

**Title: Effects of mindfulness and distraction on pain depend on individual differences in pain catastrophizing: An experimental study.**

Running head: Effects of mindfulness versus distraction on pain

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**What's already known about this topic?**

- Distraction reduces pain but pain catastrophizing interferes with this effect
- Mindfulness-based interventions are beneficial for the treatment of chronic pain but it is unclear if mindfulness can be induced to deal with acute pain
- Mindfulness is believed to counteract catastrophic thinking about pain

**What does this study add?**

- A direct comparison of distraction and mindfulness inductions during experimental pain
- Overall pain perception is not different under conditions of distraction and mindfulness
- Mindfulness works better than distraction when pain catastrophizing is high, whereas the opposite is true when pain catastrophizing is low

## **Abstract**

### *Background*

The aim of this study was to investigate whether the perception of experimental pain was different during a mindfulness manipulation than during a distraction manipulation.

Furthermore it was examined if effects were moderated by dispositional pain catastrophizing.

### *Methods*

Undergraduate students (N = 51) completed self-report measures of pain catastrophizing and mindfulness. Subsequently they were administered a series of mildly painful heat stimuli, which they had to rate. During pain induction, participants listened to either a pre-recorded mindfulness instruction (mindfulness group) or a pre-recorded story (distraction group).

### *Results*

After controlling for baseline experimental pain ratings, we found no overall group effect, indicating that there was no difference in experienced pain between the mindfulness group and the distraction group. However, a significant moderation effect was found. When dispositional pain catastrophizing was high, pain was less pronounced in the mindfulness group than in the distraction group, whereas the opposite effect was found when the level of pain catastrophizing was low.

### *Conclusions*

The findings suggest that in persons with a high level of catastrophic thinking about pain, mindfulness-based coping may be a better approach than distraction.

## **Introduction**

A common way to control pain is distraction. The underlying assumption is that when attention is engaged into the external environment, less resources are left for the processing of pain (McCaul and Malott, 1984; Villemure and Bushnell, 2002). The effects of distraction have mainly been investigated in laboratory studies using experimental pain. Often these studies have demonstrated beneficial effects of distraction on pain perception, assessed by self-report as well as neurophysiological measures (Petrovic et al., 2000; Tracey et al., 2002; Wiech et al., 2005; Van Damme et al., 2008; Van Ryckeghem et al., 2013).

However, distraction may not always be effective. A threatening appraisal of pain is believed to make it difficult to ignore pain or direct attention away from it (Eccleston and Crombez, 1999; Van Damme et al., 2010). Such threatening appraisal is typically found in persons with high levels of pain catastrophizing, defined as an exaggerated negative mental set brought to bear during actual or anticipated painful experience, including cognitions related to excessive threat appraisal, rumination, and helplessness (Sullivan et al., 2001). It has been shown that persons characterized by high pain catastrophizing have difficulty disengaging attention from pain and to focus on tasks during pain (Crombez et al., 1998; Van Damme et al., 2004).

An apparently opposing strategy is mindfulness, which involves paying attention to one's pain in an accepting and nonjudgmental way. Mindfulness has been defined as an openhearted, moment-to-moment, non-judgmental awareness, or being aware of the present moment with an attitude of curiosity, openness and acceptance (Kabat-Zinn et al., 1986; Davis and Hayes, 2011). Mindfulness is believed to counteract worrying and catastrophic thinking about pain (Schütze et al., 2010; Zeidan et al., 2012). Although mindfulness-based interventions have shown promising for the treatment of chronic pain (Chiesa and Serretti, 2011; Veehof et al., 2011), it is less clear if brief inductions of mindfulness may help coping

with an acute pain stimulus. A number of studies investigated the effects of brief mindfulness interventions on experimental pain perception. It was shown that healthy persons who had received brief mindfulness training showed decreased experimental pain sensitivity (Zeidan et al., 2010; Liu et al., 2013). Interestingly, this mindfulness group showed lower pain sensitivity when using the acquired mindfulness skills than when they were distracted, although this was only the case when affective rather than sensory aspects of pain were considered, and when pain was of low intensity.

