Impact of chronic somatoform and osteoarthritis pain on conscious and preconscious cognitive processing

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Abstract

The study investigates the impact of chronic pain (CP) on conscious and preconscious cognitive processes and on guessing behavior, and examines the mediating effect of a depressive state. Twenty-eight patients with CP due to hip osteoarthritis, 32 patients with a somatoform disorder including pain symptoms, and 31 participants who did not have CP were examined within the framework of a modified Process-Dissociation-Procedure. Neutral, health threatening and general threatening stimuli were presented acoustically in a lexical decision task. Parameters of conscious processing, preconscious processing, and of chance were estimated by a multinomial modelling procedure. CP-patients with osteoarthritis showed the lowest level of conscious processing and the highest level of guessing behavior. Patients with somatoform pain tended to react preconsciously to health threatening stimuli but overall showed a profile similar to that of controls who did not have CP. The impact of the threatening quality of stimuli on different levels of cognitive processing was weak. Depression did not mediate between the experience of pain and estimates of conscious and preconscious processing.

Perspective: The impact of CP on preconscious and conscious cognitive processing depends on types and causes of pain. The experience of CP caused by inflammation or physical damage tends to reduce the probability of conscious processing and to provoke memory biases. CP in the context of a somatoform disorder seems to have less impact on cognitive functions.

INTRODUCTION

There is evidence of a cumulative impact of chronic pain (CP) on several levels of cognitive functioning including attentional and memory processes (3, 11, 12). Cognitive deficits due to CP are relevant with respect to both assessment and medication of CP-patients. Many patients with pain-related disability or need for compensation or early retirement due to CP complain about attentiondeficits or memorydeficits (39, 15). As a result, physicians and other therapists have to assess the impact of CP on their patients´ cognitive functioning and to consider these results in their clinical assessments and therapeutic strategies.

Pincus and Morley (31) reviewed 23 studies on attention bias, interpretation bias, and memory bias in CP-patients. Attentional bias occurs when a CP-patient´s response to a definded group of stimuli is disrupted or facilitated due to a cognitive schema of pain or health. According to Pincus et al. (31), findings from 11 experiments with the emotional Stroop or dot-probe tasks show varying results. The hypothesis that CP biases attention toward pain- or health related stimuli was not consistently confirmed. There was evidence that the attentional bias toward pain-related stimuli was affected by anxiety rather than by pain.

Studies of the interpretation bias in processing pain or health related stimuli use homophone or homonym tasks or word stem completion tasks. In these tasks, ambiguous stimuli of pain or health are presented without contextual information. A higher rate of pain-related or health-related interpretations of ambiguous stimuli is interpreted as falling back on the internal predominant accessible cognitive schema of pain or health. Previous studies support the hypothesis that CP-patients tend to generate specific responses to pain- or health-related stimuli (13, 31).

There is robust evidence for a memory bias and interference with conscious encoding and rehearsal processes in CP-patients. Kuhajda et al (24) and Brown et al. (1) found evidence for a delay in the encoding phase in CP-patients. According to Dick and Rashiq (7) and Ling et al. (25), processes of maintaining and rehearsal are disrupted in CP-patients. However, it is not clear whether memory biases in CP-patients are specific to pain-related contents and whether mood influences the process (31). Overall, the given studies show consistent impact of CP on interpretation and memory processes. The impact of CP on fast (preconscious) attentional processes seems questionable.

One problem in interpreting these studies is that the majority of the used methods do not integrate conscious processes (i.e. interpretation, rehearsal, retrieval), preconscious processes (subliminal attention), and chance-bias (guessing) into a consistent model of cognitive processing. Test scores of the Stroop-test, of dot-probe tasks, of stem completion tasks, and of memory achievement tests are of limited benefit if the aim is to disentangle different levels of cognitive processing. Grisart et al. (16) critizised that results on explicit memory tests overestimate the role of conscious processes while the impact of preconscious processes will falsely be ignored. As a result, they used a process-dissociation procedure (22) which enables researchers to assess conscious and preconscious processes based on a consistent model of cognitive processing. Although they did not find a significant bias of CP on preconscious processing we share the view that a consistent theoretical framework is necessary in order to describe the potential impact of CP on cognitive processing.

Possibly, the equivocal results about the impact of CP on cognitive processing might be explained by diagnostic features of CP-syndromes. Preconscious processing seems to be biased predominantly in patients with chronic somatoform pain or patients with elevated emotional disturbance (26, 37, 8). In contrast, studies of experimental pain or CP caused by physical damage fail to show either an impact of pain on preconscious processes (16) or an impact of preconscious processes on pain (42). The impact of pain on chance-bias, which is affected neither by conscious nor by preconscious processes, has been widely neglected so far. According to Hecker et al. (18), a chance-bias is expected to reflect a higher level of affect-related cognitive confusion or exhaustion. There is evidence that affective factors like depression mediate the relationship between pain and memory in CP-patients (1, 17). When analyzing the impact of CP on cognitive processing, the mediating effect of depression has to be taken into account.

The aim of the study is to test relations between different types of CP and conscious, preconscious, and guessing processes in a memory task. CP-patients are expected to show lower levels of conscious processing compared to non-CP controls because of the disrupting effect of pain on the central executive function (Hypothesis 1). In patients with CP-symptoms embedded in multiple somatoform symptoms, a preconscious bias to health-related or threat-related stimuli is predicted because of stronger schema-guided facilitation or inhibition (i.e. preconscious processing) of threatening stimuli (Hypothesis 2). An elevated chance bias is expected to occur in CP-patients because the resource-demanding character of CP will lead to cognitive confusion and random behavior (Hypothesis 3). Finally, negative affect is expected to mediate between pain and cognitive processing (Hypothesis 4).

PARTICIPANTS AND METHODS

Participants

Recruitment of participants. A sample of 91 volunteers was assessed, with 28 participants diagnosed as CP-patients with osteoarthritis (OA) of the hip, 32 patients with a somatoform disorder including pain symptoms (ICD10: F45.x), and 31 controls who did not have CP.

Patients with pain caused by OA were outpatients of two medical health care centers. They had clinical findings and radiographic changes diagnostic of that disorder and had complained of pain for at least 6 month. Originally, 38 OA-patients were asked by their physician whether they were willing to participate in the study about aspects of information processing.

