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Interpreting ambiguous health and bodily threat: Are individual differences in pain-related vulnerability constructs associated with an on-line negative interpretation bias?

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ABSTRACT

The present study examined the association between pain-related anxiety and an on-line interpretation bias for putative physical health threat. Healthy volunteers ($n = 80$) completed measures on Anxiety Sensitivity, Injury/illness Sensitivity, Fear of Pain and Pain Catastrophizing. Furthermore, they performed an interpretation task, in which spontaneous (on-line) inferences were indirectly assessed from reaction times and accuracy of a lexical decision to the final word of an ambiguous description. Results demonstrated a general facilitation of responses to final words that endorsed a health-threatening resolution of ambiguity (e.g., illness). This effect correlated positively with individual levels of Fear of Pain, but was found to be unrelated to levels of Anxiety Sensitivity, Injury/illness Sensitivity or Pain Catastrophizing. Implications of the findings and recommendations for future research are discussed.

1. Introduction

It is well acknowledged that information processing biases can act as latent vulnerability factors for the onset and maintenance of affective and emotional disorders like anxiety and depression (Beck &

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Clark, 1997; Mathews & MacLeod, 1994). Given the core role of anxiety and other emotions in chronic pain, the same cognitive mechanisms that operate in emotional and affective disorders have been suggested to be of importance in the development and persistence of chronic pain as well (Pincus & Morley, 2001). Corroborating this suggestion, several studies have demonstrated the occurrence of information processing biases in relation to (chronic) pain, that are characterized by the prioritizing of information relating to health threats or pain at both an explicit and an implicit level (Asmundson, Carleton, & Ekong, 2005; Keogh, Dillon, Georgiou, & Hunt, 2001; Pincus & Morley, 2001; Roelofs, Peters, Zeegers, & Vlaeyen, 2002).

One cognitive bias that has been frequently studied in relation to pain is the negative interpretation bias, or the tendency to interpret innocuous situations, symptoms, or sensations in a negative or threatening fashion. Studies using homophones (McKellar, Clark, & Shriner, 2003; Pincus, Pearce, McClelland, Farley, & Vogel, 1994), homographs (Pincus, Pearce, & Perrott, 1996), and word-stem completion tasks (Edwards & Pearce, 1994) have demonstrated that patients with pain make more threat and pain-related interpretations in comparison with healthy controls. Additionally, this negative interpretation bias has been observed in healthy individuals possessing elevated levels of pain-related anxiety as well; i.e., Trait Anxiety, Negative Affectivity, Anxiety Sensitivity (AS), Injury/illness Sensitivity (IS), Fear of Pain (FoP), or Pain Catastrophizing (PC) (Keogh & Cochrane, 2002; Pincus & Morley, 2001; Vancleef & Peters, 2008). Moreover, Keogh et al. (Keogh & Cochrane, 2002; Keogh, Hamid, Hamid, & Ellery, 2004) demonstrated that a negative interpretation bias mediated the relation between levels of Anxiety Sensitivity and tolerance for cold-pressor pain. Accordingly, it may be suggested that the interpretation bias acts as a latent vulnerability construct in the development and exacerbation of pain problems in those who are vulnerable for developing chronic pain (Pincus & Morley, 2001).

Despite accumulating evidence for the importance of negative interpretation bias in pain processing, studies have predominantly relied on direct self-report measures to assess this bias up to now. Because these measures are subject to response bias and conscious reconsideration, they impede deciding whether manifested negative interpretations are the result of (1) respondents wanting to comply with experimenter demands, (2) retrospective judgements that are made on the basis of negative beliefs and representations at the moment of responding, or (3) the routinely, automatic interpretation of ambiguity (Hirsch & Mathews, 1997, 2000). One possible way to overcome these problems is to use paradigms that allow the assessment of more automatized and spontaneous interpretations (i.e., on-line interpretations), like the lexical decision paradigm (Hirsch & Mathews, 1997, 2000). In the lexical decision paradigm, narrative texts that incorporate critical incomplete ambiguous sentences are presented to respondents. The incomplete sentences can have a threatening resolution, and they are completed by the appearance of a probe word that either confirms or disconfirms the implied threat. The task of respondents is to make a lexical decision on this probe word. It is assumed that *if* respondents make on-line inferences regarding the likely outcome of the incomplete sentence, *then* responses will be faster and more accurate to probe words that match this inference. The instruction to respond 'as fast as possible' to the probe words impedes the opportunity to construe retrospective judgements to the probe words. Moreover, the lexical decision (word versus non-word) to the probe words does not require referral to the preceding text and is, therefore, assumed to foster spontaneous inferences.