The aim of the present study was to compare experimental pain perception during conditions of distraction and mindfulness. Furthermore, it was investigated if the difference between the conditions was moderated by dispositional pain catastrophizing. Healthy volunteers, while undergoing painful heat stimuli, were either distracted or were receiving mindfulness instructions. After the pain induction, participants rated sensory, affective, and cognitive aspects of the experienced pain. We hypothesized that experimental pain would be less pronounced in the mindfulness group than in the distraction group, and that this would be particularly the case in high pain catastrophizers.

## **Method**

### *Participants*

Fifty-one undergraduate students (43 females and 8 men; mean age = 20.10, SD = 2.27) participated in the experiment, which took between 45 and 60 minutes. They were compensated for their participation with either course credits or an incentive of €8. The study was approved by the local ethical committee and was performed according to the ethical standards laid down in the declaration of Helsinki. The participants were informed about the experimental procedure and their right to withdraw from the experiment at any time without consequences, and signed an informed consent. Participants were excluded from statistical

analysis when they reported current pain of at least moderate intensity ( $> 4/10$ ;  $N = 1$ ). Participants were also excluded when they reported to practice some form of meditation at least weekly ( $N = 4$ ), as this could interfere with the experimental manipulation. Analyses were conducted on a final sample of 46 participants.

### *Pain induction*

Experimental pain was induced by heat stimuli generated by a Somedic Thermostest™ (Stockholm, Sweden) with a 2.5 cm×5.0 cm thermode. Each stimulus had a duration of 4 seconds, with a 32°C baseline temperature, a 46°C peak temperature, and a 7°C/s temperature change rate. These parameters were selected based upon piloting, with the aim to induce a mild pain experience that would allow participants to use the attention manipulations and instructions presented. Note that very intense pain is highly interruptive, which would possibly interfere with these attention manipulations and instructions (Eccleston and Crombez, 1999). Prior to the start of the experiment, participants were familiarized with the heat pain by presenting 3 stimuli on the left lower arm (just above the wrist). During the experiment heat pain stimuli were administered 7 times on the right lower arm (above the wrist as well).

### *Experimental manipulation*

In the mindfulness group, pre-recorded instructions were provided through headphones during the experimental pain induction. The instructions (see appendix 1) were designed by one of the authors (BP), who is an experienced mindfulness meditation trainer. Mindfulness was previously defined as an openhearted, moment-to-moment, non-judgmental awareness. In order to establish this, our instructions were designed to cultivate 4 highly interrelated processes, specified within the third wave of behavioral and cognitive therapies in the so-called “hexaflex” (Fletcher and Hayes, 2005): contact with the present moment, acceptance, defusion and self as context. The participants were invited to look at the painful

sensation (contact with the present moment) with an open mindset (acceptance). By labeling the process ('this is painful'), defusion was promoted, and when there were no stimuli the participant could 'rest' in awareness (self as context). To start, the participants were asked to direct their attention to the breathing and bodily sensations and were reminded that they could always come back to these sensations when drifted away, while trying to incorporate a gentle and mild attitude towards their experience. Furthermore, it was emphasized that participants did not have to reach any particular goal and that they didn't have to change anything during the exercise. Below, we discuss more in detail the course of the exercise.

In the first part of the mindfulness induction participants were asked to embody an investigating, open attitude by curiously paying attention to whatever is there at the present moment (thoughts, feelings, physical sensations or even sounds), by mentally labeling them as such when the experience was there. The attention was first directed to a stable object present in every moment: the breath. Participants were instructed to pay attention to the flow of breath and to be aware of the sensations of the body while breathing. It was proposed to label the sensations of the breath and the body sensations that were there in the present moment (e.g., 'warmth', 'cold', 'tension'), a common practice in the mindfulness training (Davis and Hayes, 2011).

