional absorption by pain-related stimuli in everyday situations (McCracken, 1997; Crombez, 2006). In contrast, the experimental tests of attention target the implicit selection of pain-related information, which can be assessed only at a behavioral level (De Houwer, Teige-Mocigemba, Spruyt, & Moors, 2009). The two best-known candidates are the emotional Stroop test and the dot-probe task; the latter has become the major tool in pain research in recent years. The dot-probe task has promised to assess both attentional engagement and disengagement by using pain words or pain faces as pain-related stimuli (Crombez, Van Damme, & Eccleston, 2005; Crombez, 2006). Although both self-reported hypervigilance and the attentional biases assessed by the dot-probe task have appeared to be useful predictors for certain dimensions of clinical pain (Lautenbacher, *et al.*, 2009, 2010), they have not been highly inter-correlated (Roelofs, Peters, van der Zijden, Thielen, & Vlaeyen, 2003), challenging the perspective on hypervigilance as a unidimensional concept.

Beyond the variables just described with a focus on attentional filtering, it has been assumed that emotional factors affect the experience of pain, e.g., pain catastrophizing and pain-related anxiety. Pain catastrophizing is considered to be an exaggerated negative interpretation of actual and anticipated pain experiences, which enhances pain sensitivity (Kunz, Chatelle, Lautenbacher, & Rainville, 2008; Quartana, Campbell, & Edwards, 2009). Pain-related anxiety or fear of pain include, in cognitive terms, concern about the consequences of pain, and in physiological terms, they include symptoms of fear associated with the expectation of pain, as well as behavioral avoidance of those activities which may increase pain. Pain-related anxiety and fear of pain appear to be relevant predictors of experimental pain sensitivity and of pain reports of patients (Van den Hout, Vlaeyen, Houben, Soeters, & Peters, 2001; George, *et al.*, 2006; Hirsh, George, Bialosky, & Robinson, 2008).

Earlier reports suggest there is a close relationship between pain anxiety and pain catastrophizing on the one hand and self-reported pain hy-

pervigilance on the other hand, whereas attentional bias measures derived from the dot-probe task do not correlate well with emotional factors (Roelofs, Peters, & Vlaeyen, 2002; Roelofs, Peters, van der Zijden, *et al.*, 2003). Accordingly, self-reported hypervigilance is likely to influence pain sensitivity in conjunction with self-reported pain anxiety and pain catastrophizing, whereas the attentional filtering assessed at a behavioral level by the dot-probe task is supposedly a completely different influence. Accordingly, one objective of the study was to investigate the inter-correlations of the self-report measures (anxiety, catastrophizing, hypervigilance) and the behavioral test of pain-related attentional processing (dot-probe task). A second objective was, if the assumed low correlation between self-report and behavioral measures could have been verified, to assess their contributions to the explanation of pain sensitivity separately. As a third objective, the role of general state anxiety for these predictions was examined. To understand this argument more clearly, a few words might be necessary. The processing of pain-related information has been observed to depend also on general state anxiety (e.g., Sullivan, *et al.*, 2004). Additionally, pain sensitivity has been found to be influenced by general state anxiety (Komiyama, Wang, Svensson, Arendt-Nielsen, Kawara, & De Laat, 2008; Tekdogan, Tuncel, Nalcacioglu, Kisa, Aslan, & Atan, 2008). Therefore, it was assumed that the influences of pain-related attentional and emotional processing on pain sensitivity require a general activation of the fear and anxiety system. In other words, the more specific attentional and emotional influences on pain sensitivity come into play only when an individual becomes sufficiently anxious and frightened. Therefore, it was proposed that these influences might be moderated by the state anxiety. Pursuing the third objective was definitely innovative, whereas pursuing the other two objectives was likely to add valuable results because a particularly large sample was investigated, balanced in sex with an informative age range (not only student populations), and screened carefully for acute or past pain experiences with potential effect on the results.

Method

Participants

One hundred sixty individuals (80 women) ranging in age from 13 to 61 years ($M = 31.8$, $SD = 14.7$), free from major health problems, participated in the study. Participants were recruited via announcement in public buildings in Bamberg and amongst students of the Otto-Friedrich University of Bamberg. Sex of the individuals was equally distributed in each age range. Furthermore, female participants were asked whether they used contraceptives; in women not using oral contraceptives, sessions were scheduled in a way that all phases of the natural menstrual cycle were equally frequent. This scheduling of sessions allowed for control of po-

tential menstrual cycle effects, which are likely in the case of pain parameters (Teepker, Peters, Vedder, Schepelmann, & Lautenbacher, 2010). No sex differences were found in any of the variables included in the study.

