Open access • Journal Article • DOI:10.1016/J.PAIN.2012.01.025

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Published on: 01 Jan 2012 - Pain (Elsevier)

Topics: Attentional bias

RUNNING HEAD: NON-PAIN GOAL PURSUIT INHIBITS ATTENTION TO PAIN

Non-pain goal pursuit inhibits attentional bias to pain

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Number of text pages of the entire manuscript: 33

Number of tables: 2

Number of figures: 1

Abstract

Although dealing with pain is a vital goal to pursue, most individuals are also engaged in the pursuit of other goals. The aim of the present experiment was to investigate whether attentional bias to pain signals is inhibited when one is pursuing a concurrent salient but non-pain task goal. Attentional bias to pain signals was measured in pain-free volunteers (N = 63) using a spatial cueing task with pain cues and neutral cues. The pursuit of a concurrent goal was manipulated by including additional trials on which a digit appeared at the middle of the screen. Half of the participants (goal group) were instructed to name these additional stimuli aloud. In order to increase the affective-motivational value of this non-pain-related goal, monetary reward and punishment were made contingent upon the performance on this task. Participants of the control group did not perform the additional task. As predicted, the results show attentional bias to pain signals in the control group, but not in the goal group. This indicates that attentional bias to signals of impending pain is inhibited when one is engaged in the pursuit of another salient but non-pain goal. The results of this study underscore a motivational view on attention to pain, in which the pursuit of multiple goals, including non-pain goals, is taken into account.

Keywords: attention, pain, fear, motivation, goal pursuit

1. Introduction

An influential idea is that attention to pain and somatic threat plays an important role in acute and chronic pain [7,11,28,47,52]. Consistent with this idea, evidence from behavioural and neurobiological studies suggests attentional bias favouring the processing of pain-related information in both healthy persons and chronic pain patients [35,47]. However, also some seemingly inconsistent and inconclusive findings have been reported regarding attentional biases to pain-related information, particularly for pain patients [35,47]. These inconsistencies might be resolved by assuming that, in contrast to what is often thought, attention to pain-related information is not a stable mechanism [47]. It has for example recently been argued that attention to (signals of impending) pain, as well as affective information processing in general, depends on the motivational context or in other words the pursuit of concurrent goals [33,47]. Indeed, pain and pain-related fear mostly occur within a context in which individuals also face pain-unrelated tasks and challenges.

When confronted with multiple goals, the pursuit of one goal often impairs the likelihood of achieving other goals [30]. Commitment to one goal might result in reduced accessibility of alternative goals [12,40,41] and attentional priority to information related to the focal goal [17,22,27,53,54]. Within such a goal-pursuit perspective, the extent to which pain captures attention is not merely dependent upon characteristics related to the painful stimulus, but also upon characteristics of the focal goal [11,47]. In that respect, one could expect attention to pain being attenuated by top-down processing induced by non-pain goals [21].

Supporting this reasoning, previous research has shown that engagement in a pain-unrelated task modulates the processing of pain and pain-related information. For

instance, cognitively demanding distraction tasks have been associated with lower pain ratings and reduced pain-related brain activity [1,2,39,49]. Moreover, there are indications that working memory load during nociceptive stimulation [20] and motivational relevance of the task [49] modulate the disruptive effect of pain on task performance. In the present experiment, we advance this work by directly measuring the effects of a concurrent non-pain goal on attentional bias to pain-related information.

More specifically, the present experiment tests the hypothesis that biasing attention to pain signals, as previously observed [43,45,46,48], is inhibited when a concurrent non-pain goal is pursued. Attentional bias was assessed with a spatial cueing task in otherwise pain-free participants [43,45,46,48]. Non-pain goal pursuit was manipulated independently of the cueing task: In half of the participants, the cueing task was combined with an independent goal task (cf. [31,32]). To enhance motivational salience of the goal task, participants were led to believe that they could win or lose money depending on their performance on this task. Because the goal task was presented concurrently (intermixed) with the cueing task, motivational context and non-pain goal pursuit remained salient during the cueing task and thus during assessment of attentional bias for pain signals. We predicted that in participants who were motivated to engage in the goal task, attentional bias to pain signals would be smaller compared to participants who only performed the cueing task.