During the second part participants were instructed that they simple could be open for whatever what was coming up while looking at the body sensations with an interested, investigating and friendly attention. This is achieved by paying attention to what is there in the present moment with an open and inviting attitude. Also it was asked to explore and label the emotions that are accompanied by these bodily sensations. Later on, sensory pain adjectives of the Dutch translation of the MPQ-DV (Vanderiet *et al.*, 1987) were incorporated in the mindfulness-induction so that the instructions were able to match the sensations one may typically experience during the thermal stimulation. To guarantee an optimal guidance

the mindfulness-instructions were also synchronized with presentation of the pain stimuli. When a pain trial was administered participants were instructed, for example, to label these sensations as ‘heat’ or ‘stinging’. Full instructions and timing of pain stimuli can be found in the appendix.

In the distraction group, no instructions about how to cope with the pain were provided, and instead participants listened to 2 fairytales during the pain induction phase. These stories (available upon request) were pre-recorded by the same voice as the mindfulness instructions, and presented through headphones.

### *Self-report measures*

A general questionnaire was used to collect demographic information and past and current pain experience. Pain items were based on the McGill Pain Questionnaire for the Dutch language (MPQ-DV, (Vanderiet *et al.*, 1987). Specifically, participants were asked to indicate whether or not they had experienced pain during the past six months, and if so, to rate on 11-point numerical rating scales what was the average intensity of this pain, to what extent it interfered with their daily activities, and how intense the pain was at this moment. Participants were also asked about their experience with meditation (‘Do you weekly practice one of the following: meditation, yoga, tai-chi, qi-gong, breathing exercises or other related activities?’).

Dispositional pain catastrophizing was assessed using the Dutch version of the Pain Catastrophizing Scale (Sullivan *et al.*, 1995; Van Damme *et al.*, 2000). This 13-item scale is suitable to assess pain catastrophizing in both clinical and healthy populations. Participants were asked to reflect on past painful experiences and to indicate the degree to which they experienced each of the 13 thoughts or feelings during pain (e.g. ‘I become afraid that the pain may get worse’) on a five-point scale from 0 (not at all) to 4 (all the time). The Dutch version of the PCS has been shown to be valid and reliable, and the Cronbach’s alpha

obtained in the present study (0.87) corresponds with earlier research for non-clinical populations (Van Damme *et al.*, 2002).

Dispositional mindfulness was assessed using 2 questionnaires, each emphasizing a core characteristic of mindfulness. The first one was the Mindful Attention and Awareness Scale (Brown and Ryan, 2003). This 15-item questionnaire assesses open or receptive awareness of and attention to what is taking place in the present (e.g. ‘I could be experiencing some emotion and not be conscious of it until sometime later.’). Scores range from 1 (almost always) to 6 (almost never), and higher scores are indicative of higher levels of mindfulness. The scale shows strong psychometric properties (Brown and Ryan, 2003), and has been validated in samples of cancer patients (Carlson and Brown, 2005) and chronic pain patients (McCracken *et al.*, 2007). The internal consistency in the present study was good (Cronbach’s alpha of 0.87). The second questionnaire, the Acceptance and Action Questionnaire-II (Bond *et al.*, 2011) is an instrument designed to assess individual differences in psychological flexibility, as conceptualized within Acceptance and Commitment Therapy (ACT). It consists of 10 items, rated on a scale of 1 (‘never true’) to 7 (‘always true’), concerning negative evaluations of feelings (e.g., “anxiety is bad”), avoidance of thoughts and feelings (e.g., “I try to suppress thoughts and feelings that I don’t like by just not thinking about them”), distinguishing a thought from its referent (e.g., “when I evaluate something negatively, I usually recognize that this is just a reaction, not an objective fact”), and behavioral adjustment in the presence of difficult thoughts or feelings (e.g., “I am able to take action on a problem even if I am uncertain what is the right thing to do.”). A higher score is indicative of higher acceptance and less experiential avoidance (Bond *et al.*, 2011). The scale shows strong psychometric properties (Jacobs *et al.*, 2008), and the internal consistency in the present was good (Cronbach’s alpha of 0.89).

