Does severe acute pain provoke lasting changes in attentional and emotional mechanisms of pain-related processing? A longitudinal study

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Abstract

Pain experiences, learning, and genetic factors have been proposed to shape attentional and emotional processes related to pain. We aimed at investigating whether a singular major pain experience also changes cognitive-emotional processing. The influence of acute postoperative pain after cosmetic surgery of the thorax was tested in 80 preoperatively pain-free male individuals. Acute pain was measured as independent variable during the first week postsurgery by pain intensity ratings and the requested analgesic boluses (Patient-Controlled Epidural Analgesia (PCEA)). Pain catastrophizing (Pain Catastrophizing Scale (PCS)), pain anxiety (Pain Anxiety and Symptom Scale (PASS)), pain hypervigilance (Pain Vigilance and Awareness Questionnaire (PVAQ)), and attentional biases to emotionally loaded stimuli (including pain) in a dot-probe task were assessed 1 week, 3 months, and 6 months postsurgery as dependent variables. Hierarchical regression analyses were performed to test whether the 2 acute pain parameters can predict these cognitive-emotional variables. As a rigorous test, significant prediction was required in addition to the prediction of the dependent variables by themselves with lag-1. Acute pain (mainly the pain ratings) appeared to be a significant predictor for PCS, PASS, and PVAQ 1 week after surgery ($R^2 = [8.7\% \text{ to } 11.3\%]$). In contrast, the attentional biases in the dot-probe task could not be predicted by the pain ratings. The levels of pain catastrophizing and pain hypervigilance increased in the acute phase after surgery when influenced by acute pain and declined, along with pain anxiety, during the next 3 months. In conclusion, a one-time intense pain experience, such as acute postoperative pain, appeared to produce at least short-lived changes in the attentional and emotional processing of pain.

1. Introduction

Attentional and emotional mechanisms related to pain processing, such as pain catastrophizing, fear of pain, hypervigilance, and attention to pain (ie, attentional focusing or avoidance), have turned out to contribute to interindividual variance in pain sensitivity [11,17,20], and to promote the development and maintenance of chronic pain [6,7,10,25,34]. The fear-avoidance model and its variants give a theoretical frame for the understanding of the reciprocal relationship between such cognitive-affective variables and pain experience [41,43].

However, the development of these pain-related psychological variables is still largely unknown. A little more is known about the development of pain perception. Besides genetic factors, previous experiences of pain seem to be relevant factors influencing future pain perception. Effects of previous pain experiences can go two ways. On the one hand, previous pain experiences can lead to adaptation [3,4,8,15,29,31] and thus to a decrease in pain sensitivity. The assumption of such adaptation level effects implies that major pain experiences in the past serve as a frame of reference for subsequent pain experiences [37]. On the other hand, sensitization due to continuous or repeated noxious stimulation can also occur, leading to an increase in pain sensitivity [23,30,38]. Sensitization...
Severe pains in the past seem to alter not only future pain perception, but also pain-related psychological variables, as a study on children with neonatal pain experience recently demonstrated [18]. These children reported increased pain catastrophizing at school age. However, not much more evidence is available on this matter.

For now, we can assume: first, pain can alter future pain perception, and second, these changes may be long-lasting. Third, in accordance with the results of Hohmeister et al. [18], pain experience may affect not only sensory mechanisms, but also cognitive and emotional processing related to pain. Interestingly, the relevance of such experience-based changes in cognitive and emotional processing is a prominent topic in fear research. Even a single-episode trauma may result in altered cognitive-emotional processing for a long while [14]. Is it possible that a one-time severe pain experience can have a similar effect, provoking lasting changes in pain-related cognitive and emotional processing?

The present study aimed at investigating how a singular major pain experience can affect attentional and emotional processing related to pain. Postoperative pain after a cosmetic correction of chest malformations was chosen as a model of major pain. The surgical intervention causes vast lesions in muscle and bone tissues that are sufficient to cause intense postoperative pain. Moreover, the patients are young and until the surgery had no exposure to severe pain. Technically speaking, the predictive power of acute postoperative pain for changes in pain-related cognitive and emotional processing assessed by self-report (eg, pain catastrophizing, pain anxiety, pain hypervigilance) and by a behavioral test (attentional biases toward pain, social threat, and positive words assessed in a dot-probe task; nonpain words were added to test for general emotional changes) was determined 1 week, 3 months, and 6 months after surgery.