The inclusion criteria for the study were (1) age between 13 and 65 years and (2) satisfactory performance on a word-comprehension task as well as a reading task to ensure that participants read and understand words sufficiently in the dot-probe task. An age range between 13 and 65 years was used to cover adolescents and adults from puberty to old age. Such an approach helps to avoid misleading overgeneralization of age-specific findings. Individuals were excluded if they: (1) reported history of any psychiatric or neurological disorders when asked for in the standardized diagnostic screening (Mini–DIPS; Margraf, 1994), (2) were under psycho-pharmacological treatment, (3) took analgesics, (4) reported any acute or chronic pain conditions, or (5) previous surgical interventions.

The study protocol was approved by the ethics committee of the medical faculty of the University of Erlangen. All participants gave written informed consent. Except for students, who received course credit as compensation for their efforts, all participants were paid for participation. Neither the number of credit points nor the sum of money was dependent on the test performance to keep incentives similar for all participants.

Procedure

The session took place from 3:00 p.m. to 7:00 p.m. and lasted for approximately 2 hours and 15 minutes. It included the following tests, which were administered in the given order: (1) a screening for psychological disorders by use of a standardized psychological interview (Mini–DIPS; Margraf, 1994), (2) assessment of variables targeting the attentional and emotional mechanisms of pain processing (dot-probe task and questionnaires: Pain Vigilance and Awareness Questionnaire, McCracken, 1997; Pain Anxiety and Symptom Scale, McCracken, Zayfert, & Gross, 1992; Pain Catastrophizing Scale, Sullivan, Bishop, & Pivik, 1995), (3) assessment of pain sensitivity (pain thresholds), and (4) assessment of state anxiety (questionnaire: State-Trait Anxiety Inventory, Laux, Glanzmann, Schaffner, & Spielberger, 1981). State anxiety was assessed at the end of the session on purpose because the interest was whether the effects of anticipatory thoughts and emotions relating to pain assessed by questionnaires in (2) on pain sensitivity assessed by experimental pain tests in (3) were dependent on the activation of the fear system. This effective activation was assumed to become first apparent during or after the experimental pain test.

Measures

Assessment of Attentional and Emotional Mechanism of Pain Processing

Dot-probe task.—A selective attention task for emotionally loaded

stimuli (words) based on the dot-probe task described by Keogh, *et al.* (Keogh, Ellery, Hunt, & Hannent, 2001) was used. A German version had been developed and described—also regarding the selection of words—in detail by the authors (Huber, Kunz, Artelt, & Lautenbacher, 2010). The task contained three emotional word categories: pain-related [e.g., *stechend (Ger.)*/stinging], social threat [e.g., *beschämt (Ger.)*/ashamed], and positive words [e.g., *glücklich (Ger.)*/lucky]. A fourth category of neutral words [e.g., *Anstrich (Ger.)*/paintwork] was added. The emotional words were paired with neutral words; neutral-neutral word pairs served as control items. All participants faced the same randomized order of word-pairs in the dot-probe task.

Following Keogh, *et al.* (Keogh, Ellery, *et al.*, 2001), a fixation cross in the center of a computer screen was presented first for 500 msec. Next, two words (a neutral one paired with an emotional one) were presented concurrently, one below and one above the center. After another 500 msec., words were removed and a dot appeared in the location of one of the words. Individuals were required to indicate via a key press as quickly as possible where the dot appeared (below, above) and reaction time was measured. After 20 practice trials, participants had to complete 128 test trials (32 trials per word-pair category; see also Lautenbacher, *et al.*, 2009).

Three different bias indices were calculated based on the reaction times but only for the pain-neutral word pairs: traditional bias index, congruency index, and incongruency index. The aim of the present study was to investigate the relationship between pain-related attention and pain sensitivity: attentional biases for other emotions were not examined in this report. The traditional bias index is a widely used score (Keogh, Dillon, Georgiou, & Hunt, 2001), from which positive values can be interpreted as attentional preference for the pain words and negative values as attentional avoidance of the pain words. However, the traditional bias index appears to be a compound measure mixing several processes. For example, positive values suggest either enhanced attentional engagement with pain stimuli or difficulty in disengaging attention from them, which are not mutually exclusive processes but can concur as earlier studies demonstrated (Roelofs, Peters, Fassaert, & Vlaeyen, 2005; Asmundson & Hadjistavropoulos, 2007). For separate analyses of these different attentional processes, the congruency and incongruency indices reflect more selectively attentional engagement or disengagement (Koster, Crombez, Verschuere, & De Houwer, 2004). Accordingly, besides the traditional bias index, the other two suggested bias indices were computed, the congruency index to indicate attentional engagement and the incongruency index to indicate attentional disengagement.