In order to estimate pre-experimental pain sensitivity, participants were asked to rate the stimuli used to familiarize them with the heat pain before the actual experiment, on 4 items with 11-point numerical rating scales: (un)pleasantness (“How unpleasant did you find the heat stimulus?”; -5=very unpleasant; +5=very pleasant), intensity (“How intense did you find the heat stimulus?”; 0=not at all; 10=very), pain (“How painful did you find the heat stimulus?”; 0=not at all; 10=very), and fear (“How fearful are you for the heat stimulus?”; 0=not at all; 10=very).

In order to compare the pain experience between the 2 groups, the participants completed a 20-item pain questionnaire with 11-point rating scales, specifically developed in our lab for assessment of experimental pain (Goubert *et al.*, 2004; Van Damme *et al.*, 2008). The questionnaire consists of 4 subscales: sensory pain (2 items, e.g. ‘How much pain did you maximally experience during the thermal stimulation of your arm?’), affective pain (10 items, e.g., ‘I wondered whether this could be detrimental for my arm’), attention to the pain (3 items, e.g. ‘I could not think about anything but the pain’), and general anxiety (5 items, e.g., ‘I felt nervous’). Items were rated on an eleven-point scale where 0 indicated ‘not at all’ and 10 indicated ‘very much’, except for the sensory pain subscale (0 = no pain; 10 = worst imaginable pain). The subscales have been shown to be reliable in previous studies (Goubert *et al.*, 2004; Van Damme *et al.*, 2008). In the present study reliability was good for sensory pain (Cronbach’s alpha = 0.91), affective pain (Cronbach’s alpha = 0.87), and general anxiety (Cronbach’s alpha = 0.85), but not for the attention subscale (Cronbach’s alpha = 0.47). The latter subscale was therefore not included in further analyses.

### *Procedure*

In a first phase, participants completed the general questionnaire, PCS, MAAS, and AAQ-II. The experimental procedure was explained, and three pain stimuli were administered on the left arm, which participants were asked to rate. Next, a short relaxation exercise

(breathing focus – concentration meditation) was administered before the start of the proper experiment to all participants. The instruction was: “When you notice that your mind has wandered, gently bring it back to the sensations of the breath”. Concentration meditation produces a feeling of calmness. We induced this relaxation baseline in both the distraction and mindfulness group, to make sure that potential effects of the mindfulness induction were not simply due to the relaxation component of mindfulness, and thus to create a highly sensitive measurement of mindfulness effects (for a discussion about the differentiation between mindfulness and relaxation, see Siegel (Siegel *et al.*, 2009) and Stanley (Stanley, 2012)).

Then, participants were randomly assigned to the mindfulness group or the distraction group. During the experimental phase, participants received 7 pain stimuli on the right arm over a period of 10 minutes. We preferred not to work with one continuous pain stimulus, but rather with repeated, short, pain inductions to which corresponding mindfulness-based instructions could be presented. The heat stimuli were not administered according to a random schedule, but they were programmed so that they would optimally match the instructions of the mindfulness induction. After the completion of the experimental phase, participants rated their pain experience during pain induction using a 20-item questionnaire.

#### *Data-analysis*

First, descriptive statistics were performed on the baseline self-report measures and questionnaire scores, and Analysis of Variance (ANOVA) was used to identify possible pre-existing differences between the groups. Next, Pearson correlations between all questionnaires and baseline experimental pain ratings were computed. In order to test the primary hypothesis, a multivariate general linear model was performed with the post-experimental self-reports (sensory pain, affective pain, and general anxiety) as dependent variables and Group (mindfulness versus distraction) as a between-subjects factor. In order to control for baseline experimental pain sensitivity, baseline ratings of unpleasantness,

intensity, pain, and fear were included as covariates. To test the secondary hypothesis, a multivariate general linear model was performed with the post-experimental self-reports (sensory pain, affective pain, and general anxiety) as dependent variables, Group (mindfulness versus distraction) as between-subjects factor, and PCS and PCS x Group as additional predictors.