Using the lexical decision paradigm, the current study aims to provide a first step in examining the relation between individual levels of pain-related anxiety in healthy individuals (AS, IS, FoP, and PC), and the tendency to make on-line negative interpretations of ambiguous situations that imply health threat (relating to pain, injury or illness). Both AS and IS are conceived as fundamental fears that comprise vulnerability factors within the onset and maintenance of chronic pain (e.g., Asmundson, Wright, & Hadjistavropoulos, 2000; Stewart & Asmundson, 2006; Vancleef, Peters, Roelofs, & Asmundson, 2006). PC and FoP are conceived as pain-specific constructs that play a crucial role in the transition from acute to chronic pain (e.g., Roelofs, Peters, Deutz, Spijker, & Vlaeyen, 2005; Sullivan, Bishop, & Pivik, 1995; Vlaeyen & Linton, 2000).

Recently, AS and IS were found to be differentially predictive of explicit negative interpretations of ambiguity that referred to anxiety-related internal sensations (e.g., heart palpitation, shortness of breath) and non-anxiety-related bodily symptoms (e.g., an aching back, spots on skin), respectively (Vancleef & Peters, 2008). In this same study, PC and FoP were found to be predictive of negatively interpreting ambiguity that implied bodily sensations and symptoms. In the current study, it is hypothesized that elevated levels of AS, IS, FoP, and PC are associated with the tendency to make on-line health-threatening inferences of ambiguity. Despite available evidence on the relation between pain-related anxiety and interpretation bias, it remains unclear whether these interpretations are made at a largely unconscious and spontaneous level already, or if they result from more elaborative processing only. Furthermore, information processing theorists have suggested that cognitive processing in the early stages of information processing will guide more spontaneous response patterns than processes that occur in the later stages of information processing (Beck & Clark, 1997; McNally, 1995). As such, it might be speculated that on-line inferences are associated with specific spontaneous response patterns (for example, increase in muscle tension, physiological reactions) that fuel further dysfunctional processing and accompanying maladaptive responses to pain. The current study aims to provide a first step in examining this idea by focusing on the relation between pain-related anxiety and on-line inferences.

2. Method

2.1. Participants

Eighty participants (69 female; $M = 24$ years; SD = 6.70, range = 18–48), recruited at Maastricht's University local community took part in the study. Inclusion criteria constituted being in good mental health (no diagnosis of current psychopathology) and being free of acute or chronic (over three months) pain complaints. Conducting this study in a healthy population allows to attribute eventual findings on the relation between pain-related anxiety and a negative inferential bias to the presence of elevated levels of anxiety, ruling out these results are contaminated by the state of being in pain, being dyslexic, or being mentally unhealthy. Persons who were dyslexic or whose mother tongue was other than Dutch were not included in the study, since they might experience difficulties with the ambiguity in the interpretation task. Compliance with inclusion criteria was verbally checked with the candidate participants prior to inclusion in the study. All participants gave written informed consent and received financial compensation for participating.

2.2. Measures

2.2.1. Self-report measures

Both AS and IS were assessed with the Dutch version of the Sensitivity Index (SI)[1] (Vancleef et al., 2006). This questionnaire is a composite measure consisting of three subscales tapping AS, IS and Fear of Negative Evaluation (FNE). The latter construct was disregarded since it did not contribute to the focus of the study. In the SI, AS is measured with the 16-item Anxiety Sensitivity Index (ASI) (Peterson & Heilbronner, 1987). The ASI comprises three subscales, namely physical concerns, cognitive concerns, and social concerns, with the former subscale assumed to be of particular importance in the domain of pain (e.g., Keogh, 2004). In the SI, IS is assessed with the 11-item Injury/illness Sensitivity Index (ISI) (Taylor, 1993). Participants indicate their degree of agreement with all items on a 5-point Likert scale (1 = not at all; 5 = very much).[2] Psychometric properties of the SI and its subscales were found to be satisfactory (English version: Taylor, 1993; Dutch version: Vancleef et al., 2006).