All patients with a somatoform disorder including pain symptoms were inpatients of a psychosomatic clinic. Based on results of medical examinations at the beginning of their stay, 35 were asked whether they were willing to participate in the study. No information was collected about patients´ reasons to decline participation. The assessments were conducted within the first week of in-patient treatment to avoid additional treatment effects.

Healthy controls were recruited by an announcement in a local newspaper and by announcements on notice-boards in the University of Bonn. In order to homogenize the samples with respect to age, 5 participants aged over 65 years were excluded from the OA-pain group.

The study was approved by the Institutional Review Board at University of Bonn, and all participants signed informed consent before undergoing study-related evaluations.

In order to describe the samples, the following instruments were used:

- *International Diagnosis Checklists for ICD-10* (IDCL; 20).
- *Screening for Somatoform Disorders* (SOMS; 33). The questionnaire consists of 68 items of bodily symptoms which are associated with somatiziation and classification criteria of somatoform disorders. The test score indicates the tendency to report symptoms that might be relevant for the diagnoses of a somatoform disorder. Reliability scores are $\alpha = .88$ for internal consistency and $r_{tt} = .85$ for retest. In the present sample, reliability scores ranged from $\alpha = .79$ (healthy controls) to $\alpha = .87$ (OA-group) to $\alpha = .90$ (somatoform group). Validity of the test score has been shown for results of structured clinical interviews, personality inventories, and SCL-90-R.

Self-Recorded State of Health (SF-36; 2). The SF-36 was designed for use in clinical practice and research, health policy evaluations, and general population surveys. The instrument includes one multi-item scale that assesses eight health concepts: 1) limitations in physical activities because of health problems; 2) limitations in social activities because of physical or emotional problems; 3) limitations in usual role activities because of physical health problems; 4) bodily pain; 5) general mental health (psychological distress and well-being); 6) limitations in usual role activities because of emotional problems; 7) vitality (energy and fatigue); and 8) general health perceptions. Several studies have shown good reliability of the SF-36 scales (Cronbach's alpha greater than 0.85, reliability coefficient greater than 0.75 for all dimensions) and good construct validity in terms of distinguishing between groups with health differences. In the given sample, the reliability of the total SF-36-disability index caused by health related problems varied from $\alpha = .86$ for the OA-pain group and $\alpha = .76$ for the somatoform pain group to $\alpha = .69$ for the healthy control group. The low reliability in the healthy control group was due to the absence of severe health related complaints and disability. However, all reliability scores were suffient for group comparisons.

- *Symptom Checklist Revised* (SCL-90-R; 14). The test provides a direct assessment of psychological symptoms and a limited range of health disorders based on 90 items. Participants have to assess subjective impairment caused by psychological and bodily symptoms during the last week. There are eight subscales (e.g. Somatization, Obsessive-compulsive, Depression, Anxiety, Hostility) and three global indices. Reliabilities ranged from α = .86 to α = .95 in the norming study. In the present study, internal consistencies of the summed score of disability due to mental symptoms (global severity index) were α = .96 for OA-patients, α = .91 for somatoform patients, and α = .87 for healthy controls. The test was used to validate the diagnostic classification of the patient groups and to describe the extent of suffering from mental and somatic symptoms.
- *Vocabulary Test* (Wortschatztest, WST; 36). This recognition test was used to assess verbal fluency and to ensure that the samples were comparable with respect to verbal capacity. The instrument consists of 40 items each with a target word and 5 distractors. The test has good reliability of α = .95 and is validated with scores of intelligence and education level. In the present sample, consistency indices were α = .90 for the OA-group, α = .86 for the somatoform group, and α = .92 for the healthy control group.

Sample characteristics

Sociodemographic characteristics. The groups did not differ with respect to age and gender. The CP groups did not differ in the mean duration of pain or other somatic symptoms (see Table 1). The control group consisted of more students than both of the clinical groups. In contrast, most of the patients were working as employees (Table 1).

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Pain. CP-patients differed significantly from control participants without CP with respect to all relevant aspects of pain (Table 2). Although 20 % of the participants of the control group reported headache and 30 % reported back pain, no one suffered from pain for longer than 3 months. In contrast, all CP-patients complained about constant or varying pain for more than half a year. Compared to OA-patients, patients with somatoform pain showed a greater heterogeneity of pain sites, and they complained more frequently about headache and stomach ache (Table 2). Reliability scores for the pain intensity index were α = .81 for the OA-group, α = .89 for the somatoform group, and α = .71 for the healthy control group. The pain-groups did not differ with respect to mean intensity of bodily pain in the past week (six-point numerical rating scale, SF-36, "Bodily pain").

Psychological symptoms. CP-patients differed on all SCL-90-R subscales from participants without CP. Patients with somatoform pain showed higher scores of global severity of mental and bodily symptoms (Table 1) and a higher number of psychological symptoms than OA-patients. More specifically, somatoform patients showed elevated scores of somatization as measured by SCL-90-R and by SOMS. Mental health was poorer and emotional disturbance was higher in somatoform pain patients compared to OA-patients.

Concept of illness and illness behavior. Information about the lay concept of illness and illness behavior was relevant to diagnose a somatoform disorder. Participants without CP showed the lowest level of illness behavior and the lowest use of the medical health care system (Table 2). Patients with OA differed from patients with somatoform pain in their explanations of pain and their use of the medical heath care system. The majority of OA-patients were convinced that their pain was caused by physical impairment. Somatoform pain patients had consulted more physicians in the last year and reported much more difficulty in accepting the lack of explanation for their symptoms. The results support the differentiation between somatoform pain and pain predominantly caused by physical damage.

Disability and limitations in daily activity. The comparison of both CP-groups with the non-CP control group showed significant differences across all parameters of disability and daily activity including physical and social functioning, mental and general health and physical and emotional roles. Profiles of participants with pain caused by OA and somatoform pain were widely similar with respect to self-reported status of function and health-related disability. Patients with somatoform pain complained about lowered vitality and more mental health problems.

Verbal Fluency. Although patients with somatoform disorder showed less verbal fluency than OA-patients and healthy controls, the mean scores of all groups were at average of the normal population.