The traditional attentional bias score was calculated from reaction

times using the formula [(pudl − pldl) + (pldu − pudu)]/2 (Keogh, Dillon, *et al.*, 2001; Keogh, Ellery, *et al.*, 2001; Keogh, Thompson, & Hannent, 2003), where "p" is the pain word and "d" is the dot, "l" is the lower position on the computer screen and "u" is the upper position (e.g., "pudl" means pain word on the upper position and dot on the lower position). The congruency index was calculated by using the formula [(nudu + nudl + nldu + nldl)/4] − [(pudu + pldl)/2], and the incongruency index by using the formula [(pudl + pldu)/2] − [(nudu + nudl + nldu + nldl)/4] , where "p" represents the category of pain words and "n" represents the neutral word category in the trials with neutral word pairs (control items). The meanings of "d," "l," and "u" are the same as described above. Positive scores on the congruency index reflect enhanced engagement with pain stimuli, whereas difficulty in disengaging from pain stimuli is indicated by positive scores on the incongruency index.

Additionally, participants completed a word-comprehension task (Intelligence Structure–Test 2000R Form A, Amthauer, Brocke, Liepmann, & Beauducel, 2001) as well as a reading task (analogue to the dot-probe task, word pairs of real and nonsense words were presented on a computer screen for 500 msec. and individuals had to indicate by key press where the real word appeared) to ensure that participants read and understood words sufficiently (Huber, *et al.*, 2010). Individuals with results poorer than 1.5 standard deviations below the mean in the word comprehension task would have been excluded from the analysis as well as those with more than 15 missing or false values in the reading task. However, none of the 160 participants had to be excluded.

Self-report questionnaires.—Attentional and emotional processes related to pain, of which an individual can principally be aware, were assessed by self-report questionnaires (German versions) for pain hypervigilance (Pain Vigilance and Awareness Questionnaire, PVAQ; McCracken, 1997), pain-related anxiety (Pain Anxiety Symptoms Scale, PASS; McCracken, *et al.*, 1992), and pain catastrophizing (Pain Catastrophizing Scale, PCS; Sullivan, *et al.*, 1995).

The Pain Vigilance and Awareness Questionnaire (McCracken, 1997) was developed as a comprehensive measure of attention to pain and has been validated for use in chronic pain and nonclinical samples (McWilliams & Asmundson, 2007). It consists of 16 items (e.g., "I am quick to notice changes in pain intensity") that are rated on a 6-point scale with anchors 1: Never and 6: Always and that assess awareness, vigilance, preoccupation, and observation of pain. The PVAQ demonstrated good internal consistency (Cronbach's $\alpha = .86$) and good test-retest reliability ($r_{tt} = .80$; McCracken, 1997). For further analyses, the combined sum score of the PVAQ was used, as advised in the literature (McCracken, 1997). PVAQ total scores range from 0–80.

The Pain Anxiety Symptoms Scale (McCracken, *et al.*, 1992; German version: Walter, Hampe, Wild, & Vaitl, 2002) is composed of four subscales: cognitive anxiety, escape/avoidance, fearful appraisal, and physiological anxiety, and is designed to measure pain anxiety across cognitive, behavioral, and physiological domains. The items (e.g., "When I feel pain I am afraid that something terrible will happen") were rated on a 7-point scale with anchors 1: Never and 7: Always. For analyses, the combined sum score (40 items) of the PASS was used as recommended by other authors (McCracken, *et al.*, 1992; Walter, *et al.*, 2002). PASS total score (range 0– 240) showed good internal consistency: Cronbach's $\alpha = .94$ (McCracken, *et al.*, 1992).

The Pain Catastrophizing Scale (Sullivan, *et al.*, 1995; Van Damme, Crombez, Bijttebier, Goubert, & Van Houdenhove, 2002) was developed as a measure of catastrophizing related to pain. It contains 13 items (e.g., "I worry all the time about whether the pain will end") that can be divided into three subscales, namely rumination, magnification, and helplessness. The items were rated on a 5-point scale with anchors 1: Doesn't apply at all and 5: Applies always. The combined sum score of the PCS was used as has been recommended in preceding studies (Sullivan, *et al.*, 1995; Meyer, Sprott, & Mannion, 2008). Pain Catastrophizing Scale total scores range from 0–52. The PCS showed good internal consistency (Cronbach's $\alpha = .95$) for the general scale as well as good test-retest reliability $r_{tt} = .75$ (Sullivan, *et al.*, 1995). According to the user manual, a total PCS score of 30 represents a clinically relevant level of catastrophizing.