## **Results**

### *Descriptive statistics*

The participants overall reported having good or outstanding health (95.8%). Most of the participants (75%) had experienced some form of pain during the past six months (mainly abdominal/menstrual pain, headaches, pain as a result of injury, inflammation pain, muscle soreness). Most of the time the pain was not severe ( $M = 3.39$ ,  $SD = 2.38$ ) and did not interfere with their daily activities ( $M = 1.90$ ,  $SD = 2.02$ ). At the time of the experiment current pain intensity was low ( $M = 1.00$ ,  $SD = 1.55$ ). However, one participant reported pain of at least moderate intensity (6/10) and was excluded from further analyses. Four participants reported to weekly perform some form of meditation exercises. These participants were also excluded from further analyses.

There were no significant baseline differences between groups on the questionnaire scores and on the ratings of the pain stimuli before the experimental manipulation (all  $F$ s < 1). Table 1 summarizes all means, standard deviations, and statistics.

INSERT TABLE 1

### *Correlation analyses*

Pearson correlations between all questionnaires and baseline experimental pain ratings are presented in Table 2. The 2 mindfulness questionnaires (MAAS, AAQ) were significantly interrelated, and showed significant negative associations with dispositional pain catastrophizing (PCS). The 4 baseline pain sensitivity ratings were strongly interrelated. Higher PCS scores were associated with higher baseline experimental pain sensitivity (although the correlation with unpleasantness was not significant). Correlations between dispositional mindfulness questionnaires and baseline experimental pain sensitivity showed no significant associations, although there was an overall tendency that higher AAQ-II scores were associated with lower baseline pain sensitivity. The MAAS did not show any meaningful correlation with baseline experimental pain sensitivity ratings. Higher dispositional mindfulness was associated with lower dispositional pain catastrophizing, although the correlation with the MAAS was not significant.

#### INSERT TABLE 2

#### *Comparison of mindfulness and distraction group*

A multivariate general linear model was performed with the post-experimental self-reports (sensory pain, affective pain, and general anxiety) as dependent variables and Group (mindfulness versus distraction) as between-subjects factor. In order to control for baseline experimental pain, this variable was included as a covariate. No significant multivariate main effect of Group was found ( $F(3,38) = 0.75, p > .10$ ). Significant multivariate main effects of baseline pain ( $F(3,38) = 4.93, p < .01$ ) and baseline fear ( $F(3,38) = 8.44, p < .001$ ) were found, indicating that baseline pain and fear were strong predictors of post-experimental ratings. The univariate effects of baseline pain were only significant for sensory pain ( $F(1,40) = 13.83, p < .01$ ), and not for affective pain ( $F(1,40) = 0.62, p > .10$ ) and anxiety ( $F(1,40) =$

0.84,  $p > .10$ ). The univariate effects of baseline fear were significant for affective pain ( $F(1,40) = 15.29, p < .001$ ) and anxiety ( $F(1,40) = 13.39, p < .01$ ), but not for sensory pain ( $F(1,40) = 0.13, p > .10$ ). Note that these effects remained the same when including only female participants.

#### *Moderating role of dispositional pain catastrophizing*

A multivariate general linear model was performed with the post-experimental self-reports (sensory pain, affective pain, and general anxiety) as dependent variables, Group (mindfulness versus distraction) as between-subjects factor, and PCS and PCS x Group as additional predictors. The multivariate main effect of PCS was not significant ( $F(3,40) = 2.01, p > .10$ ). A significant multivariate main effect of Group ( $F(3,40) = 3.20, p < .05$ ) was found, but this was qualified by a significant multivariate Group x PCS interaction effect ( $F(3,40) = 3.02, p < .05$ ). Follow-up univariate analyses showed that this interaction was significant for affective pain ( $F(1,42) = 9.05, p < .01$ ), but not for sensory pain ( $F(1,42) = 2.59, p > .10$ ) and general anxiety ( $F(1,42) = 1.30, p > .10$ ). Note that these effects remained the same when including only female participants.