Overall, patients with OA-pain predominantly complained about joint-related localized pain of their hip and about local pain in the back and legs. More than 90 % of them were convinced that their CP was caused by physical damage exclusively. Patients with somatoform pain showed the typical pattern of multilocal or generalized pain symptoms, broader impairment and disability due to physical and mental symptoms, more illness behavior and doctor shopping, more intake of drugs, and characteristic cognitive features such as low willingness to accept medical explanations of physical symptoms.

Procedure

Rationale of the Process-Dissociation-Procedure (PDP)

There are several experimental approaches for analyzing and comparing conscious and preconscious processes such as procedures using divided attention, unconscious evaluative conditioning, dissociation between direct and indirect measures, and subliminal semantic activation (28). In the present study, the concept of subliminal semantic activation was used in order to analyze preconscious processes and to differentiate these processes from conscious processes and from chance bias (guessing). Within the approach of subliminal semantic activation, a semantic schema is first activated by a priming procedure. Subsequently, the impact of the activated schema on processing of vague and plurivalent verbal stimuli is assessed based on reaction times or accuracy. The basic idea is that responses to vague verbal stimuli after a priming phase are subliminally modulated by the previously activated semantic schema. In general, the impact of preconscious processes on cognitive processing can be estimated by calculating the difference between processing of stimuli related to the activated semantic schema vs. stimuli not related to the activated schema.

A sophisticated approach to analyzing this difference is the process-dissociation-paradigm (PDP; Jacoby, 22). Within this model, cognitive processes are assumed to be determined by conscious and preconscious processes. Essentially, the approach consists of placing two different types of experimental conditions in opposition to each other through the use of instruction or stimulus material. An impact of preconscious processes on cognitive processing is assumed if a specific memory trace from a priming task either facilitates or inhibits the processing of subsequently presented stimuli. In the present study, different types of stimuli ("words" and "non-words") were used in a lexical decision task to create conditions of facilitation ("inclusion" in terms of PDP) and inhibition ("exclusion" in terms of PDP). In the facilitation condition, conscious and preconscious processes are working together in order to produce the same response pattern. In the inhibition condition, conscious and preconscious processes are competing against each other.

In the present study, participants first had to process a list of neutral and threatening words in a priming phase. Later on, they had to decide whether a given sound was a "word" or a "non-word" (lexical decision task). These sounds were presented phonologically to be either similar or not similar to the words from the priming phase. The facilitation condition holds when an "old" word from the priming phase was presented and conscious processes (c) and preconscious processes (p1(1 – c)) lead to correctly discriminating this stimulus as a word. In case of no conscious discrimination, preconscious processes leading to a feeling of familiarity with an "old" stimulus from the priming phase will facilitate the reaction "word" rather than "non-word". The inhibition condition holds when a non-word is presented. In this condition, conscious explicit discrimination (probability: c) results in correctly rejecting a non-word. In case of no conscious discrimination (probability: 1 – c), a non-word might falsely be classified as a "word" because of interference from an "old" word from the priming phase (probability: p2 (1- c)).

Based on this taxonomy, conscious processing is defined as correctly identifying items as words or non-words. Preconscious processing occurs when a masked word is more likely to be correctly recognized as “word” after presentation during the priming phase (typical priming effect) or when a masked non-word derived from a word from the priming phase is more likelly to be recognized as “word” after its corresponding word had been presented in the priming phase (effect of activated schema).

Vaterrodt-Plünnecke (44) criticized the original PDP-model as preconscious processes cannot reliably be discriminated from chance. She argued that automatic processes are a result of either preconscious processes or of chance processes when preconscious processes are absent. Absence of preconscious processes might be due to stimulus characteristics, to the dominating impact of conscious processes, or to motivational factors. In the given model, preconscious processes are triggered by the previous presentation of a word during the priming phase. In contrast, baseline performance (i.e. “chance bias” within the modified PDP-model) refers to the probability of thinking of a word that was not presented during the priming phase. As a result, the estimate for baseline performance was derived from the relative frequency of identifying a word that was not previously presented. Therefore, the chance-bias-parameter (b) was added into the model in order to provide a valid distinction between preconscious processing and guessing. The validity of this distinction in the given sample was supported by the multinomial modeling procedure and the goodness of fit statistic.

Selection of items

Out of 90 words, 30 had been selected to be "neutral" (e.g., soap, sport, towel), 30 to be "health threatening" (e.g., pus, fever, cancer), and 30 to be "general threatening" (e.g., crime, fear, loss). Health threatening stimuli were used to elicit pain or health specific schema-guided preconscious processes. The words had a high concreteness and a low metaphorical quality because general words with lower concreteness fail to produce an attentional bias (48). The items were collected from a study of German word properties which provided ratings for familiarity and threat (30). They consisted of one up to three syllables (10 % one, 47 % two, 33 % three syllables). All groups of words were matched for familiarity and number of syllables but differed with respect to threat [neutral words: $M = 1.34$, $SD = 0.37$; general threatening words: $M = 2.69$, $SD = 0.78$; health threatening words: $M = 5.28$, $SD = 0.33$, $F(2,57) = 3.21$, $p < .01$]. Non-words were constructed from the list of 90 real words by replacing phonemes in the first or middle syllable of the original word (e.g., clinic → calnic). Reliability scores (internal consistency estimates) based on correlations between items and group means for familiarity and threat were between α = .90 and α = .93.

Masking of stimuli

Stimulus processing in the lexical decision task test phase was made difficult by masking to increase the likelihood of preconscious processing and of guessing behavior. In order to hamper a conscious decision, the stimuli were masked by white noise during the test phase with a constant signal-noise ratio of -17dB. This was done using a standardized algorithm proposed by Ott & Curio (28) and Ott, Curio, and Scholz (29).

The algorithm was derived from psychoacoustical laws concerning frequency and time-weighting of sound. Spectral characteristics were taken into account by mixing signal and white noise within frequency ranges defined through critical bandwidth. Furthermore, time-weighting was taken into account using sound-pressure patterns generated through low pass filters. Low pass filters used for time-weighting ensured that the masking sound did follow the speech signal with a standardized latency and thus made the identification of the speech signal more difficult. This technique ensures that several acoustically presented stimuli are not identifiable to a standardized degree. Ott et al. (29) have shown that in the white-noise condition, the probability of correctly identifying a target word significantly differs from the probability of identifying a word without this noise. There was evidence that under the noise condition the probability of implicit preconscious schema-guided processing is elevated. Note that in the framework of the chosen model, reactions to masked stimuli are not identical to estimates of preconscious processing. The order of masked vs. unmasked presentation was counterbalanced.