Fear of pain was assessed with the 30-item Fear of Pain Questionnaire (FPQ: McNeil & Rainwater, 1998). Respondents indicate how fearful they are of three types of pain; i.e., severe pain, minor pain, and medical pain on a 5-point Likert scale (1 = not at all; 5 = extreme). The psychometric properties of the FPQ are satisfactory, and the measure is appropriate for usage in both healthy and clinical populations (English version: McNeil & Rainwater, 1998; Dutch version: Roelofs et al., 2005).

[1] The English version of the Sensitivity Index was translated in Dutch and subsequently back translated, after which the item content was checked against the original content. The Dutch version of the Sensitivity Index is available from the corresponding author.

[2] Note that the scoring format from the original ASI (Peterson & Heilbronner, 1987) ranges from 0 (very little) to 4 (very much).

Pain Catastrophizing is assessed with the Pain Catastrophizing Scale (PCS; Sullivan et al., 1995). Participants indicate on a 5-point Likert scale (0 = not at all; 4 = all the time) to what extent they have experienced each of 13 feelings and thoughts when they were in pain. The PCS has proven to be a reliable and valid measure and was found suitable to measure Pain Catastrophizing in both healthy volunteers and clinical populations (English version: Sullivan et al., 1995; Dutch version: Severeijns, van den Hout, Vlaeyen, & Picavet, 2002; Van Damme, Crombez, Bijttebier, Goubert, & Van Houdenhove, 2002).

2.2.2. On-line interpretation paradigm

The on-line interpretation task consisted of 124 situational descriptions with a length of four lines (mean amount of words for each description = 22) (see Appendix for examples). The final sentence of each description was incomplete, lacking the end word that was presented as the probe requiring a lexical decision. The task incorporated 52 ambiguous descriptions that could lead to either a health-threatening[3] (A_H) or a safe (A_S) resolution. Of these 52 ambiguous descriptions, 26 ended on a *word* leading to a health-threatening resolution (A_H_W) or a safe (A_S_W) resolution, and the other 26 ended on a *non-word* leading to a health-threatening (A_H_NW) or a safe (A_S_NW) resolution. The non-words were created by shuffling the letters of a putative target word through each other. In order to control for the possible influence of particular descriptions, both groups of ambiguous word and non-word descriptions were again split-up, such that for each participant half of the descriptions was presented in their health-threatening resolution and the other half in their safe resolution. These groups were counterbalanced over participants so that one and the same ambiguous description was never presented in its two possible resolutions to the same participant. Thus, each participant received 13 ambiguous descriptions with a health-threatening word resolution (A_H_W_1 or A_H_W_2), 13 descriptions with a safe word resolution (A_S_W_1 or A_S_W_2), 13 descriptions with a health-threatening non-word resolution (A_H_NW_1 or A_H_NW_2) and 13 descriptions with a safe non-word resolution (A_S_NW_1 or A_S_NW_2).

Additionally, forced inference descriptions were incorporated in the task (*see* Hirsch & Mathews, 2000). These descriptions were created in such a way that they led inevitably to either a health-threatening (F_H) or a safe (F_S) probe resolution and are, therefore, reflective of pure on-line inference responses. Within participants, the forced inference descriptions shared the end word or non-word with the ambiguous descriptions, and they are thus inextricably bound up to an ambiguous description. Because the forced inference descriptions are assumed to yield on-line inferences, responses to this type of descriptions can be regarded as baseline measures of making on-line inferences, against which the responses to ambiguous descriptions can be set. Last, we included 20 control ambiguous descriptions (C) in the task of which half ended on a non-word. These descriptions dealt with trivial situations and were not at all related to health threats. The logic for including these descriptions was that they could provide an additional check for the effect of individual differences for dealing with ambiguity altogether. When a relation between levels of pain-related anxiety and a negative on-line bias is detected, inspection of performance on the control descriptions provides information as to whether this effect is not attributable to pain-anxious individuals providing slowed down responses to ambiguity in general.