The Pain Vigilance and Awareness Questionnaire and the Pain Catastrophizing Scale were translated by the authors. For that purpose, the two questionnaires were submitted to a forward–backward procedure of translation, which means that the German translations were in turn the starting point for a translation by an English native speaker (with German as his second language) back to English (Lautenbacher, *et al.*, 2009). Translations were improved until the original English versions and the final English versions were sufficiently similar. The intercorrelations of the three German questionnaires (PCS, PVAQ, PASS) administered to native German speakers ranged between $r = .47$ and $r = .76$, which was in accordance with intercorrelations reported in the literature for English and Dutch versions administered to native English and Dutch speakers, respectively (Roelofs, Peters, Muris, & Vlaeyen, 2002; Burns, Glenn, Bruehl, Harden, & Lofland, 2003; Roelofs, Peters, McCracken, & Vlaeyen, 2003; Roelofs, McCracken, Peters, Crombez, van Breukelen, & Vlaeyen, 2004; Moss-Morris, Humphrey, Johnson, & Petrie, 2007). Cronbach's alpha coefficients ranged from .86 to .94 for the original English versions, and from

.87 to .93 for the German versions. According to these results, the English and German versions appeared to be sufficiently similar.

Assessment of Experimental Pain Sensitivity

Experimental pain sensitivity was assessed through the measurement of pressure pain threshold, cold pain threshold, and heat pain threshold. All participants were trained until they understood all procedures and were able to follow the instructions before testing. The assessments of pain thresholds were the same as described by Lautenbacher, *et al.* (2009).

Pressure pain threshold.—The assessment of pressure pain threshold was performed using a hand-held pressure algometer (Somedic Sales AB, Algometer type II, Sweden) with a probe area of 1 cm^2. The site of stimulation was the volar site of the right forearm. The pressure was increased from 0 kPa at a rate of change of 50kPa/sec. until the participants felt the first pain sensation and pressed a button. There were five trials and the threshold was calculated as the average of these trials.

Cold and heat pain thresholds.—Thermal stimuli were delivered by use of a Peltier-based, computerized thermal stimulator (Medoc TSA-2001; Medoc Ltd., Ramat Yishai, Israel) with a 3×3 cm^2 contact probe. Site of stimulation was the volar site of the left forearm, where the contact thermode was attached. For the assessment of cold and heat pain thresholds, thermode temperature started from a baseline of 32°C at a rate of 1°C/sec. until the participants felt the first pain sensation and responded by pressing a button; then the temperature returned to the baseline temperature, which was held constant until the next trial. There were five trials each of heat and cold stimulation and the pain thresholds were the average of the five trials.

A decision had to be reached whether the three pain thresholds should be kept separate as criteria or whether an aggregation into one single measure of pain sensitivity should be attempted. Both options have good and bad aspects. The arguments favoring the use of three separate criteria were the low correlations found between pain thresholds induced by different physical stressors in some studies (e.g., Janal, Glusman, Kuhl, & Clark, 1994). However, recent evidence allowed for the assumption of a common factor of pain sensitivity despite qualitative perceptual differences due to the physical properties of the stressors (Neddermeyer, Flühr, & Lötsch, 2008). Furthermore, the data did not refute the use of a single measure because the pain threshold scores were statistically significantly correlated with each other (heat versus cold pain threshold $r = -.41$; heat versus pressure pain threshold $r = .40$; cold versus pressure pain threshold $r = -.41$, respectively; all $ps < .001$). Therefore, a single parameter for pain sensitivity was computed after the normalization of the data.

Assessment of State Anxiety

The State-Trait Anxiety Inventory–State (Laux, *et al.*, 1981) is a self-rating scale and contains 20 items that were designed to measure transitory anxiety states—that is, subjective feelings of apprehension, tension, and worry that vary in intensity and fluctuate based on the situation. Items were rated on a 4-point rating scale with anchors 1: Not at all and 4: Very much so. The STAI–State total score ranges from 20–80. The STAI–State has been demonstrated to have good internal consistency (Cronbach's $\alpha = .90$; Laux, *et al.*, 1981). The STAI–State was applied as a moderator variable, supposed to explain in part the strength of the relationship between experimental pain sensitivity (criterion) and the dot-probe biases, PVAQ, PCS, and PASS (predictors).

Structured Interview

The Mini–DIPS (Margraf, 1994) was used as an initial screening to exclude participants who suffered from psychiatric disorders. The Mini–DIPS is a structured interview according to the *Diagnostic and Statistical Manual of Mental Disorders* (DSM)–IV and International Classification of Diseases (ICD)–10 criteria for current Axis I disorders.

Analysis

To address the current hypotheses, hierarchical multiple regression analyses were performed. The criterion variable was pain sensitivity. To obtain this variable, the three measures of pain threshold were first normalized to a mean of 0 and standard deviation of 1 (z scores). This was done because the units of the three measures differed strongly (°C, kPa). Second, signs of the scores were adjusted to reflect pain sensitivity equally. Third, the means of the three threshold scores were entered as criterion variables as suggested by Diatchenko, *et al.* (Diatchenko, Slade, Nackley, Bhalang, Sigurdsson, Belfer, *et al.*, 2005) for further analysis.