Procedure

1. At first, all participants were asked about hearing deficits because they had to process acoustic stimuli; no participant reported any difficulties.
2. In the priming phase, 90 words were presented acoustically by headphones. In order to process these stimuli and to create memory traces, each participant had to construct a

sentence with each of these 90 words and to say the sentence aloud (Instruction: "Please, make a sentence with this word!")

3. In the subsequent test phase, 180 target items (90 words and 90 non-words) were presented with white noise (subliminal), and 180 items were presented unmasked (supraliminal). Participants were instructed to decide whether the given sound was a word or a non-word by pressing a response key. There were four subsets of items for each category of threat (neutral, health threatening, general threatening): 30 words as in priming phase; 30 non-words phonologically similar to the words from the priming phase; 30 new words, calibrated for familiarity, not processed in the priming phase; and 30 non-words phonologically similar to the new words. All words from the three lists (health-threat vs. general threat vs. neutral) were matched according to the position of the replaced phoneme within the syllable. The items were presented in random order to avoid primacy or recency effects in the test phase.

Data Analysis

Multinomial Modelling. Multinomial modelling allows the estimation of parameters which represent the probabilities of unobservable cognitive events and the integration of these estimates into statistically testable theoretical models. This analytic approach was necessary to assess different levels of processing within a consistent model of cognitive processing. In the present study, the approach was used to estimate to what extent conscious processing and preconscious processing and guessing behavior contribute to the identification of verbal stimuli. The procedure was carried out using the modified Two-Threshold-PDP model proposed by Vaterrodt-Plünneke (43, 44).

Firstly, a goodness of fit test (Power-divergence statistic, see Read and Cressie, 32) was carried out to make sure that the model contains the right number of parameters and that the data fit to the theoretical model. The goodness of fit statistic was computed based on hits (reaction "word" after stimulus "word"), misses (reaction "non-word" after stimulus "word") , false alarms (reaction "word" after stimulus "non-word"), and correct rejections (reaction "non-word" after stimulus "non-word") for every experimental condition (unmasked - old word, unmasked – old non-word; masked – old word, masked – old non-word, masked – new word, masked - new non-word). Hits, misses, false alarms and correct rejections are defined in the Appendix. Parameters were estimated by means of computer programs by Hu (21) and Rothkegel (35). These programs provide the following four parameters by using a goodness of fit statistic (29):

- c = conscious discrimination of the items (as word or non-word)
- p1 = preconscious facilitation (increased correct discrimination of old items relative to new items)
- p2 = preconscious inhibition (increased false alarm responding to "old" non-words relative to "new" non-words due to elevated perceptual fluency of "old" non-words resulting from previous presentation of corresponding words)
- b = response bias as the tendency to respond with false alarm.

Each of these parameters were calculated for neutral (n) , health threatening (ht), and general threatening (gt) words. The goodness-of-fit-statistic was tested with the G^2 statistic which is asymptotically χ^2 distributed if the null hypothesis (and therefore the model) is valid. Our model fit the data excellently ($G^2 = 2.55$, $df = 3$, $\alpha = \beta = 0.001$, $G^2_{crit} = 24.63$). Small G^2 values indicate good model fits, large G^2 values indicate poor fits. The goodness of fit statistic confirms that the theoretical model distinguishing between conscious processes, preconscious facilitating processes, preconscious inhibiting processes, and chance (response bias) is useful to describe the relevant processes underlying every individual reaction pattern in the lexical decision task.

Analysis of variance. Further data analysis was based on a 3 factor model with group (OA-group vs. somatoform pain group vs. non-CP group) as a between factor variable and level of processing (conscious processes vs. preconscious facilitating processes vs. preconscious inhibiting processes vs. chance bias) and stimulus type (neutral vs. health threatening vs. general threatening) as within-factor variables. Dependent variables were the estimates of the modified PDP-model. Post-hoc tests were calculated with respect to the 4 hypotheses. They included

- contrasts for CP-patients vs. non-CP controls with respect to conscious processing of all type of stimuli (Hypothesis 1)

- contrasts for patients with somatoform pain vs. OA-pain vs. non-CP controls with respect to preconscious processing of health related stimuli (Hypothesis 2)
- contrasts for OA-patients vs. somatoform pain patients vs. non-CP controls with respect to chance bias with respect to all type of stimuli (Hypothesis 3)

The score of the SCL-90-R subscale "Depression" was used as a covariate to estimate the impact of depression in the previous week on parameters of cognitive functioning. The score on the SF36 subscale "Bodily pain" was used as a covariate to estimate the impact of self-reported experience of pain in the last month on the PDP-parameters. The effect size (eta^2) indicates the strength of the relationship between depression and pain intensity on the one hand and parameters of cognitive processing on the other for the whole sample (Hypothesis 4).

Power analysis

The multinomial model analysis was based on 101 participants with 90 items each, resulting in a total of 9090 observations. For this sample size, 3 *df*, and an α-error level of 1 %, the statistical power is approximately 1 for χ^2-comparisons with small effects. Thus, the probability was high for identifying a true difference between conscious processes, facilitating preconscious processes, inhibiting preconscious differences, and chance.

The power of the group comparison was weaker because each model parameter estimate was considered as a single observation. We expected a large effect for the impact of pain (group membership) on conscious processing but a weaker effect for the impact on parameters of preconscious processing. For a large effect size (ES = .40), an α-error level of 5 % and a sample size of 91, the statistical power is .95. Accordingly, the power was high enough to reveal large size effects and to estimate medium size effects with the given sample size.

RESULTS

Preliminary analyses

There was an interaction effect of group membership, levels of processing, and type of stimulus (Wilk´s λ = .82, F = 1.79, df = 12/186, p <.05). That is, OA-patients, somatoform pain patients, and pain free controls reacted differently to lexical decision tasks at different levels of cognitive processing.