To further disentangle the significant Group x PCS interaction on affective pain, we followed the guidelines by Holmbeck (2002) for post-hoc probing of moderation effects without having to create subgroups. In short, the following steps were followed: (1) We computed new conditional moderator values for PCS (i.e., PCS Low = 1SD below mean; PCS High = 1 SD above mean). (2) Then we computed new interactions terms: one interaction term to generate the slope for low PCS (PCS Low x Group) and one interaction term to generate the slope for high PCS (PCS High x Group). (3) Next we conducted new regressions to generate the slope for low PCS and high PCS. For each regression, the new conditional PCS value and group were entered as a first step in the regression, and the new interaction term (PCS conditional x group) was entered in the second step. The standardized beta

coefficient of group in these regressions indicates the direction of the effect and whether the effect is significant or not. (4) Finally, in order to present the slopes in a figure, values can be calculated for high versus low PCS levels in both the mindfulness and distraction groups. These are calculated by the following formula: intercept + unstandardized beta of group (for mindfulness group), and intercept – unstandardized beta of group (for distraction group). This was done separately for the high PCS and low PCS slopes, resulting in the 4 values depicted in Figure 1. The regressions indicated that for low levels of dispositional catastrophizing, the effect of Group was significant ( $\beta = 0.49, p = .013$ ), with lower affective pain scores in the distraction group than in the mindfulness group. For high levels of dispositional catastrophizing, the reverse pattern was found, with higher affective pain scores in the distraction group than in the mindfulness group ( $\beta = -0.38, p = .075$ ).

INSERT FIG 1

## **Discussion**

The aim of the present study was to investigate whether experimental pain would be experienced differently during a mindfulness induction than during a distraction induction, and if this would be moderated by dispositional pain catastrophizing. The main findings of the study are as follows. There was no overall difference in experimental pain experience between the mindfulness group and the distraction group. The effect of Group (mindfulness versus distraction) on affective pain experience was moderated by dispositional pain catastrophizing. More specifically, the mindfulness induction resulted in lower affective pain than the distraction induction when the level of dispositional pain catastrophizing was high, whereas the opposite effect was found for low levels of pain catastrophizing.

These findings deserve further discussion. The lack of an overall group difference is not in line with a study by Zeidan et al. (2010), who found that a 3-days mindfulness training reduced sensitivity for experimental pain more than a distraction task. Another study by Liu et al. (2013) showed a more complex pattern of results, with more reductions in distress during experimental pain as a result of a short mindfulness intervention compared to a distraction intervention, but with similar effects of both interventions on pain tolerance. However, note that in both of these studies, mindfulness training was much more extensive than in the present study, and that mindfulness skills were learned before confrontation with pain, whereas in our study mindfulness instructions were provided during pain administration. A more powerful mindfulness intervention may be needed to obtain an overall benefit of mindfulness over distraction. This is also in line with the conclusion of Sharpe et al. (2013), who found that a single brief mindfulness session was not sufficient to alter experimental pain perception in comparison with relaxation.