Predictor variables were grouped into self-report measures (PVAQ, PASS, PCS) and behavioral measures (dot-probe). To reduce the effects of multi-collinearity and to prepare the predictor variables for interaction analysis including the moderator variable, all predictor variables were centered (Aiken & West, 1991; Field, 2005). The traditional bias index and the new bias measures (congruencey and incongruency indices) are based in part on identical raw data and, as such, are statistically not independent due to their principles of construction. Therefore, these parameters were entered into two separate regression analyses, as they constitute partially redundant information (i. new bias indices, ii. traditional index).

In a first step, bias indices of dot-probe or PVAQ, PCS, PASS, respectively, combined with STAI–State (moderator variable) were entered. The inclusion of STAI–State in Step 1 was necessary to test the effect of the

moderator variable as a simple predictor, which, on this basis, can only be compared in its interaction with the other predictors as an additional source of explained variance (moderator term; Aiken & West, 1991). This model tested whether the attentional bias indices of the dot-probe task, as well as self-reported hypervigilance, pain catastrophizing, and pain-related anxiety, were meaningful predictors of experimental pain sensitivity and, further, whether these predictors interacted with state anxiety (moderator term; Cohen & Cohen, 1983). For a descriptive analysis of relationships, Pearson correlation analyses were computed. For all analyses in the present study, results were reported as significant if meeting a minimum alpha level of $p \leq .05$.

Results

Descriptive Data and Correlations Among Theoretically Relevant Variables

Table 1 shows mean values and standard deviations of age, experimental pain thresholds, attentional biases from dot-probe task, and questionnaire scores. Pearson correlation coefficients for relationships between and within questionnaires and bias indices based on the dot-probe reaction times are depicted in Table 2. The three dot-probe bias indices were strongly related to each other (all significant at $p < .001$). As expected, the

TABLE 1

Means and Standard Deviations For Measures of Pain Threshold and Indicators of Attentional and Emotional Mechanisms of Pain Processing and State Anxiety

	M	*SD*
Age, yr.	31.98	14.81
Pain threshold[a]		
Heat (°C)	44.41	2.56
Cold (°C)	12.44	8.06
Pressure (kPa)	295.05	118.66
Attentional and emotional mechanisms of pain processing		
PCS	15.33	8.11
PVAQ	34.44	12.13
PASS	71.59	27.90
Attention to pain words		
Traditional attentional bias index	0.28	44.66
Congruency index	−6.87	40.74
Incongruency index	7.16	33.88
State anxiety		
STAI–State	33.48	6.93

Note.—PCS = Pain Catastrophizing Scale; PVAQ = Pain Vigilance and Awareness Questionnaire; PASS = Pain Anxiety Symptoms Scale; STAI–State = State Trait Anxiety Inventory–State. [a]The pain thresholds are not scaled into the same direction. High scores mean high thresholds in the case of heat and pressure pain thresholds whereas low scores mean high thresholds in the case of cold pain threshold. Therefore, signs had to be adjusted when computing the mean score for pain sensitivity.

traditional attentional bias index was positively related to the two new indices, which was in part due to the principles of construction of the indices. The congruency index and the incongruency index, on the other hand, were negatively correlated with each other, which is not trivial and means that increased attentional engagement with pain stimuli was strongly related to lower difficulty in disengaging from pain stimuli. As a note, a "hypervigilant" type of allocation of attention is characterized by both an enhanced tendency to engage and difficulty disengaging. None of the self-report measures (PVAQ, PASS, PCS) was substantially associated with the bias indices. Not surprisingly, however, the self-report measures were significantly interrelated.

TABLE 2

Intercorrelations Between Measures of Attentional and Emotional Mechanisms of Pain Processing

	1	2	3	4	5	6
Self-report						
1. PCS		.42*	.73*	−.01	−.06	.06
2. PVAQ			.48*	.05	−.03	.10
3. PASS				.04	−.06	.13
Dot-probe task						
4. Traditional attentional bias index					.69*	.49*
5. Congruency index						−.30*
6. Incongruency index						

Note.—PCS = Pain Catastrophizing Scale; PVAQ = Pain Vigilance and Awareness Questionnaire; PASS = Pain Anxiety Symptoms Scale. *$p < .001$.

Regression Analyses

The summary of the regression analyses is given in Table 3. First, PVAQ, PCS, and PASS scores were assessed to see if they were significant predictors of pain sensitivity and, additionally, if state anxiety moderated the relation between experimental pain sensitivity and these variables. Step 1 of the model, entering the predictors PVAQ, PCS, and PASS and the moderator variable (STAI–State), accounted for a significant amount of variance (adj $R^2 = .065$, $F_{4,155} = 3.78$, $p < .01$). A significant univariate main effect was found for self-reported hypervigilance to pain stimuli. However, the direction of the relationship between PVAQ and pain sensitivity was contrary to expectations, indicating that low self-reported hypervigilance was associated with increased pain sensitivity. There were no significant univariate main effects of pain catastrophizing (PCS), pain-related anxiety (PASS), and STAI–State. The moderator term was calculated by multiplying the STAI–State by the mean value of PVAQ, PCS, and PASS. Adding this moderator term in a second step did not lead to a significant improvement of the explained variance of the model ($\Delta R^2 = .001$, $F_{1,154} = 0.24$, $p = .62$).