The ambiguous descriptions that were used in the task were chosen on the basis of a pilot study that was conducted in 17 volunteers. In this pilot, 64 experimenter-created ambiguous descriptions were presented with the omission of the end word. Respondents were required to first write down the word that they expected to complete the description. Next, respondents were offered the two experimenter forecasted end words (health-threatening and safe), and a likelihood percentage between 0 and 100 was assigned to each alternative. We first eliminated those descriptions in which the spontaneous completion by respondents in no case matched with one of the intended resolutions of the experimenters. From the remaining descriptions, we selected 26 descriptions that reached likelihood percentages above 50% for each alternative end word to be included in the task.

[3] Note that the health-threatening resolutions imply resolutions of ambiguity that refer to sickness, injury, pain, or dead. A broad spectrum of health-threatening situations was chosen in order to make the descriptions relevant for this healthy study population that is free from specific pain-related pathology.

2.3. Procedure

Upon entering the test room, participants received verbal instructions from the experimenter. In these instructions, participants were informed that they took part in a study on individual differences with respect to reading and comprehension of Dutch sentences and words. In these instructions, participants were informed about the anonymous processing of their data and they were informed that they could refrain their participation at any given time during the experimental procedure. Next, participants signed an informed consent form. The on-line interpretation task was then started with six practice trials, to get the participant acquainted with the test procedure and the response format. The descriptions appeared line-by-line on the computer screen and participants could navigate through each description at their own pace. A next line appeared each time when the participant pressed the middle button of a three-button response box. When the last line of a description had been presented, pressing the middle button of the response box led to the presentation of red fixation crosses in the centre of the screen. These crosses signalled the appearance of the probe word and remained on screen for 750 ms. In this time frame, participants could prepare the lexical decision by placing their fingers on the outer left (labelled with a 'W' (word)) and the outer right (labelled with a 'N' (non-word)) button of the response box. The probe word remained on the screen for maximally 2500 ms. Incorrect responses or responses that were not given within 2500 ms were signalled by a sound and the first line of the next description was presented at 1000 ms after the response or the sound. Reaction times and errors were registered.

To ensure that participants kept their attention focused on the task they were led to believe that they would be tested on the content of the descriptions afterwards. To increase credibility of this argument participants already had to answer some questions regarding the content of the practice descriptions in between the practice and test phase of the task. Following the completion of the task participants answered questions regarding the professions and sports they remembered from the descriptions in the task, and they indicated which description was most notable for them. Next, participants filled out the self-report measures.

2.4. Statistical analyses

Based on inspection of the distributions of the dependent variables, one participant was deleted from further analyses since error percentage deviated more than three standard deviations from the mean error percentage. Altogether, the mean error percentage was 2.03 ($SD = 1.57$), indicating that only few errors were made on the lexical decision trials. Because the error percentage was too low in order to conduct meaningful data analyses on them, further analyses were conducted on the reaction time data only. All analyses were conducted on median latencies since median scores are less sensitive to outlying values than mean reaction times (Ratcliffe, 1993). Only trials with a correct first response were incorporated in these analyses.

In addition to the data analyses that were needed to answer the research hypotheses, we first conducted a paired sample *t*-tests to verify whether responses were faster to the word trials than to the non-word trials. These analyses served as a control for the effectiveness of the task in measuring semantic inferences. Reading through the descriptions is assumed to activate semantic processing that makes participants expect a word rather than a non-word to finish the incomplete sentence. Faster reaction times to the word trials are, therefore, indicative of semantic processing of the descriptions.

Further analyses were conducted on latencies of the word descriptions only. The effects of description type and valence were examined with a 2 (description type: ambiguous versus forced inference) $\times$ 2 (valence: health-threatening versus safe) repeated measures ANOVA. All variables were within subject.