2. Materials and methods

2.1. Subjects

Eighty male patients with funnel chest (mean age 19.2 ± 4.6 years, range 14 to 33 years) participated in the study. The patients underwent the surgical correction of a congenital malformation of the thorax at the Department of Pediatric Surgery of the University of Erlangen. The surgical center is well known in Germany as a specialist center in the correction of thorax malformations. The sample was selected amongst consecutively admitted inpatients according to the following inclusion criteria: 1) male patients (because of the high rates of male patients undergoing the surgical correction), 2) age between 14 and 35 years, and 3) no medical risk indication for applying the surgical procedure. Exclusion criteria were as follows: 1) concurrent acute or chronic pain conditions, 2) previous severe pain experiences, 3) previous major surgical interventions (minor surgical interventions such as tonsillectomies or dental procedures were allowed), 4) strong levels of discomfort due to functional limitations because of the chest malformation, 5) current or previous psychological disorders, and 6) analgesic treatment different from the patient-controlled epidural analgesia (PCEA), because of conditions (eg, skin acne or inflammation at or near the location for the insertion of the PCEA catheter, or intake of blood-thinning drugs during the previous 7 days) that would not allow for the epidural catheter needed for the PCEA to be inserted into the interspinal space. The study protocol was approved by the ethics committee of the medical faculty of the University of Erlangen. All participants gave written informed consent. In the case of participants not having reached the age of maturity, written informed consent was obtained from their parents and written assent from the subject. All subjects received financial compensation for their participation.

2.2. Surgical intervention and analgesic treatment

The surgical manipulation, the so-called Erlangen technique of funnel chest correction, consists first in the freeing of the lower part of the sternum through an interior incision. Afterward, the sternum is mobilized by the freeing of the xiphisternum. A spring balance is attached to the sternum with a hook, and the sternum is moved in the required position. Finally, the chest wall is stabilized with a lightweight transfemoral metal implant (for detailed description of the technique see [45]). The metal implant is usually removed 1 year after surgery. Patients are discharged from the hospital within 7 to 10 days postsurgery.

All participating patients were treated with standardized analgesia during and after surgery, and received the most commonly applied and recommended thoracic Patient-Controlled Epidural Analgesia (PCEA). Before the induction of general anesthesia for surgery, an epidural catheter was inserted through the interspinal space at Th6/Th7 or Th7/Th8. Postoperative PCEA was provided using a standard PCA pump. The pump was set to deliver 0.2% ropivacaine plus 1.0 μg/ml sufentanil at a basal rate of 6 to 8 ml/hour. The patient could additionally request a bolus dose of 3 ml every 30 minutes by pressing a trigger button. Repeated pressing of the trigger button did not provide more than 1 bolus per 30 minutes. Additionally, nonopioids were available as rescue analgesia on demand. The patient's requests for analgesic treatment were recorded for further analysis. After 2 to 3 days postsurgery, the catheter was removed.

2.3. Procedure

The present study was a prospective longitudinal study to assess the influence of acute postoperative pain as a one-time major pain experience on pain-related emotions and attention in the future. Four testing sessions were run at different points in time: 1) day before surgery (T0), 1 week after surgery (T1), and again approximately 3 months (T2) and 6 months (T3) after surgery. The testing sessions took place in a pain laboratory of the Department of Anesthesiology (University of Erlangen), mostly in the afternoon.

Postoperative acute pain was assessed by the use of 1) self-rated pain intensity (pain ratings) and 2) use of PCEA, which were the so-called independent or predictor variables. Data about the frequency of the demand for analgesics by using the PCEA system were collected for 1 to 3 days after surgery. Patients rated the intensity of acute postoperative pain 1 week after surgery (T1). Both measures of acute pain were defined as independent predictors as they represent different aspects of acute pain. The pain ratings measure the subjective perceived intensity of acute postoperative pain; the PCEA use provides an additional behavioral measure of the reaction to pain (drive for analgesia).

In each testing session (T0 to T3), self-report measures of pain catastrophizing, pain-related anxiety, and pain hypervigilance were obtained, and a dot-probe task was run to assess attentional biases to pain-related and other emotionally loaded stimuli. These were the so-called dependent or criterion variables. The T0 session was scheduled to control for preoperative levels of the criterion variables, whereas the remaining sessions (T1 to T3) were supposed to track the effects of acute postoperative pain.

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The patients were informed that they could receive additional analgesic boluses by pressing a trigger button, and that no matter how often they press the button, they would receive an additional analgesic bolus solely every 30 minutes (30 minutes lockout period). The patients were instructed to use the trigger button to keep pain at a level they would call moderate and good-tolerable. The number of requested PCEA boluses (pump calls, including those during lockout periods) during the whole time under PCEA (usually 1 to 3 days) was assessed and recorded as mean PCEA boluses requested per hour.