TABLE 3

Results of Stepwise Regression Analyses For the Relationship Between Attentional and Emotional Mechanisms of Pain Processing (Predictors) and Pain Sensitivity (Criterion)

	ΔR^2	*t* (each predictor)	β	sr^2	*p*
Predictors: self-report measures					
Dependent variable: pain sensitivity					
Step 1	.065				.01†
PASS		1.40	0.17	.01	.16
PVAQ		−2.48	−0.22	.04	.01*
PCS		1.37	0.16	.01	.17
STAI–State		0.39	0.07	.01	.39
Step 2	.001				.62
Self-report × State anxiety		0.49	0.04	.00	.62
Predictors: dot-probe task biases					
Dependent variable: pain sensitivity					
Step 1	.037				.03*
Congruency index		1.70	0.14	.02	.09
Incongruency index		−1.25	−0.10	.01	.21
STAI–State		1.69	0.13	.02	.09
Step 2	.002				.58
Dot-probe task × STAI–State		0.56	0.04	.00	.58
Dependent variable: pain sensitivity					
Step 1	.007				.22
Traditional attentional bias index		0.58	0.05	.00	.57
STAI–State		1.62	0.13	.01	.11
Step 2	.002				.58
Attentional bias × STAI–State		0.55	0.04	.00	.58

Note.—PASS = Pain Anxiety Symptoms Scale; PVAQ = Pain Vigilance and Awareness Questionnaire; PCS = Pain Catastrophizing Scale; STAI = State-Trait Anxiety Inventory. β = standardized beta weight; sr^2 = squared semi-partial correlation. *$p < .05$. †$p < .01$.

To exclude the possibility that the surprising negative predictive value of the PVAQ for pain sensitivity was the result of a statistical suppression effect, further analyses were run (Tabachnik & Fidell, 2006). First, the correlation analysis between PVAQ and experimental pain sensitivity was calculated. The correlation coefficient $r = -.08$ was not significant, indicating that the inclusion of the PCS and the PASS may have overestimated the predictive power of the PVAQ. Next, partial correlations between PVAQ and experimental pain sensitivity were calculated that eliminated the variance of the PVAQ shared with the PCS and PASS. The partial correlation coefficient $r = -.21$ ($p < .01$) indicated that the part of the PVAQ which is independent from PCS and PASS was, in fact, inversely related to experimental pain sensitivity.

According to a factor analysis of Roelofs, *et al.* (Roelofs, Peters, McCracken, *et al.*, 2003), only the "attention to changes in pain" scale of the

PVAQ was a factor statistically distinct from PCS and PASS, whereas the "attention to pain" scale shared variance with those scores. In a new multiple regression analysis, including the two subscales of the PVAQ along with all other self-report measures, the first step explained a significant amount of variance of the criterion pain sensitivity ($\Delta R^2 = .114$, $F_{5,154} = 3.98$, $p = .002$). Whereas the regression weights of PCS, PASS, STAI–State, and PVAQ–Attention to pain did not reach significance, not surprisingly, the scale PVAQ–Attention to changes in pain did ($\beta = -0.26$, $t = -3.11$, $p = .002$).

The three bias indices based on the reaction times in the dot-probe task were entered into two separate regression analyses (i. new bias indices, ii. traditional index), because the new bias indices are statistically not independent from the traditional one due to their principles of construction and, therefore, constitute partially redundant information. Entering both new bias indices, namely the congruency and the incongruency indices, and STAI–State into regression analysis in Step 1 explained 4% of the overall variance of the model (adj $R^2 = .037$, $F_{3,156} = 3.06$, $p < .05$; see Table 3). There were no univariate significant main effects of any of the two bias indices; the congruency index, however, appeared to be the stronger predictor of pain sensitivity in this model but still was not significant ($\beta = 0.14$, $p = .09$). The direction of regression weight indicated that increased pain sensitivity was associated with an enhanced tendency to attend to pain-related stimuli (congruency index). The interaction of attentional bias indices × state anxiety (STAI–State) was not a significant predictor of pain sensitivity.

In the second analysis, the traditional bias index alone was not a significant predictor of experimental pain sensitivity (adj $R^2 = .007$, $F_{2,157} = 1.54$, $p = .22$). The moderator term state anxiety (STAI–State) × traditional attentional bias index was also not a significant predictor in the model. Repeating all regression analyses controlling for age and sex in the first step did not change the results, which are therefore not reported here.