There was a significant interaction between type of stimulus and levels of processing (Wilk´s λ = .94, F = 3.1, df = 6/97, p < .05). Accordingly, participants tended to react differently at different levels of cognitive processing to threatening and non-threatening stimuli.

The interaction between type of stimuli and group membership did not reach significance (Wilk´s λ = .97, F = .91, df = 4/194, n.s.). Thus, overall the groups did not process threatening and non-threatening stimuli differently as long as the level of processing was not taken into account. As a result, group differences are presented separately for conscious processes, preconscious processes, and chance bias. *Differences between OA-patients, patients with chronic somatoform pain, and participants who did not have CP*

Mean estimates of the PDP-parameters for neutral stimuli, health threatening stimuli, general threatening stimuli, and for all levels of the factor stimulus type combined are presented separately for each participant group in Figure 1. The level indicates the proportion of each specified process within a unique model of cognitive processing.

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Conscious processing (Hypothesis 1). The interaction of levels of processing and group membership was significant (Wilk´s λ = .86, F = 2.62, df = 6/192, p <.01) with an elevated level of conscious processing in non-CP participants compared to CP-participants. OA-patients showed the lowest estimates of conscious processing for neutral stimuli (T = 2.98, df = 1/63, p < .01), for general threatening stimuli (T = 2.73, df = 1/64, p < .01), and averaged over all type of stimuli (T = 2.70, df = 1/64, p<.01). Patients with somatoform pain tended to show less conscious processing than participants who did not have CP but these differences were not significant (T = 1.12, df = 1/63, n.s.). Hypotheses 1 was confirmed for OA-patients but not for patients with somatoform CP.

Preconscious processing (Hypothesis 2). An impact of CP on preconscious processing of general threatening and health threatening stimuli was expected for the somatoform pain group rather than for the OA-group. In the facilitating condition, neither patients with somatoform CP nor patients with OA-pain differed from participants who did not have CP (F = .21, df = 2/98, n.s.). However, there was a main effect of group membership on preconscious inhibition (exclusion condition: F = 2.92. df = 3, p <.05) for health threatening stimuli. As expected, patients with somatoform CP showed higher levels of preconscious inhibition during processing of health threatening stimuli compared to participants without CP (T = 2.4, df = 1/65, p < .05). Hypothesis 2 was confirmed for preconscious inhibiting processes but not for preconscious facilitating processes.

In addition, we found that OA-patients showed a lower level of preconscious inhibition during processing of neutral stimuli (“exclusion condition”: T = 2.13, df = 1/64, p < .05) than healthy controls. OA-patients and somatoform pain patients showed lower preconscious inhibition for general threatening stimuli compared to controls without CP (F = 3.11, df = 2/98, p < .05).

Chance bias (Hypothesis 3). OA-patients showed the highest level of chance bias (F = 3.72, df = 2/94, p < .05) for all stimuli combined compared to the other groups. Even compared to patients with somatoform pain, OA-patients showed a higher chance bias for neutral stimuli (T = 1.8, df = 1/65, p < .05) and health threatening stimuli (T = 2.72, df = 1/64, p < .01). Patients with chronic somatoform pain and participants without CP did not differ with respect to chance bias. Hpothesis 3 was confirmed for OA-patients but not for patients with somatoform CP.

Effect of pain status and depression during the previous week on PDP-parameters (Hypothesis 4) The SF-36 index "Bodily pain" – score was highly correlated with all pain items from the SOMS-Scale and the pain items from the interview. Thus the "Bodily Pain" – score was the best indicator of pain status. Results showed that neither pain status (SF-36 "Bodily Pain") nor depression during the previous week (Subscale "Depression" of the SCL-90-R) were significantly correlated with the PDP indices. The impact of pain status on cognitive processing was either equal to or stronger than the effect of depression (Figure 2). Correlations between the depression score and indices of conscious processing were slightly lower than correlations between the pain score and indices of conscious processing. Overall, type of stimulus did not affect the effect of pain status and of depression on PDP parameters. Hypothesis 4 was not confirmed.

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DISCUSSION

The chosen methodological approach of multinomial modelling allows to estimate parameters of processing within a consistent three-component model of cognitive functioning. The major advantage of this approach is that theoretical conclusions about the impact of CP on cognitive processing can be drawn from theory-based estimates of parameters of cognitive processing. Cognitive processing is analyzed in a range between conscious thinking and random reacting.

Impact of CP on conscious processing

It was predicted that CP-patients show lower levels of *conscious processing* for all types of stimuli compared to controls without CP because of the disturbing impact of pain on central executive functions. However, the results showed no consistent effect of CP on conscious cognitive processing for both CP-groups. While OA-patients with pain as a predominant sensory problem showed lower levels of conscious processing than non-CP controls, somatoform patients with pain as a complex of sensory and behavioral dysfunctions did not differ significantly from non-CP controls. OA-patients tended to process neutral and general threatening stimuli less consciously than non-CP controls. The difference between OA-patients and controls for different types of stimuli was in line with previous studies (47, 5, 34) showing that attention and memory functions were impaired in CP-patients for several qualities of stimuli. The result also supports results of previous studies showing cognitive dysfunctions in CP-patients by use of cognitive achievement tests. Since attention and memory achievement tests usually require a high level of conscious processing (12, 47), poor performance in cognitive achievement tests is consistent with a low level of conscious processing in the present study. However, the difference between OA-patients and somatoform patients on one hand, and the similarity of the profile of patients with somatoform pain to that of controls without CP on the other, was surprising because both OA and somatoform patients complained about CP of similar intensity. Moreover, in our sample patients with somatoform pain specified more pain sites than OA-patients. We conclude that the impact of pain on conscious processing is related to the disturbing pain sensation (as in OA-patients) rather than to the expression of pain (as in somatoform patients). This view is supported by studies of Curio and Scholz (4) and Viitanen, Kautiainen and Isomaki (46). They have shown that pain sensations caused by bodily damage do not reflect the same sensory experience as pain described by patients with somatoform complaints. As a result, pain from bodily damage and somatoform pain will probably not provoke the same disturbing cognitive effect.