The negative interpretation index (INT_rt) was calculated by subtracting latencies on the ambiguous health-threatening descriptions from latencies on the ambiguous safe descriptions. To increase the sensitivity of the interpretation index we next subtracted the difference score for the forced inference descriptions (calculated in the same manner) from the obtained difference score on the ambiguous descriptions. The interpretation index was thus calculated as follows:

INT_rt = [(rt_A_S_W − rt_A_H_W) − (rt_F_S_W − rt_F_H_W)]. A positive difference score indicates faster responses on the ambiguous descriptions that have a health-threatening resolution. A positive value of INT_rt thus reflects the tendency to interpret the ambiguous descriptions in a negatively biased manner. The relation between the interpretation bias index and the scores on the self-report measures (ASI, ASI subscales, ISI, PCS, FPQ) is examined with Pearson correlation coefficients.

3. Results

The overall mean median reaction time in the task was 649.89 ms (SD = 117.35). Sustaining the validity of the task, a paired sample *t*-tests showed that responses were significantly faster on descriptions that ended on a word (623 ms) than descriptions that ended on a non-word (672 ms), with $t(78) = -6.19$, $p < 0.001$. Mean median latencies for the ambiguous and forced inference word descriptions, as well as the descriptives of the self-report measures are presented in Table 1.

The 2 (description type) × (valence) ANOVA revealed a significant main effect of description type ($F(1,78) = 146.56$, $p < 0.001$, $d = 0.65$) with faster responses on the forced inference descriptions than on the ambiguous descriptions (557 ms versus 695 ms). There was no significant main effect of valence. The description type × valence interaction was significant: $F(1,78) = 19.25$, $p < 0.001$, $d = 0.20$. The interaction effect was further examined with post hoc paired sample *t*-tests, demonstrating that on the ambiguous descriptions, latencies were significantly faster for the health-threatening resolution ($t(78) = -3.89$, $p < 0.001$), whereas on the forced inference descriptions, latencies were significantly faster on descriptions with a safe resolution ($t(78) = 3.10$, $p < 0.01$).

We next calculated the interpretation index ($M = 71.49$, SD = 144.83) that was then correlated with the self-report measures (Table 2). Fear of pain correlated significantly with INT_rt. None of the other individual difference measures showed a significant correlation with the INT_rt. Correlations between the subscales of the ASI and the interpretation index ranged between −0.09 and 0.05.

Post hoc analyses were conducted to further explore the association between FoP and the interpretation bias. With a median split on the FPQ scores a high (score ≥ 76; $N = 41$) and a low (score < 76; $N = 38$) FoP groups were created. A 2 × 2 repeated measures ANOVA with description type and valence as within subjects factor and FoP as between subject factor on the latencies resulted in a significant three-way interaction with $F(1,77) = 9.54$, $p < 0.01$, $d = 0.11$. For the low FoP group, latencies for the health-threatening resolutions did not differ from latencies on the safe resolutions in the ambiguous (666 ms versus 685 ms) as well as the forced inference descriptions (544 ms versus 542 ms). For the high FoP group, significant faster responses were observed on the health-threatening resolutions of

Table 1
Mean median latencies and standard deviations for the ambiguous and forced inference word descriptions (ms), and for the self-report measures ($N = 79$)

	Mean	SD	Min	Max
On-line inference task				
Ambiguous safe	717.82	185.17		
Ambiguous health-threatening	672.65	120.83		
Forced inference safe	545.01	116.58		
Forced inference health-threatening	672.22	146.80		
Self-report measures				
ASI-total	24.36	4.84	18	48
ASI physical concerns subscale	10.10	2.76	8	27
ASI cognitive concerns subscale	5.03	1.31	4	12
ASI social concerns subscale	9.24	2.20	4	14
ISI	21.73	6.32	12	39
PCS	11.64	6.57	0	29
FPQ	75.28	15.13	40	115

Note. ASI = Anxiety Sensitivity Index; ISI = Injury/illness Sensitivity Index; PCS = Pain Catastrophizing Scale; FPQ = Fear of Pain Questionnaire.