2.3.2. Assessment of the dependent (criterion) variables

2.3.2.1. Self-ratings of pain catastrophizing, pain-related anxiety, pain hypervigilance. Pain catastrophizing, pain-related anxiety, and pain hypervigilance were assessed through self-rating questionnaires (Pain Catastrophizing Scale [PCS] [40], Pain Anxiety Symptom Scale [PASS] [27]; German version by Walter et al. [44]).

The PCS was developed as a measure of catastrophizing related to pain. It contains 13 items that can be divided into 3 subscales, namely rumination, magnification, and helplessness. The items are rated on a 5-point scale. For further analyses, we used the sum score for the PCS averaged over all 3 subscales.

The PASS is designed to measure fear of pain across cognitive, behavioral, and physiological domains. It is composed of 4 subscales: cognitive anxiety, escape/avoidance, fearful appraisal, and physiological anxiety. The items are rated on a 6-point scale. For further analyses, we used the sum score (40 items) of the PASS.

The PVAQ was developed as a comprehensive measure of pain-specific changes in attentional and emotional mechanisms of pain-related analgesia. The items are rated on a 6-point scale. For further analyses, we used the sum score for the PVAQ. All 3 questionnaires have been shown to have good internal consistency in a sample of 160 healthy individuals (Cronbach $\alpha$ = 0.87–0.93), which is similar to the Cronbach $\alpha$ coefficients of the original English versions.

2.3.2.2. Dot-probe task. The dot-probe task used in the present study was based on the version described by Keogh et al. [21]. It contains 3 emotional word categories: pain-related (eg, stechend [German]/stinging), social threat (eg, beschämt [German]/ashamed), and positive words (eg, glücklich [German]/happy). These words are paired with neutral words (Anstrich [German]/paintwork); neutral-neutral word pairs served as filler items. We translated the words of the original version by Keogh et al. [21] into German. Because not all words in German fulfilled the criteria of being similar in length and frequency of use, a series of words had to be replaced. A pilot study tested whether each word of the new list (containing more items than necessary) was representative for the designated word category. If this was not the case, these words were excluded from the final use in the dot-probe task. This German version of the dot-probe task has already successfully been used in studies on healthy participants and cancer patients [1,24].

Following Keogh et al. [21], a fixation cross in the center of a computer screen was presented first for 500 ms. After this, 2 words (a neutral one paired with an emotional one) were presented concurrently, one below and one above the center. After another 500 ms, words were removed and a dot appeared in the location of one of the words. Patients were required to indicate via a key press as quickly as possible where the dot appeared (below, above). Reaction time was assessed. After 20 practice trials, patients had to complete 128 test trials (32 trials per word-pair category), all of which were presented in a random order. Three bias indexes were computed on the basis of reaction times to assess the attentional bias toward each emotional word category separately. Each bias index was calculated according to the formula by Keogh et al. [21]: Bias score = $\frac{((eudl-eldl) + (eldu-eudu))/2}{e = emotional word, d = dot, u = upper position, l = lower position. A positive score indicates an attentional preference for the location of the emotional word, which may suggest vigilance, whereas a negative score may suggest attentional avoidance. The dot-probe task with the 3 different emotional word categories allowed for assessing pain-specific attentional effects and for comparing such effects with those elicited by other negative or positive word stimuli. By that, pain-specific changes in attentional biases can be distinguished from changes that generalize across other negative and positive emotions. The 3 bias scores for each emotional category were used for further statistical analyses.

Additionally, patients completed a reading task (similar to the dot-probe task, word pairs of real and nonsense words were presented at a computer screen for 500 ms and the patients had to indicate by key press where the real word appeared) to ensure their capacity to read and understand words quickly enough. Patients providing more than 15 errors in total in the reading task (misses or false alarms) would have been excluded from analyses.

2.4. Statistical analysis

Data were analyzed using SPSS version 17.0 for Windows. To analyze the influence of acute postoperative pain on attentional and emotional mechanisms related to pain processing, hierarchical linear regression analyses (blockwise entry) were run for each dependent variable, namely PCS, PVAQ, PASS, and the 3 bias scores from the dot-probe task (bias scores for pain, social threat, and positive words) at T1, T2, or T3, separately. The just preceding level of the dependent variable under investigation (lag-1; T0 for T1, T1 for T2, T2 for T3) was entered as a predictor in the first step of the hierarchical regression analysis. The 2 acute pain predictors (pain
ratings and PCEA boluses/h were entered blockwise in the second step of the regression analysis.

The rationale for using this lag-1 approach as first step was to consider, besides the predictor of interest, namely acute postoperative pain, the levels of the dependent variables directly before the time point under investigation, because a variable in the past is mainly the best predictor for the same variable in the future and constitutes therefore a particularly critical frame of reference. If acute postoperative pain has substantial impact on the cognitive-emotional processing of pain, it should significantly exceed the explanatory power produced by the dependent variable alone using lag-1.