The pattern of results in our study suggests that distraction and mindfulness may have differential effectiveness depending upon the level of pain catastrophizing. In high catastrophizers the mindfulness group had lower pain ratings than the control group, while in low catastrophizers the reverse was true. This is in line with theoretical and empirical work suggesting that distraction may not be effective in persons with a high tendency to catastrophize about pain (Heyneman et al., 1990; Goubert et al., 2004; Van Damme et al., 2010; Verhoeven et al., 2010). In contrast, mindfulness-based interventions or techniques may be especially helpful in these high catastrophizing persons, by blocking the automatic negative appraisals usually evoked by pain. Those who do not catastrophize may rather benefit from distraction techniques. It must be noted here that the Group by PCS interaction effect was only significant for affective pain, and, although in the same direction, just failed to reach significance for sensory pain. The observation that the effects are more pronounced for

affective pain than for sensory pain is not surprising, as mindfulness is not primarily aimed at symptom reduction, but rather at altering individuals' relationship with their symptoms (Chiesa and Serretti, 2011).

The results from the present study are in line with the idea that mindfulness may affect pain experience by counteracting catastrophic thinking about pain. This idea stems from previous work in patients with chronic pain, which has shown significant negative correlations between measures of dispositional mindfulness and pain catastrophizing (Schütze et al., 2010; Cassidy et al., 2012), as well as reductions in pain catastrophizing after mindfulness-based pain management programs (Gardner-Nix et al., 2008; Cusens et al., 2009). Mindfulness may counteract catastrophic thinking in several ways. Firstly, mindfulness promotes paying attention on purpose to what is happening in the present moment. As such it can reduce the future-oriented, ruminative style of thinking that is often automatically invoked in those persons with a high level of catastrophic thoughts about pain (Sullivan et al., 2001; Schütze et al., 2010). Secondly, by inducing an open, accepting, attitude towards emerging thoughts and feelings, mindfulness may reduce the constant struggle to control or suppress pain, which is often seen in high pain catastrophizers, and which has been shown to have counter-productive effects on pain experience (McCracken and Eccleston, 2003; Masedo and Esteve, 2007; Chiesa and Serretti, 2011). Thirdly, the labeling of the pain experience may create a distance between the experience and the observer, a process that is called diffusion (McHugh, 2011). As such, individuals may learn so see their catastrophic thoughts for what they are, and not as reliable reflections of reality determining what to do next (Davis and Hayes, 2011). This is also in line with studies showing that in high catastrophizing persons, sensory monitoring, i.e., focusing on and reporting the sensory characteristics of the pain, is more fruitful than distraction because it dissociates the sensation from the negative emotions (Roelofs et al., 2004). It is not yet clear which of these components have the strongest impact,

so it would be interesting to conduct more systematical research to disentangle the role of each of these possible mechanisms.

The findings of this study may have implications for interventions in the context of acute pain or aversive physical sensations in the context of medical procedures. Although distraction of attention is often the default coping strategy used in such situations, our results suggest that this may not be the most adaptive strategy for everyone, as already suggested by other studies (Roelofs et al., 2004; Van Damme et al., 2004; Verhoeven et al., 2010). More specifically, persons characterized by a tendency to experience catastrophic thoughts when confronted with pain or adversity may benefit less from distraction during aversive or painful medical procedures. In these persons, mindfulness-based guidance techniques, in which an openhearted, moment-to-moment, non-judgmental awareness is promoted, may be more helpful, as this could counteract the automatic negative appraisals usually evoked by pain. Of course, it should be kept in mind that replication of these findings using “real” aversive medical procedures is necessary before drawing firm conclusions.

A number of issues concerning this study require further consideration. First, power analyses showed that we would need at least 98 participants to detect the tested effects with a medium effect size and with a power of 50%. This is a limitation of our study, and replication with larger sample sizes is required. Likewise, the differentiation between low and high levels of pain catastrophizing was relative and specific for this sample. Replication of the findings in a study with pre-selected high versus low PCS scorers according to normative data is recommended. Second the present study was conducted using mild experimental pain stimuli and a very brief mindfulness and distraction induction in (mainly female) undergraduate students. The results should therefore not be readily generalized to other healthy populations or to populations with clinical or more severe procedural pain. Also, generalization to more extensive mindfulness-based stress reduction programs may not be justified. Third, we have