Table 2
Pearson correlation between the interpretation bias index and the self-report measures ($N = 79$)

	ASI	ISI	PCS	FPQ
ISI	0.44*	1		
PCS	0.53*	0.50*	1	
FPQ	0.13	0.46*	0.41*	1
INT_rt	0.01	0.12	0.18	0.25*

Note. ASI = Anxiety Sensitivity Index; ISI = Injury/illness Sensitivity Index; PCS = Pain Catastrophizing Scale; FPQ = Fear of Pain Questionnaire; INT_rt = interpretation bias index.
*$p < 0.01$.

ambiguity (677 ms) than on the safe resolutions of ambiguity (747 ms) with $t(40) = -3.82$, $p < 0.001$. On the forced inference descriptions, responses were faster on the safe resolutions (547 ms) than on the health-threatening resolutions (595 ms) with $t(40) = 4.40$, $p < 0.001$.[4]

4. Discussion

The present study aimed to examine whether individual levels of AS, IS, FoP, and PC are associated with on-line negative interpretations of ambiguous situations implying bodily and health threat. Results demonstrated a general facilitation of responses to the health-threatening resolution of ambiguity, and this effect was especially pronounced in participants possessing elevated levels of FoP. No relation was found between the negative interpretations and the other pain-related constructs, i.e., IS, AS, and PC.

These findings suggest that people may be generally inclined to make spontaneous on-line negative inferences when confronted with health-threatening ambiguity, thereby echoing results of a recent study, in which a generalized automatic threat appraisal was observed towards verbal stimuli representing injury, illness, and pain (Vancleef, Peters, Gilissen, & de Jong, 2007). Cognitive theories have emphasized the evolutionary benefits that are connected to a fast and early detection of (health) threat. More specifically, these theories assume the functioning of an early threat detection system, that enhances survival chances through warning individuals for and protecting them against serious physical damage (e.g., Beck & Clark, 1997; Lang & Craske, 1997; Öhman, 1979). However, in high-anxious individuals, the early threat detection system is assumed to have lost its evolutionary value, and to have evolved into a continuous 'anxious processing mode' characterized by an excessive orientation towards threat that dominates cognitive, physiological, behavioural and affective responses to putatively innocuous situations. Contrary to the present findings, healthy low-anxious individuals are thus not assumed to possess a negative interpretation bias in general. Moreover, research within the domain of social anxiety demonstrated that healthy participants were characterized by a *positive* on-line interpretation bias (Hirsch & Mathews, 1997, 2000). The main difference between these social anxiety studies and the present one might concern the object of the implied threat, being social or health related. The importance of the threat value in the manifestation of information processing biases in healthy individuals has been stressed in several cognitive models of anxiety (e.g., Mathews & Mackintosh, 1998; Mogg & Bradley, 1998). According to these models, severely threatening stimuli are prioritized and negatively processed by high- *and* low-anxious individuals, given the evolutionary benefits of an early detection of severe threat. Conversely, moderately or non-threatening stimuli will be avoided or positively processed by non-anxious individuals (Mathews & Mackintosh, 1998; Mogg & Bradley, 1998). Following this perspective, it might be suggested that the severe threat value of stimuli in the present study (implying death, serious injury, and illness) ensures an initial negative processing of these stimuli by all individuals, irrespective of their pain-related anxiety level.

It should be acknowledged that the general spontaneous negative interpretation bias in the present study might have (partly) resulted from an undesirable priming effect. Since many of the situational

[4] Similar analyses as conducted with median split groups for the other individual difference measures (ASI, ISI, PCS) did not result in significant three-way interactions and are as such not reported in this manuscript.

descriptions in the lexical decision paradigm related to pain and disease, expectations for a pain or disease-related resolution of ambiguity might have been raised. Although descriptions in the task were based on a pilot study and intended to entail full ambiguity, it cannot be ruled out that a general negative framework was activated by the task anyway.