For analyzing time-dependent changes in the levels of the dependent variables, repeated measurement ANOVAs were performed for the self-report questionnaires and the 3 types of attentional biases from the dot-probe task, separately. Post-hoc analyses (t-tests) were conducted in case of significance. Pearson correlations were computed to determine the association, 1) between the 2 independent variables (predictors) and 2) between all dependent variables (criteria) at T0 to T3 with the questionnaires PCS, PASS, and PVAQ, but not for PASS (for PCS: \( t_{T0-T1} (N = 80, df = 79) = -2.909, P = .005 \); for PVAQ: \( t_{T0-T1} (N = 80, df = 79) = -4.174, P < .001 \); for PASS: \( t_{T0-T1} (N = 80, df = 79) = 0.407, p = .685 \)); significant differences between T1 and T2 for all 3 questionnaires (for PCS: \( t_{T1-T2} (N = 80, df = 79) = 8.238, p < .001 \); for PVAQ: \( t_{T1-T2} (N = 80, df = 79) = 6.166, p < .001 \); for PASS: \( t_{T1-T2} (N = 80, df = 79) = 8.607, P < .001 \)); significant differences between T2 and T3 for PVAQ, but not for PCS and PASS (for PVAQ: \( t_{T2-T3} (N = 80, df = 79) = 2.724, P = .008 \); for PCS: \( t_{T2-T3} (N = 80, df = 79) = 1.789, P = .077 \); for PASS: \( t_{T2-T3} (N = 80, df = 79) = 1.497, P = .138 \). These tests suggested that the scores of PCS and PVAQ increased from the preoperative to acute postoperative periods, and for all 3 questionnaires the scores decreased substantially thereafter until 3 months after surgery, to remain later in the case of PCS and PASS at this level.

Repeated measurement ANOVAs of the 3 attentional biases from the dot-probe task did not reveal any effects for time of assessment (bias score for pain words: \( F(2,916) = 0.232, P = .869 \); bias score for social threat words: \( F(2,962) = 0.783, P = .499 \); bias score for positive words: \( F(2,689) = 1.346, P = .262 \) (Table 1).

### 3.3. Correlation analyses

The numerical pain ratings for acute postoperative pain and the requested PCEA boluses/h within the first days after surgery (predictor variables) were moderately correlated \( (r = 0.331, P = .003) \), suggesting that the 2 variables target the same process from different perspectives.

Correlation analyses for the relationship between the questionnaires PCS, PASS, and PVAQ on the one hand and the bias scores from the dot-probe task on the other hand showed varying but mainly weak associations. Correlation coefficients reached significance only for PCS, and the bias score for pain-related words at the assessment points in time T0 and T1 \( (r_{T0} = -0.237, P = .035; r_{T1} = 0.295, P = .008) \). The negative correlation at T0 suggests that a high score in PCS is associated with a low bias score for pain-related words. In contrast, at T1 a positive association was found between these 2 variables.

### 3.2. Change in level

Repeated measurement ANOVAs revealed significant main effects for the time of assessment on all 3 questionnaires (PCS: \( F(2,774) = 40.022, P < .001 \); PASS: \( F(2,623) = 55.151, P < .001 \); PVAQ: \( F(2,879) = 25.548, P < .001 \)). Post-hoc t-tests for differences between times of assessment T0 to T3 produced the following findings: significant differences between T0 and T1 for PCS and PVAQ, but not for PASS (for PCS: \( t_{T0-T1} (N = 80, df = 79) = -2.909, P = .005 \); for PVAQ: \( t_{T0-T1} (N = 80, df = 79) = -4.174, P < .001 \); for PASS: \( t_{T0-T1} (N = 80, df = 79) = 0.407, p = .685 \)); significant differences between T1 and T2 for all 3 questionnaires (for PCS: \( t_{T1-T2} (N = 80, df = 79) = 8.238, p < .001 \); for PVAQ: \( t_{T1-T2} (N = 80, df = 79) = 6.166, p < .001 \); for PASS: \( t_{T1-T2} (N = 80, df = 79) = 8.607, P < .001 \)); significant differences between T2 and T3 for PVAQ, but not for PCS and PASS (for PVAQ: \( t_{T2-T3} (N = 80, df = 79) = 2.724, P = .008 \); for PCS: \( t_{T2-T3} (N = 80, df = 79) = 1.789, P = .077 \); for PASS: \( t_{T2-T3} (N = 80, df = 79) = 1.497, P = .138 \). These tests suggested that the scores of PCS and PVAQ increased from the preoperative to acute postoperative periods, and for all 3 questionnaires the scores decreased substantially thereafter until 3 months after surgery, to remain later in the case of PCS and PASS at this level.