Discussion

The first objective of the present study was to investigate the intercorrelations of self-report measures [questionnaires for hypervigilance (PVAQ), pain catastrophizing (PCS), pain-related anxiety (PASS)] and the behavioral test (dot-probe task) of the attentional and emotional processing of pain-related information. As assumed, the self-report and the behavior domains appeared only weakly related and qualified as independent influences on pain sensitivity. Accordingly, as a second objective, the influence of these two domains on pain sensitivity in particular was examined. The results showed that increased pain sensitivity was significantly related to lower self-reported hypervigilance as well as associated with enhanced attentional engagement with pain-related cues (words). In

contrast, self-reported pain catastrophizing and pain-related anxiety did not explain a significant amount of variance of the experimental pain measures. As a third objective, the moderating role of general state anxiety (STAI–State) for the relationship between the self-report and behavioral measures of the attentional and emotional processing of pain-related information, on the one hand, and experimental pain sensitivity on the other hand, was examined. This was done because it was assumed that the relationships become manifest only in an activated fear and anxiety system. State anxiety did not moderate these relationships, in contrast to expectation. These findings will be discussed in detail in the same order of appearance as in the present paragraph.

Self-reports of hypervigilance to pain, pain catastrophizing, and pain-related anxiety did not correlate significantly with the attentional bias indices of the dot-probe task. Previous studies (Roelofs, Peters, & Vlaeyen, 2002; Roelofs, Peters, van der Zijden, *et al.*, 2003) making use of the dot-probe task or the emotional Stroop paradigm likewise produced no positive evidence that the behaviorally-assessed attentional bias for pain stimuli is related to self-reports of pain catastrophizing, fear of pain, and pain vigilance. Therefore, the present findings obtained in a large sample correspond with the literature and suggest a distinction of self-report and behavioral assessment. This does not exclude the alternative that the weak relationship between self-report and behavioral measures on the level of raw data might be a more substantial relationship at a higher-order data level.

The significant intercorrelation of self-report measures also replicated the results of previous studies (Roelofs, Peters, McCracken, *et al.*, 2003; Goubert, *et al.*, 2004; Roelofs, McCracken, *et al.*, 2004). Whereas a strong relationship between anxiety-related pain measures like the PCS and PASS is not surprising, the association of self-reported hypervigilance to pain (PVAQ) and these measures is noteworthy.

Self-reported hypervigilance to pain was a significant predictor of experimental pain sensitivity but in the opposite direction as expected. Increased self-reported hypervigilance was associated with higher pain thresholds or, in other words, lower pain sensitivity. One possible explanation of the described inverse relationship between hypervigilance and pain sensitivity might be that in healthy individuals without any previous major pain experience, a certain amount of attention to pain-related stimuli is necessary to develop adequate coping strategies, which results in increased pain thresholds, which was also assumed by Roelofs and colleagues (Roelofs, Peters, McCracken, *et al.*, 2003). Such a form of attention to pain might be skill-building in healthy individuals but not in chronic pain patients (Nouwen, Cloutier, Kappas, Warbrick, & Sheffield, 2006).

Evidence for the benefit in healthy individuals was provided by findings from Keogh and colleagues (Keogh, Hatton, & Ellery, 2000), indicating that directing attention toward experimentally induced pain may be a more adaptive coping strategy than avoiding it. These results suggest that healthy people, who avoid any confrontation with pain-related stimuli and who remain too "pain-naïve," might be unable to cope sufficiently with pain and, therefore, may show increased pain sensitivity.

Interestingly, when considering the two subscales of the PVAQ, only one, namely the scale "attention to changes in pain," was a significant predictor of pain sensitivity. This scale was shown to be rather independent from the emotional components of processing of pain-related stimuli (e.g., pain catastrophizing or pain anxiety; Roelofs, Peters, McCracken, *et al.*, 2003). It is conceivable that people who are aware of changes in pain early enough are mainly well prepared and do not perceive pain as uncontrollable. From this point of view, attending to changes in pain could be understood as an adaptive coping strategy. It has to be kept in mind that, according to the present data and the data of other authors, such a relationship holds true only for low to moderate hypervigilance (e.g., Roelofs, Peters, Muris, *et al.*, 2002).

Only cross-sectional data, however, were collected in this study. Therefore, the direction of the effect modeled from hypervigilance on pain sensitivity could not be verified. Some researchers have proposed just the opposite, namely that pain sensitivity modulates attention to pain (Crombez, Eccleston, Van de Broecks, Goubert, & Van Houdenhove, 2004), whereas others agreed with the model proposed here (Roelofs, Peters, van der Zijden, & Vlaeyen, 2004; Hirsh, *et al.*, 2008). Only a longitudinal design will answer this question.