no information whether the participants in the mindfulness group actually followed the instructions, and about the extent to which participants in the distraction group were effectively distracted by the pre-recorded fairytale. This lack of a manipulation check is clearly a limitation of our study. Fourth, the instructions in the mindfulness group were specifically timed in relation to painful stimuli, while the pre-recorded story presented in the distraction group was rather continuous. Future studies should consider matching these conditions better. Fifth, the questionnaire used to assess baseline pain sensitivity was not the same as the questionnaire used to compare pain perception between the mindfulness and the distraction conditions. It may be recommended that future studies use the same questionnaire for both pre- and post-testing of pain experience. Furthermore, because the lack of a “spontaneous coping” group, it could not be shown to what extent the mindfulness and distraction inductions actually reduced pain perception.

In sum, the findings of our study indicate that the level of pain catastrophizing should be considered when using techniques to cope with acute or procedural pain. While distraction may be helpful particularly in low pain catastrophizers, mindfulness techniques may be preferable in high catastrophizing persons.

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## **Author contributions**

All authors substantially contributed to the conception and design of the study, discussed the results, commented on the manuscript, and approved the submitted version. Björn Prins and Anouk Decuypere share first authorship as they equally contributed to the manuscript.

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## **Table legends**

*Table 1.* Mean questionnaire scores and experimental pain ratings before the experimental manipulation. Values between brackets are standard deviations.

*Table 2.* Pearson correlations between dispositional mindfulness and pain catastrophizing, and baseline experimental pain in the total sample

## **Figure legends**

*Fig. 1.* Regression slopes for the moderating role of dispositional pain catastrophizing in the effect of Group (distraction versus mindfulness) on affective pain, based on an estimation of low versus high scores on PCS (mean  $\pm$  1 standard deviation).

*Table 1.* Mean questionnaire scores and baseline experimental pain ratings before the experimental manipulation. Values between brackets are standard deviations.

	Mindfulness group	Control group	F(1,49)
MAAS	58.15 (9.51)	57.56 (9.38)	0.05
AAQ-II	48.69 (10.28)	48.16 (10.70)	0.03
PCS	20.73 (10.06)	18.76 (8.38)	0.58
Intensity	6.12 (2.10)	5.76 (2.24)	0.34
Unpleasantness	-1.04 (2.25)	-1.44 (1.26)	0.61
Painfulness	3.46 (2.61)	3.24 (2.47)	0.10
Fear	3.00 (2.56)	3.20 (2.78)	0.07

*Note:* MAAS = Mindful Attention and Awareness Scale; AAQ-II = Acceptance and Action Questionnaire-II; PCS = Pain Catastrophizing Scale

*Table 2.* Pearson correlations between dispositional mindfulness and pain catastrophizing, and baseline experimental pain in the total sample

	Mean (SD)	1	2	3	4	5	6
1. MAAS	58.72 (9.06)						
2. AAQ-II	48.80 (10.58)	0.43 <sup>b</sup>					
3. PCS	19.22 (9.21)	-0.28	-0.40 <sup>b</sup>				
4. Baseline unpleasantness	-1.33 (1.73)	0.03	0.27	-0.24			
5. Baseline intensity	5.85 (2.20)	-0.01	-0.26	0.34 <sup>a</sup>	-0.59 <sup>c</sup>		
6. Baseline pain	3.39 (2.49)	-0.01	-0.17	0.32 <sup>a</sup>	-0.68 <sup>c</sup>	0.72 <sup>c</sup>	
7. Baseline fear	3.13 (2.65)	0.07	-0.25	0.36 <sup>a</sup>	-0.68 <sup>c</sup>	0.64 <sup>c</sup>	0.71 <sup>c</sup>

<sup>a</sup>  $p < .05$ ; <sup>b</sup>  $p < .01$ ; <sup>c</sup>  $p < .001$

*Note:* MAAS = Mindful Attention and Awareness Scale; AAQ-II = Acceptance and Action Questionnaire-II; PCS = Pain Catastrophizing Scale