### 3.1. Descriptive statistics

Descriptive statistics (means and standard deviations) for the independent and dependent variables are shown in Table 1. The scores of the 3 questionnaires (PCS, PASS, and PVAQ) assessed at the 4 points in time were comparable to the scores reported from one of our studies by Baum et al. \[1\] in a population of 160 healthy individuals (mean score for PCS = 15.33, mean score for PASS = 71.59, mean score for PVAQ = 34.44).

### Table 1

<table>
<thead>
<tr>
<th>Assessment time</th>
<th>T0</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Independent variables (predictors)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Numerical pain ratings</td>
<td>3.81 (2.14)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCEA boluses/h</td>
<td>1.55 (1.50)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dependent variables</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCS</td>
<td>16.57 (5.89)</td>
<td>18.69 (7.73)</td>
<td>12.72 (5.82)</td>
<td>11.60 (7.57)</td>
</tr>
<tr>
<td>PASS</td>
<td>71.55 (23.54)</td>
<td>70.50 (27.50)</td>
<td>51.34 (21.66)</td>
<td>48.81 (24.58)</td>
</tr>
<tr>
<td>PVAQ</td>
<td>31.71 (12.06)</td>
<td>36.42 (8.80)</td>
<td>29.37 (12.03)</td>
<td>26.14 (12.12)</td>
</tr>
<tr>
<td>Dot-probe task</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain bias</td>
<td>–1.81 (49.37)</td>
<td>0.82 (58.99)</td>
<td>1.97 (44.94)</td>
<td>–4.52 (55.46)</td>
</tr>
<tr>
<td>Social threat bias</td>
<td>–0.87 (41.41)</td>
<td>3.67 (45.46)</td>
<td>–2.59 (44.70)</td>
<td>–6.64 (43.09)</td>
</tr>
<tr>
<td>Positive bias</td>
<td>–4.79 (46.83)</td>
<td>–19.25 (65.21)</td>
<td>–14.13 (43.58)</td>
<td>–8.95 (42.50)</td>
</tr>
</tbody>
</table>

PCEA = patient-controlled epidural analgesia, requested boluses/h; Pain bias = bias score for pain-related words; Social threat bias = bias score for social threat words; Positive bias = bias scores for positive words; T0 = 1 day presurgery; T1 = 1 week postsurgery; T2 = 3 months postsurgery; T3 = 6 months postsurgery.

* Minimum/maximum = 0.00/9.00.
* Minimum/maximum = 0.03/7.66.

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3.4. Results of the hierarchical regression analyses

Results of the hierarchical regression analyses for the self-report questionnaires and the dot-probe task are presented in detail in Tables 2 and 3, respectively. Predicting the scores of PCS, PASS, and PVAQ using the preceding scores of the same variables as predictor (lag-1) led to significantly explained variance ranging from 33.3% to 36.1% at T1, 30.8% to 48.4% at T2, and 37.5% to 63.1% at T3 for each of the questionnaires (step 1, Table 2). The numerical ratings of acute postoperative pain and the PCEA boluses/h when entered in the second step could explain significantly 8.7% to 11.3% delta variance in addition to the variance already explained by the dependent variables themselves with lag-1 for all questionnaires 1 week after surgery at T1 (Table 2). After Bonferroni correction, the additional variance explained by the 2 measures of acute postoperative pain at T1 was still significant at the adjusted α level of 0.006. The pain ratings proved to be the significant predictors in all dependent variables in step 2 for all 3 of the self-report questionnaires at T1 (PCS β = 0.275, P = .003; PASS β = 0.309, P = .001; PVAQ β = 0.294, P = .002) in contrast to the PCEA boluses/h. This result holds even after Bonferroni correction (Table 2).

With regard to the prediction of the questionnaires at 3 (T2) and 6 months (T3) postsurgery, no significant influence of either of the 2 predictors (pain rating, PCEA boluses) was found after Bonferroni correction (Table 2).

Regarding the results in the dot-probe task (biases for pain words, social threat words, and positive words), the prediction by the dependent variables themselves with lag-1 for all assessment points of T2 and 1.8% to 4.4% for the assessment point in time T3. The additionally explained variance by step 2 in the hierarchical regression analyses ranged from 0.7% to 3.0% for the 2 predictors (pain rating, PCEA boluses/h), and this result was significant after Bonferroni correction (Table 2).

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dbxetab = standardized beta coefficient; PCEA = patient-controlled epidural analgesia, requested boluses/h; PCS = Pain Catastrophizing Scale; PASS = Pain Anxiety Symptom Scale; PVAQ = Pain Vigilance and Awareness Questionnaire; T0 = 1 day presurgery; T1 = 1 week postsurgery; T2 = 3 months postsurgery; T3 = 6 months postsurgery.