Independent of whether persons generally hold a negative bias towards ambiguous health-related situations, or whether this effect was strengthened by task-specific priming effects, it is notable that FoP resulted as the only pain-related construct that was positively associated with the negative interpretation bias. Moreover, post hoc analyses as conducted on the high and low FoP groups demonstrated that favouring the pain-related interpretation of ambiguity was specific to the high FoP pain group only. FoP has been suggested as a very pain-specific construct that forms a lower-order factor of the more generalized anxiety constructs IS and AS (Keogh & Asmundson, 2004; Vancleef et al., 2006). FoP has shown to be a good predictor of pain in both healthy and clinical samples, and recently, additional support for the validity of the FoP construct as assessed with the FPQ has been offered in neuroimaging studies as well (McNeil et al., 2001; Ochsner et al., 2006; Osman, Breitenstein, Barrios, Gutierrez, & Kopper, 2002). On a cognitive level, FoP has been found associated with hypervigilance and attentional bias towards pain-related information, and proved to be a good predictor of explicitly measured negative interpretations (Crombez, Eccleston, Baeyens, Van Houdenhove, & Van Den Broeck, 1999; Peters, Vlaeyen, & Kunnen, 2002; Roelofs et al., 2002; Vancleef & Peters, 2008). The content-specificity and the proximal relation of FoP to the pain experience might account for the observed unique relation with the interpretation bias. Nevertheless, since both FoP and PC are assumed to possess similar content-specificity, the non-significant relation between PC and the interpretation bias remains puzzling in the current study (Keogh & Asmundson, 2004; Vancleef et al., 2006). Possibly, the relative low PCS scores ($M = 11$) in the present participant sample are responsible for the lack of findings with this construct. Other studies report remarkably higher PCS mean scores in both healthy ($M = 16$; Crombez, Eccleston, Baeyens, & Eelen, 1998; Van Damme et al., 2002) and clinical populations ($M = 22$; $M = 28$; Sullivan, Stanish, Waite, Sullivan, & Tripp, 1998; Van Damme et al., 2002). Scores on the FPQ ($M = 75$), on the other hand, showed a better dispersion and are comparable to other healthy samples (e.g., $M = 74$; $M = 79$; McNeil & Rainwater, 1998; Roelofs et al., 2005) and clinical samples (e.g., $M = 78$; McNeil & Rainwater, 1998).

Next to the already mentioned limitation of a putative priming effect, other shortcomings to the current study need to be addressed. First, the safe descriptions in the task referred to a broad range of situations (happiness, health, marriage, pregnancy, neutrally valenced outcomes) whereas the negative descriptions could all be chunked together as representative of health threats (death, injury, illness, and pain). The discrepancy between the homogeneity in negative meaning and the heterogeneity in safe meaning might have provoked unequal expectations regarding the target word. Participants are primed to expect a putative health-threatening resolution whereas no clear expectation is raised regarding the alternative putative solution of ambiguity. It is, therefore, suggested that future studies include two well-demarcated resolution categories in order to raise equal expectations on the potential meaning of the target word. In addition, future research might benefit from the inclusion of self-relevant descriptions only, given the idea cognitive biases will occur especially in response to self-relevant material that is congruent with the current concerns of the individual. In the current study, referral to a family member, a friend, or even an unidentified girl or boy might not have been strong enough to elicit spontaneous selective processing related to current concerns of the participant.

Furthermore, limitations to this study might have originated from the participant sample. First, since the inclusion criteria (healthy status, dyslexia, mother tongue) were queried by means of directly asking candidate participants about their presence or absence, it cannot be ruled out that some participants did not comply with these criteria after all. Second, the general faster response tendency on the health-threatening resolutions of ambiguity might be partly attributable to the fact that the participant sample consisted of females predominantly. Keogh et al. (2004) demonstrated that a negative interpretation bias mediated between Anxiety Sensitivity and cold-pressor pain tolerance in a female sample only. However, given the small proportion of male participants in the current study, testing for gender-specific effects would be inappropriate from a statistical point of view. Future studies might benefit from keeping operative gender effects into account when testing for processing biases of affective material. Third, the current healthy sample showed relatively low scores on the AS and IS constructs. Future studies might benefit from the inclusion of participant samples in which both high- and low-anxious individuals are selected for participation. Relating to this issue, future studies should pay attention to the conceptualization of AS, and possibly also IS, as continuous constructs. Recently, it has been argued that AS, as indexed by the ASI has a taxonic rather then a continuous dimensional latent structure, encompassing a high-risk form (taxon) and a low-risk form (normative) (Bernstein et al., 2006, 2007). This new conceptualization of AS holds important implications for further research and clinical applications in which AS is considered to constitute vulnerability for anxiety-related psychopathology such as chronic pain. It is advisable to adopt a taxometric approach of AS in future studies to further elucidate and validate the merits of this approach.