Elevated chance bias is an additional characteristic of CP-related cognitive dysfunction An elevated *chance bias* was expected to occur in CP-patients because the resource-demanding character of CP increases the probability of cognitive confusion and random behavior. Again, just OA-patients differed from controls without CP with respect to guessing behavior (chance bias) while patients with somatoform pain failed to show significant differences compared to controls. Apparently, an elevated chance bias is evident if sensory aspects of pain (as in OA-patients) dominate the picture. One explanation of this result is that the experience of pain leads to cognitive exhaustion which is characterized by a lack of analytical processing and of inhibition within the central executive function (19). This may provoke random behavior and elevated error rates. Furthermore, the elevated chance bias in OA-patients fits with results by Veldhijzen et al.

(45) who found that pain patients compared to pain-free controls show elevated neurophysiological reactions to task-irrelevant stimuli and higher error rates in attentional capacity tasks. It should be noted that in the chosen paradigm, conscious processes, preconscious processes, and chance bias were not stochastically related. We conclude that enduring painful sensations lead to elevated error rates in forced choice tasks because of an increased chance behavior which is not directly related to the extent of either conscious or preconscious cognitive processing.

The impact of CP on preconscious processing is rather weak and depends on type of stimuli and type of disorder

We also predicted an elevated *preconscious bias* to health-related or threat-related stimuli in patients with somatoform pain and elevated emotional disturbance compared to CP-patients with low emotional disturbance and low behavioral dysfunction (OA-patients). As expected, the former group showed the highest level of preconscious preconscious interference from previously processed health related stimuli while OA-patients did not differ significantly from non-CP controls. Since estimates of preconscious processing in the inhibition condition are better indicators of the strength of preconscious activity than estimates in the facilitating inclusion condition, this result might indicate the impact of a fear-related cognitive schema of CP in the somatoform pain group. The effect of health-threatening stimuli on preconscious processing in patients with somatoform pain can be explained by preconscious facilitation of fear-related attention and delayed disengagement of attention from pain as described by Van Damme et al. (41). Based on results by Van Damme et al (40), we can assume that in the somatoform pain group, the initial shift to health-related stimuli, the cognitive engagement with health or pain related stimuli, and a delayed disengagement from these stimuli are more pronounced than in the OA-group. Possibly, during the priming phase, the somatoform symptom group may have more readily developed sentences specific to their own health problems; thus, sentences with health-threat words created even more of a memory trace than neutral words in the somatoform group. According to this view, participants with somatoform pain may have engaged in more personal encoding of the word. This is supported by the finding that the somatoform group showed the lowest verbal fluency in the vocabulary test possibly because of restrictions of memory processes due to healthrelated fears. We conclude that if and only if CP is combined with emotional disturbance or health-related fears, the impact of CP on cognitive processing seems to depend on the type of stimuli triggering preconscious processes. However, even in patients with somatoform pain, the effect of health-threatening stimuli on preconscious processing was rather weak (see 17). The weakness of this effect may be due to the chosen type of stimuli. The stimuli used here were health-related but not strictly pain-related. Since Flor et al. (13) and Edwards and Peirce (10) proposed a selective cognitive schema of pain-related stimuli in CP-patients, items directly related to pain might have caused a stronger preconscious memory bias. Our results were consistent with findings of Snider, Asmundson, and Wiese (38) and Zaunbauer (49) who found that even for pain-related stimuli, subgroups of CP patients fail to show any selective attention under the subliminal condition. When sensory aspects dominate the pain problem (as in OA-patients), preconscious interfering processes due to fear-related or health-related stimuli seem to be overshadowed by alterations of conscious processes and elevated tendencies of guessing.

Depressive state and intensity of bodily pain do not mediate the impact of CP on cognitive processing

Depression and intensity of bodily pain were expected to trigger the cognitive disruption in CP-patients (27, 1, 16). However, neither bodily pain intensity (measured by SF-36) nor depressive state (measured by SCL-90-R) were significantly related to cognitive processing. One explanation of this result is that in our study, it was not the capacity of attention or memory that was assessed but the relative contribution of several levels of cognitive processing on the outcome of lexical decision tasks. Most empirical studies examine the mediating effect of affective factors on cognitive achievement parameters (23, 24). Possibly, self reports of depression as used here are related to achievement parameters rather than to specific levels of cognitive processing.

A second explanation of the lack of a mediating effect of depression is that depression and pain may have opposite effects on conscious processing. The suppressing impact of pain on conscious processing (16) might interfere with the elevating impact of depression on conscious processing (8) and reduce the impact of depression on conscious processing in CP-patients. Overall, the affective state does not seem to be a relevant mediator between chronic pain, pain intensity at present and the likelihood of different levels of cognitive processing.

Theoretical conclusions

Within the chosen three-component model of cognitive processing, CP has the strongest impact on conscious processing and on guessing behavior. If – as in OA-patients and in studies with experimentally provoked pain – sensory aspects dominate the picture and the level of pain-related emotional disturbance is rather low, conscious processing is clearly suppressed by pain.The ability to consciously filter relevant from irrelevant information is impaired in CP-patients, as Duckworth et al. (9) have shown. The perception of pain may delay disengagement from pain and reduce the capacity to focus on external stimuli (7). All of these features contribute to a reduction of conscious processing.

The impact of CP on guessing behavior which is affected neither by conscious nor by preconscious processes has hardly been described as yet. According to our findings, chance has to be considered as a separate component of cognitive behavior when the impact of CP on cognitive processing is analyzed. It should be taken into account that poor results in cognitive achievement tests (6) and elevated error rates in CP-patients (45) are at least partly due to guessing behavior rather than to disturbed conscious or preconscious processes. One should note that guessing behavior is probably affected by both motivational and cognitive factors. Consequently, future studies analyzing the impact of CP on cognitive functioning should focus on the relation between motivational factors (achievement motivation etc.) and chance bias.

According to the results by Grisart et al. (16), the impact of CP on preconscious processing is weak. Patients with somatoform pain show a less typical profile of pain-related cognitive dysfunction at several levels of processing than OA-patients. As a result, the impact of CP has to be interpreted differently with respect to the type of pain experience.