Significant after Bonferroni correction (P < .006).

### Table 2

Influence of acute postoperative pain intensity (pain rating, PCEA use) on the scores of PCS, PASS, and PVAQ 1 week, 3 months, and 6 months postsurgery.

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Step of the hierarchical regression</th>
<th>Independent variable</th>
<th>R²</th>
<th>ΔR²</th>
<th>P</th>
<th>β</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessment at T1</td>
<td>PCS Step 1</td>
<td>PCS T0</td>
<td>0.333</td>
<td>0.333</td>
<td>&lt;.001</td>
<td>0.577</td>
<td>6.756</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>PCS Step 2</td>
<td>Pain ratings T1 and PCEA T1</td>
<td>0.446</td>
<td>0.113</td>
<td>.001</td>
<td>0.537</td>
<td>5.891</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>PASS Step 1</td>
<td>PASS T0</td>
<td>0.361</td>
<td>0.361</td>
<td>&lt;.001</td>
<td>0.601</td>
<td>6.363</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>PASS Step 2</td>
<td>Pain ratings T1 and PCEA T1</td>
<td>0.451</td>
<td>0.090</td>
<td>.003</td>
<td>0.601</td>
<td>6.363</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>PASS Step 2</td>
<td>Pain ratings T1 and PCEA T1</td>
<td>0.451</td>
<td>0.090</td>
<td>.003</td>
<td>0.601</td>
<td>6.363</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>PVAQ Step 1</td>
<td>PVAQ T0</td>
<td>0.325</td>
<td>0.325</td>
<td>&lt;.001</td>
<td>0.570</td>
<td>6.124</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>PVAQ Step 2</td>
<td>Pain ratings 1 and PCEA T1</td>
<td>0.411</td>
<td>0.087</td>
<td>.005</td>
<td>0.494</td>
<td>5.369</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

| Assessment at T2   | PCS Step 1                          | PCS T1                | 0.330 | 0.330 | <.001 | 0.575 | 6.200 | <.001 |
|                    | PCS Step 2                          | Pain ratings T1 and PCEA T1 | 0.345 | 0.015 | .419 | 0.539 | 5.228 | <.001 |
|                    | PASS Step 1                         | PASS T1               | 0.484 | 0.484 | <.001 | 0.696 | 8.557 | <.001 |
|                    | PASS Step 2                         | Pain ratings T1 and PCEA T1 | 0.491 | 0.007 | .615 | 0.673 | 7.438 | <.001 |
|                    | PVAQ Step 1                         | PVAQ T1               | 0.308 | 0.308 | <.001 | 0.555 | 5.895 | <.001 |
|                    | PVAQ Step 2                         | Pain ratings T1 and PCEA T1 | 0.338 | 0.030 | .189 | 0.525 | 5.071 | <.001 |

| Assessment at T3   | PCS Step 1                          | PCS T2                | 0.456 | 0.456 | <.001 | 0.676 | 8.094 | <.001 |
|                    | PCS Step 2                          | Pain ratings T1 and PCEA T1 | 0.500 | 0.044 | .040 | 0.610 | 7.097 | <.001 |
|                    | PASS Step 1                         | PASS T2               | 0.631 | 0.631 | <.001 | 0.794 | 11.548 | <.001 |
|                    | PASS Step 2                         | Pain ratings T1 and PCEA T1 | 0.649 | 0.018 | .149 | 0.764 | 10.552 | <.001 |
|                    | PVAQ Step 1                         | PVAQ T2               | 0.375 | 0.375 | <.001 | 0.612 | 6.837 | <.001 |
|                    | PVAQ Step 2                         | Pain ratings T1 and PCEA T1 | 0.405 | 0.030 | .150 | 0.571 | 6.080 | <.001 |

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**Table 2**

Influence of acute postoperative pain intensity (pain rating, PCEA use) on the scores of PCS, PASS, and PVAQ 1 week, 3 months, and 6 months postsurgery.
In summary, the 2 measures of acute postoperative pain still assessed by the dot-probe task. Furthermore, no firm evidence for any of the assessment points in time after Bonferroni correction (Table 3). The pain ratings and the PCEA boluses entered together in step 2 also could not significantly increase explanatory power for any of the bias scores at any point in time (Table 3).

In summary, the 2 measures of acute postoperative pain still proved to be significant predictors of pain vigilance (PVAQ), pain catastrophizing (PCS), and pain anxiety (PASS) when added to the predictive power gained by the self-report questionnaires themselves with lag-1. In so doing, the numerical rating of postoperative pain appeared to be clearly superior as a predictor when compared with the number of requested PCEA boluses. This additional predictive power could only be shown at T1, 1 week postsurgery, pointing largely to an immediate and short-lasting influence of acute pain on cognitive-emotional pain processing.