Despite these shortcomings, it should be noted that the lexical decision paradigm emerged as a suitable paradigm to assess on-line inferences. Faster and more accurate responses were observed in response to word trials compared to non-word trials, indicating that participants make semantic inferences in the task. The lexical processing of the descriptions activates expectations of a word probe rather than a non-word probe to follow the incomplete sentence, leading to a facilitation of responses to word trials. Furthermore, we are quite confident in concluding that the ambiguity in the descriptions was effective. Within word trials, responses were faster and more accurate on the forced inference descriptions than on the ambiguous descriptions. Responses to ambiguous descriptions are thus slowed down, and this can be explained by the fact that inferences can only be made at the very end of the ambiguous description, whereas inferences evolve fast and logically from the forced inference descriptions.

The current study is the first to our knowledge that attempts to measure on-line interpretations in function of pain-related anxiety. Further research on this subject is strongly recommended to further elucidate the way in which cognitive processing biases are indeed operating mechanisms in the relation between anxiety and pain. If so, clinical practice might benefit from the inclusion of techniques that are aimed at modifying these spontaneous dysfunctional cognitions in the treatment of pain patients. However, before going over to such modification techniques, more fundamental research on the exact relation between processing biases, pain-related anxiety, and pain reactivity is warranted.

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Appendix. Examples of ambiguous word and non-word descriptions and their linked forced inference descriptions used in the task

Words	A_H_W	F_H_W
Line 1	You are visiting your grandmother. She tells	You have a birth mark that itches.
Line 2	you she has a doctor appointment tomorrow	You have had it examined by a GP,
Line 3	for the removal of two spots on the back of her	but luckily nothing was wrong.
Line 4	hand. These spots are a consequence of her	The birth mark was no indication of
Target word	cancer	cancer
	A_S_W	F_S_W
Line 1	You are visiting your grandmother. She tells	Your grandmother’s sight is getting worse.
Line 2	you she has a doctor appointment tomorrow	She needs reading glasses. The optician
Line 3	For the removal of two spots on the back of her	told her that it is common that sight
Line 4	hand. These spots are a consequence of her	deteriorates when you reach an older
Target word	age	age

(*continued on next page*)

Appendix (*continued*)

Non-words	A_H_NW	F_H_NW
Line 1	The boy lies in the bed for some	The woman is staying at the intensive care unit.
Line 2	time now. He lies there very	Her family hopes she will ever
Line 3	calm and does not respond to you	wake up again. Since a grave traffic
Line 4	He is in a deep	accident, she has been in a deep
Target word	moac	moac
	A_S_NW	F_S_NW
Line 1	The boy lies in the bed for some	Your brother has a strange
Line 2	time now. He lies there very	habit. When he is in his bed
Line 3	calm and does not respond to you	at night, he speaks out
Line 4	He is in a deep	loud, although he is in a deep
Target word	pesle	pesle

Note. A_H_W = ambiguous description with a health-threatening word resolution; A_S_W = ambiguous description with a safe word resolution; A_H_NW = ambiguous description with a health-threatening non-word resolution; A_S_NW = ambiguous description with a safe word resolution; F_H_W = forced inference description with a health-threatening word resolution; F_S_W = forced inference description with a safe word resolution; F_H_NW = forced inference description with a health-threatening non-word resolution; F_S_NW = forced inference description with a safe non-word resolution.

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