Overall, the present study underlines the necessitiy to differentiate between conscious processes, preconscious processes, and chance bias within a consistent theoretical model of cognitive processing. Eccleston and Crombez (11) argue that pain interrupts and distracts cognitive processes and demands attention per se. In contrast, our data show that the impact of CP on attention and memory depends on the level of cognitive processing and on how CP is combined with emotional disturbance and fear-related processing. A consistent impact of CP on cognitive functioning for several diagnostic groups as shown by Dick et al (6) seems to be probable if and only if different levels of processing are ignored.

Clinical implications

The results have consequences for the assessment of CP-patients looking for therapeutic help or health-related compensation. Dysfunctions of conscious memory processes seem to be elevated mainly in patients with pain caused by physical damage. For this group, direct memory tests that focus on conscious memory processes seem to deliver sufficient information about pain-related memory dysfunction. Indirect memory tests of preconscious memory dysfunction are not generally needed in order to quantify CP-related cognitive dysfunctions. Since CP seems to enhance the probability of guessing behavior in cognitive tests, estimates of reliability should explicitly be considered in the assessment of memory dysfunction in CP-patients. Patients with somatoform pain show smaller changes of cognitive processing than OA-patients. As a result, complaints of somatoform pain patients about cognitive or memory dysfunctions should be evaluated in terms of illness behavior rather than in terms of cognitive impairment.

References

1. Brown SC, Glass JM, Park DC: The relationship of pain and depression to cognitive function in rheumatoid arthritis patients. Pain 96: 279-284, 2003
2. Bullinger M, Kirchberger I: [Questionnaire on health status SF-36]. Göttingen: Hogrefe, 1998
3. Chapman CR, Gavrin J. Suffering: the contributions of persistent pain. Lancet: 353:2233-2237, 1999
4. Curio I, Scholz OB. [Pain description and illness behavior in pain diaries of fibromyalgia and polyarthritis patients]. Z Rheumatol 53:11-18, 1994
5. De Wied M, Verbaten, MN: Affective pictures processing, attention, and pain tolerance. Pain 90:163-172, 2001
6. Dick B, Eccleston C, Crombez G: Attentional functioning in fibromyalgia, rheumatoid arthritis, and musculoskeletal pain patients. Arthritis Rheum47: 639-644, 2002
7. Dick BD, Rashiq, S: Disruption of attention and working memory traces in individuals with chronic pain. Anesth Analg 104: 1223-1229, 2007
8. Dohrenbusch R, Ott R, Scholz OB: Conscious and preconscious uses of memory in patients with depressive and somatoform disorders. J Psychopathol Behav Assess 28:69-77, 2006
9. Duckworth MP, Iezzi A, Adams H, Hale D: Information processing in chronic pain disorder: A preliminary analysis. J Psychopathol Behav Assess 19:239-255, 1997
10. Edwards L, Peirce S: Word completion in chronic pain: evidence for schematic representation of pain. J Abn Psychol 103:379-382, 1994
11. Eccleston C, Crombez G: Pain demands attention: A cognitive-affective model of the interruptive function of pain. Psychol Bull 125:356-366, 1999
12. Eccleston C, Crombez G, Aldrich S, Stannard C: Attention and somatic awareness in chronic pain. Pain 72:209-215, 1997
13. Flor H, Knost B, Birbaumer N: Processing of pain- and body-related verbal material in chronic pain -patients: Central and peripheral correlates. Pain 73:413-421, 1997

14. Franke GH: [The symtom checklist by Derogatis – German Version SCL-90-R]. Weinheim: Beltz, 1995
15. Glass JM: Cognitive dysfunction in fibromyalgia and chronic fatigue syndrome: new trends and future directions. Curr Rheumatol Rep 8:425-429, 2006
16. Grisart JM, Van der Linden M: Conscious and automatic uses of memory in chronic pain-patients. Pain 94:305-313, 2001
17. Grisart JM, Van der Linden M, Masquelier E: Controlled processes and automaticity in memory functioning in fibromyalgia patients: Relation with emotional distress and hypervigilance. J Clin Exp Neuropsychol 24: 994-1009, 2002
18. Hecker Uv, Sedek G, McIntosh DN: Impaired systematic, higher order strategies in depression and helplessness: testing implication of the cognitive exhaustion model. In: Hecker Uv, Dutke S, Sedek G (eds): Generative Mental Processes and Cognitive Resources. Dordrecht NL, Kluwer, 2000, pp 245-307
19. Hertel PT, Meiser T: Capacity and procedural accounts of impaired memory in depression. In: Hecker Uv, Dutke S, Sedek G (eds): Generative Mental Processes and Cognitive Resources. Dordrecht NL, Kluwer, 2000, pp 283-307
20. Hiller W, Zaudig M, Mombour W: [International diagnostic lists for ICD-10]. Bern, Hans Huber, 1995
21. Hu X: Multinomial processing tree models: An implementation. Beh Res Meth Instr Comp 31:689-695, 1999
22. Jacoby LL: A process dissociation framework: Separating automatic from intentional uses of memory. J Mem Language 30:513-541, 1991
23. Kewman DG, Vaishampayan N, Zald D, Han B: Cognitive impairments in musculoskeletal pain patients. Int J Psychiatry Med 21: 253-262, 1991
24. Kuhajda MC, Thorn BE, Klinger MR, Rubin NJ: The effect of headache pain on attention (encoding) and memory (recognition). Pain 97:213-221, 2002
25. Ling J, Campbell C, Heffernan TM, Greenough CG: Short-term prospective memory deficits in chronic back pain patients. Psychosom Med 69: 144-148, 2007
26. Lupke U, Ehlert U. Selektive Aufmerksamkeitslenkung auf gesundheitsbedrohliche

Reize bei Patienten mit somatoformen Störungen. [Attentional bias toward health-threatening cues in patients with somatoform disorders]. Zeitschrift für Klinische Psychologie 27:163-171, 1998