### 4. Discussion

The present study investigated whether a singular experience of major pain in individuals with no history of previous severe pain is sufficient to alter pain-related attentional and emotional mechanisms. As a model for major pain, we used postsurgical pain in its acute form. The acute pain parameters chosen were self-rated pain, significantly influenced these pain-related mechanisms. As a model for major pain, we used postsurgical pain in its acute form. The acute pain parameters chosen were self-rated pain intensity and behavioral requests for analgesics (PCEA boluses/h). These dependent variables themselves with lag-1 did not reach significance for any of the assessment points in time after Bonferroni correction (Table 3). The pain ratings and the PCEA boluses entered together in step 2 also could not significantly increase explanatory power for any of the bias scores at any point in time (Table 3).

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Step of the hierarchical regression</th>
<th>Independent variable</th>
<th>R²</th>
<th>AR²</th>
<th>P</th>
<th>β</th>
<th>t</th>
<th>P</th>
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</thead>
<tbody>
<tr>
<td><strong>Assessment at T1</strong></td>
<td>Pain bias</td>
<td>Pain bias T0</td>
<td>0.010</td>
<td>0.010</td>
<td>.379</td>
<td>−0.100</td>
<td>−0.885</td>
<td>.379</td>
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<td>.968</td>
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<td></td>
<td>Social threat bias</td>
<td>Social bias T0</td>
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<td>0.020</td>
<td>.212</td>
<td>0.141</td>
<td>1.257</td>
<td>.212</td>
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<td>Pain ratings T1 and PCEA T1</td>
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<td>0.016</td>
<td>.536</td>
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<td>Positive bias</td>
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<td>0.003</td>
<td>.607</td>
<td>0.058</td>
<td>0.516</td>
<td>.607</td>
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<td>0.073</td>
<td>.056</td>
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<td><strong>Assessment at T2</strong></td>
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<td>Pain bias T1</td>
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<td>0.001</td>
<td>.863</td>
<td>−0.020</td>
<td>−0.174</td>
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<td>0.007</td>
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<td>Social threat bias</td>
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<td>0.006</td>
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<td>−0.080</td>
<td>−0.712</td>
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<td>Positive bias</td>
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<td>Social threat bias</td>
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<td>0.165</td>
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<td>.346</td>
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<tr>
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<td>Positive bias</td>
<td>Positive bias T2</td>
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<td>0.059</td>
<td>.030</td>
<td>0.243</td>
<td>2.216</td>
<td>.030</td>
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</tbody>
</table>

β = standardized beta coefficient; PCEA = patient-controlled epidural analgesia, requested boluses/h; Pain bias = bias score for pain-related words; Social threat bias = bias score for social threat words; Positive bias = bias scores for positive words; T0 = 1 day presurgery; T1 = 1 week postsurgery; T2 = 3 months postsurgery; T3 = 6 months postsurgery.

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was found that these changes were long-lasting and outlived the acute phase. In the acute phase, when postoperative pain appeared to affect attentional and emotional processing, the levels of pain-related catastrophizing and hypervigilance, but not of pain-related anxiety, were increased. Thereafter, the scores of the 3 questionnaires declined during the next 3 months to levels below the preoperative scores.

There is solid evidence that previous pain strongly affects the experience of future pain, resulting in either adaptation level effects [3,4,8,15,29,31] or perceptual sensitization [23,30,38]. However, not much research that has focused on the underlying psychological mechanisms is available. Our results suggest an immediate, short-lasting alteration of pain-related vigilance, catastrophizing, and anxiety due to major acute pain. To our knowledge, only the study by Hohmeister et al. [18] has reported related findings up to now. Hohmeister et al. [18] argued that the conditions of repeated pain exposure can provoke changes in cognitive schemata in a phase of increased neural plasticity. Although our findings point to a similar direction, we could only demonstrate a short-lasting alteration in cognitive-emotional processing of pain due to major pain experience in young adults, which hardly outlasted the acute phase. Differences in the effect sustainability between the findings of Hohmeister et al. and ours might be due to the different age of the subjects (with likely higher nociceptive vulnerability in newborns) and to the likely higher noxious impact of continued painful neonatal treatment.

Nevertheless, even a short-lasting influence of acute pain on pain-related catastrophizing, anxiety, and vigilance might be clinically of high importance, given that these variables are known to be risk factors for the development of persistent pain [13,27,42,43]. Therefore, sufficient treatment of acute pain is mandatory not only to reduce present suffering but also to prevent risk factors from developing. Furthermore, our study cannot give a definite all-clear signal that one-time major pain due to surgery in young adults may not produce enduring and maladaptive changes in pain processing, which go beyond clinically still silent risk factors. Therefore, it is still important to test also for such changes in future studies.