Regarding the bias indices of the dot-probe task, results of regression analyses indicated that an increased attentional engagement with pain words (congruency index) was related, although not significantly, to increased experimental pain sensitivity in healthy individuals. These results suggest that individuals who are more attentionally engaged with pain-related stimuli are more pain-sensitive. The lack of more pronounced relationships of the dot-probe task biases with experimental pain sensitivity might be due to the low bias in the present study, normal for pain-free individuals in nonthreatening situations. Furthermore, the present findings add to evidence from the literature that it is important to distinguish between different components of attention such as shifting toward (engagement) and away from (disengagement) pain-related stimuli (Mogg & Bradley, 2002; Van Damme, *et al.*, 2004; Crombez, 2006; Koster, Crombez, Verschuere, Van Damme, & Wiersema, 2006). Whereas the engagement process appeared to be related to pain sensitivity, the disengagement pro-

cess did not. Nevertheless, the two attentional processes did not qualify as perfectly independent from each other because the correlation coefficients showed 8% shared variance. Considering the different phases of allocation of attention while processing pain-related stimuli, early and thorough attentional engagement with pain-related stimuli might make continued engagement unnecessary and ease disengagement.

The zero-correlation between the self-reported hypervigilance and the attentional bias indices might help to understand the slightly confusing pattern of results obtained in the present study: increased pain sensitivity appeared to be associated both with increased attentional engagement with pain-related stimuli and reduced hypervigilance. Behaviorally-assessed attention to pain and self-reported attention are likely to be unrelated attentional process components, which in turn are linked differently to pain sensitivity. This assumption is plausible but only true if it applies to all participants. Alternatively, the observed correlations may exist only in subgroups of the whole sample. The inspection of the respective scatter plots supported the assumption that for some individuals, self-reported hypervigilance is negatively related to pain sensitivity, whereas in others, attentional engagement with pain-related information is positively related. Under both perspectives, the choice of the assessment tool for pain-related attention and vigilance is critical when the relationship between these variables and pain sensitivity is under investigation, because it affects not only the strength but also the direction of the observed correlations.

Surprisingly, self-reported pain catastrophizing and pain-related anxiety were not significantly positively related to experimental pain sensitivity. This result was not due to a statistical artifact, namely a floor effect, because of very low PCS and PASS scores; in fact, the scores were normally distributed and spanned a wide range. Accordingly, the results of a significant correlation between catastrophic thinking about pain and pain sensitivity obtained by others could not be confirmed (Sullivan, *et al.*, 1995; Kunz, *et al.*, 2008). A further study by Crombez and colleagues (1998), who also used stimuli of intensity near the pain threshold (electrocutaneous), found no difference in reported pain intensity between people with high and low catastrophizing scores. Consequently, to demonstrate the relationship between pain catastrophizing and pain sensitivity, strong experimental pain stimuli near the tolerance level might be most suitable.

The hypothesis that the activation of the fear/anxiety system moderates the relationship between the attentional and emotional mechanisms of processing of pain-related information (e.g., attentional biases from dot-probe task, self-reported hypervigilance, pain catastrophizing, and pain-related anxiety) on the one hand, and experimental pain sensitivity

on the other hand, was not confirmed in the present study. The state anxiety measure did not prove to be a significant moderator. One reason for this finding might be that state anxiety does not serve as a moderator of this relationship at any level. In contrast, a certain minimum state anxiety might be required to constitute this relationship, which was not surpassed in the present sample. The mean score on the STAI–State in the present study was markedly lower than the standard values for pathologic forms of anxiety. Furthermore, recent findings of direct effects of state anxiety on pain sensitivity were not corroborated (Komiyama, *et al.*, 2008).

There were a few limitations of the present study. A heterogeneous sample of pain-free adults with a wide age range was examined. The reason for doing so was the attempt to increase external validity and to exclude findings which were strictly age-specific. The necessity of including adolescents is debatable, however, their exclusion would not have changed the results. All participants should have received similarly attractive incentives for participation, which were course credits for students and reimbursements for other professions. This reasonable procedure opened another source of variance. Furthermore, the dot-probe task was used to behaviorally assess attentional engagement with and disengagement from pain-related stimuli. Although this choice of an assessment tool is not new, data on the reliability of the dot-probe task under no-threat conditions have been scarce. Therefore, future research is necessary to demonstrate that the dot-probe task is a reliable tool for the given purposes.

In sum, the results of the present study suggest that low self-reported hypervigilance to pain (PVAQ; especially the subscale "attention to changes of pain") is associated with enhanced experimental pain sensitivity in healthy individuals. This finding is slightly surprising and may be attributed to a preparatory role of minimum pain vigilance for coping with pain. Pain catastrophizing (PCS) and pain-related anxiety (PASS) did not explain a significant amount of variance in pain sensitivity in this sample. An enhanced attentional engagement with pain-related stimuli (words) assessed behaviorally by means of the dot-probe task appeared to be related (close to significance) to increased pain sensitivity, a finding which confirmed the hypotheses.

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