27. Munoz M, Esteve R: Reports of memory functioning by patients with chronic pain. Clin J Pain 21: 287-291, 2005
28. Ott R, Curio I: Masking of complex sound--technical notes for realization of constant signal-noise-ratio. Percept Mot Skills 89:137-144, 1999
29. Ott R, Curio I, Scholz OB: Implicit memory for auditorily presented threatening stimuli: a process-dissociation approach. Percept Mot Skills 90:131-146, 2000
30. Ott R, Scholz OB: Wortnormen der Bedrohlichkeit und Bekanntheit für 197 deutsche körperbezogene Substantive. [Norm data for degree of threat and familiarity of 197 body related german nouns.] Sprache & Kognition 17:214-223, 1998
31. Pincus T, Morley S. Cognitive processing bias in chronic pain: A review and integration. Psychol Bull 127: 599-617, 2001
32. Read TRC, Cressie N: Goodness-of-fit statistics for discrete multivariate data. New York, Springer, 1988
33. Rief W, Hiller W, Heuser J: [Screening test for somoatoform disorders] Screening für Somatoforme Störungen (SOMS). Göttingen, Hogrefe, 1997
34. Rode S, Salkovskis PM, Jack T: An experimental study of attention, labelling and memory in people suffering from chronic pain. Pain 94:193-203, 2001
35. Rothkegel R: AppleTree: A multinomial processing tree modelling program for Macintosh Computers. Beh Res Meth Instr Comp 31:696-700, 1999
36. Schmidt KH, Metzler P: Wortschatztest (WST). [Vocabulary test WST]. Weinheim, Beltz, 1992
37. Scholz OB, Ott R, Müller-Sinik K: Beziehungen zwischen Parametern der impliziten und expliziten Informationsverarbeitung und psychosomatischen Selbstberichtsmaßen [Relationships between parameters of implicit and explicit information processing and psychosomatic self reports]. Verhaltenstherapie 7:217-225, 1997

38. Snider BS, Asmundson GJG, Wiese KC: Automatic and strategic processing of threat cues in patients with chronic pain: A modified Stroop evaluation. Clin J Pain 16:144-154, 2000
39. Turner JA, Ersek M, Kemp C: Self-efficacy for managing pain is associated with disability, depression, and pain coping among retirement community residents with chronic pain. J Pain 6:471-9, 2005
40. Van Damme S, Crombez G, Eccleston C, Koster EH: Hypervigilance to learned pain signals: a componential analysis.J Pain 7: 346-357, 2006
41. Van Damme S, Crombez G, Eccleston C: Retarded disengagement from pain cues: the effects of pain catastrophizing and pain expectancy. Pain 100:111-118, 2002
42. Van der Laan WH, van Leeuwen BL, Sebel PS, Winograd E, Baumann P, Bonke B: Therapeutic suggestion has not effect on postoperative morphine requirements. Anesth Analg 82: 148-52, 1996
43. Vaterrodt-Plünnecke B: Multinomiale Modellierung impliciter Gedächtnisprozesse: Ein alternativer Ansatz. [Multinomial modelling of implicit memory processes: An alternative approach]. Zeitschrift für experimentelle und angewandte Psychologie 41:295-314, 1994
44. Vaterrodt-Plünnecke B, Krüger T, Gerdes H, Bredenkamp J: Prozeß-Dissoziations-Prozedur: Prüfbare Messmodelle zur Erfassung von kontrollierten, automatischen und Antworttendenz-Prozessen [The Process Dissociation Procedure: Testable models for measuring controlled, automatic, and response bias processes]. Zeitschrift für Experimentelle Psychologie 43:483-519, 1996
45. Veldhuijzen DS, Kenemans JL, van Wijck AJ, Olivier B, Kalkman CJ, Volkerts ER. Processing capacity in chronic pain patients: a visual event-related potentials study. Pain 121:60-68, 2006
46. Viitanen JV, Kautinainen H, Isomaki H: Pain intensity in patients with fibromyalgia and rheumatoid arthritis. Scand J Rheumatol 22:131-135, 1993
47. Villemure C, Bushnell MC: Cognitive modulation of pain: how do attention and emotion influence pain processing. Pain 95: 195-199, 2002

48. Williams JMG, Broadbend KD: Distraction by emotional stimuli: Use of the Stroop task with suicide attempters. Br J Clin Psychol 25:101-110, 1986
49. Zaunbauer ACM. Impliziter Gedächtnisbias für negatives Wortmaterial bei chronischen Schmerzpatienten mit einem Fibromyalgiesyndrom. [Implicit memory bias for negative words in CPpatients with fibromyalgia]. Berlin, Logos, 2004

Figure Legends

Figure 1: Estimates of conscious processing, processing preconsciously under the facilitating inclusion condition (“inclusion”), processing preconsciously under the inhibiting exclusion condition (“exclusion”), and of guessing behavior (“chance”) presented separately for neutral, health threatening, and general threatening stimuli. The figure "all stimuli" contains estimates averaged over all types of stimuli.
Legend: Healthy controls ---- Somatoform disorder – – – – OA-patients ———

Figure 2: Impact of covariates bodily pain (SF36) and depression (score of subscale SCL-90-R) on PDP parameters (no significant effects)

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APPENDIX

Definition of hits, misses, false alarms, and correct rejections in the Two-Threshold PDP- model

1. Condition supraliminal priming (old word/non-word)

H $= c + (1-c) \cdot p_1 + (1 - c) \cdot (1 - p_1) \cdot b$

M $= (1 - c) \cdot (1 - p_1) \cdot (1 - b)$

F $= (1 - c) \cdot p_2 + (1 - c) \cdot (1 - p_2) \cdot b$

CR $= c + (1-c) \cdot (1 - p_2) \cdot (1 - b)$

2. Condition subliminal priming (old word/non-word)

H $= c + (1-c) \cdot p_3 + (1 - c) \cdot (1 - p_3) \cdot b$

M $= (1 - c) \cdot (1 - p_3) \cdot (1 - b)$

F $= (1 - c) \cdot p_4 + (1 - c) \cdot (1 - p_4) \cdot b$

CR $= c + (1-c) \cdot (1 - p_4) \cdot (1 - b)$

3. Condition Nonpriming (new word/non-word)

H $= c + (1-c) \cdot b$

M $= (1 - c) \cdot (1 - b)$

F $= (1 - c) \cdot b$

CR $= c + (1 - c) \cdot (1 - b)$

H = Hit, M = miss, F = false alarm, CR = correct rejection; c = probability of conscious processing, p = probability of preconscious processing (1 = old word supraliminal, 2 = old non-word supraliminal, 3 = old word subliminal, 4 = old non-word subliminal), b = bias parameter (chance)