It might be the case that this cascade of changes does not occur in all individuals but only in those with a high sensitivity to pain traumatization [22]. Kleiman et al. [22] described this concept as “propensity to develop anxiety related somatic, cognitive, emotional and behavioral responses to pain that resemble the features of a traumatic stress reaction”.

Another interesting finding is the short-term swings in the cognitive-emotional processing of pain, with enhancement in the acute phase and normalization in the weeks thereafter. In other words, pain catastrophizing, anxiety, and hypervigilance did not appear to have stable trait-like characteristics. The scores 6 months after surgery were even lower than preoperatively, suggesting similar adaptation-level effects on cognitive-emotional variables as observed for psychophysical parameters [3,4,8,15,29,31]. However, it must be conceded that the preoperative scores were assessed only 1 day before surgery and might have already been increased above normal levels due to the expectancy of pain and surgery. If so, the postoperative decrease of pain catastrophizing, anxiety, and hypervigilance after 3 months would not really have fallen below the true preoperative levels.

A remarkable contrast was that the attentional dot-probe task biases (to pain, social threat, or positive words) could not be predicted by the measures of acute postoperative pain, whereas self-report questionnaires could. The self-report measures are based on explicit and conscious processing, which is strongly dependent on introspection, self-monitoring, and self-communication. The dot-probe task, in contrast, allows for revealing implicit and automatic modes of cognitive processing. Given these arguments, it was not surprising that the correlations between the questionnaires and the dot-probe biases were low. Such a lack of association between explicit measures (pain-related questionnaires) and implicit measures (dot-probe task, evoked brain potentials) of pain-related cognitive and emotional processing was also reported from other samples [9,19].

Our results suggest that the explicit and conscious experience of major pain affects the explicit and conscious results of pain processing more strongly than the implicit and automatic readouts. Alternatively, it might be that the poor test-retest reliability of the dot-probe biases (revealed by the lag-1 analyses) did not allow better prediction by the acute pain parameters. Furthermore, the word material used in the dot-probe task does not specifically address concerns related to pain after surgery, a fact that may have prevented stronger effects of acute postoperative pain on this measure. Lastly, within-methods correlations (within self-report measures) tend to be higher than across-methods correlations (self-report with behavioral measures), which also may have shaped our findings. In sum, there are also methodological explanations for the divergence of the prediction of the questionnaire and the dot-probe task data by the rating of acute postoperative pain besides differences in the nature of the processes.

Another result worth mentioning was that the number of postoperatively requested PCEA boluses was a very weak predictor compared to the pain ratings. These 2 measures of acute postoperative pain were positively correlated, but weakly enough to apparently tap different aspects of postoperative pain. Self-ratings of pain intensity 1 week postsurgery represent a direct measure of pain intensity. The number of requested PCEA boluses/hour is in contrast an indirect behavioral measure of acute pain because of its various additional determinants such as attitudes toward medication intake or fear of adverse side effects. Furthermore, using a PCEA system might have fostered the belief of having control over pain. Crombez et al. [5] could show that control over pain is related to less fear of pain and less vigilance. By these means, the PCEA-related belief of control might have temporarily decreased the threat value of pain. Accordingly, assessing pain by use of the requested PCEA boluses may have integrated situational characteristics of pain not assessed by the pain ratings.

The present study also has some limitations. First, the reported influence of acute pain on pain-related cognitive processing was demonstrated in only 1 clinical sample, which, although providing almost ideal study conditions, had received only 1 type of surgical and analgesic treatment. Furthermore, a control group without surgery might have been useful to estimate the general test-retest reliability of the questionnaires and the dot-probe task. Especially, the reliability of the dot-probe task appeared to disqualify this measure for tracking changes in attentional performance over time despite its merits as a potent predictor of postoperative pain [24,25]. Second, a larger sample size might have been preferable to further increase statistical power. Third, the tested predictive model gave first support to the idea that a singular pain event can temporally change cognitive-emotional processing of pain. It is of great importance to extend the set of predictors and to test other potential pathways of causation, moderation, or mediation in future analyses.

In conclusion, the experience of a single major pain may exert a short-lasting influence on the level of pain catastrophizing, pain anxiety, and pain hypervigilance. Although this influence seemed to be only short-lived, it can complicate the patient’s postoperative recovery by anxiety, unrealistic beliefs, and dysfunctional concerns
regarding the further course of pain. Therefore, our findings inspire the search for preoperative resilience factors that may counterbalance these consequences of postoperative pain in the acute phase of recovery, such as optimism and endogenous pain inhibition [32,33,39].

Acknowledgments

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