2. Method

2.1. Participants

Sixty-three undergraduates (11 men) with a mean age of 20.7 years (SD = 2.4) participated. Candidate participants were recruited through advertisements at Maastricht

University. Exclusion criteria included pain complaints (acute/chronic), pregnancy, electronic implant, attention deficit disorder, and insufficient knowledge of the Dutch language. All participants reported to be healthy, to have (corrected to) normal vision and colour vision, and were naïve as to the purpose of the experiment. They gave informed consent and received €10. The department's Ethics Committee approved the study.

2.2. Apparatus and Task Materials

2.2.1. Electrocutaneous Stimuli

Electrocutaneous stimuli (bipolar sinus waveform; 300-ms duration) were administered by a direct current stimulator with 50-Hz internal frequency (Instrument Development Engineering & Evaluation, Maastricht University). Stimuli were applied to the external side of the left ankle using two 8-mm stainless steel electrodes, vertically placed with 1-cm inter-electrode distance and filled with hypertonic gel. Stimulus intensity was individually determined using a work-up procedure. More specifically, a series of electrocutaneous stimuli with gradually increasing intensity was delivered. After each stimulus, participants rated its unpleasantness on an 11-point Likert scale (0 = 'not unpleasant at all'; 10 = 'very unpleasant') and indicated whether the stimulus was tolerable or not. Intensity was increased to a rating of 9. Then the series was delivered again. The stimulus that was perceived as very unpleasant (rating 9) and difficult to tolerate during the second series was presented during the computer task. Participants were not informed about these procedural details.

After the work-up procedure, in order to increase the threat value of the electrocutaneous stimuli, participants were led to believe that stimuli of a higher intensity than selected would be occasionally presented during the test phase [4]. Participants had

no prior experience with such a high-intensity stimulus. In fact, no stimuli of higher intensity were delivered. The threat value of the electrocutaneous stimuli was increased because attentional bias has been especially found for stimuli associated with relatively high levels of threat (cf. [4,5,26,42]).

2.2.2. Spatial Cueing Task

Throughout the task, a black fixation cross (7 mm x 7 mm) was presented on a light grey background at the centre of the computer screen. Two black rectangular frames (6.5 cm high x 4.8 cm wide), serving as position markers for spatial cues, were continuously displayed at the left and right of fixation (distance from screen centre to the centre of each frame = 9.8 cm). Participants were encouraged to fixate the cross consistently.

The typical trial configuration of the cueing task was as follows. After 1000 ms, a spatial cue (i.e., coloured rectangle) appeared for 200 ms within the left or right frame, completely filling the frame. On half of the trials, the cue was pink; on the other half, green (e.g., [43,45,46,48]). Each cue colour appeared equally often at either position. Thirty ms after cue offset, a small target ('/'or '\'; 4 mm) appeared at the centre of either the left or the right frame. Following each cue colour, each target identity appeared equally often. Within each combination of cue colour and target identity, on half of the trials, the target appeared at the position previously occupied by the spatial cue (*valid trials*); on the other half of the trials, the target appeared at the other position (*invalid trials*). Participants' task was to press on each trial, as quickly and accurately as possible, the top key on a response box with the right index finger to '\' and the bottom key with the left index finger to '/'. Targets were displayed until a response was made or for max. 2000 ms. Inter-trial interval randomly varied from 1000 ms to 1500 ms.

Attention to the visual cue is reflected in faster responses to targets at cue location than to targets at the other location (i.e., *cue validity effect*) (e.g., [29,55]).

2.2.3. Differential Conditioning

During the test phase (see paragraph 2.3.), spatial cues were conditioned stimuli, with one of the colours (*pain cue*) followed by an aversive electrocutaneous stimulus, whereas the other colour was never followed by electrocutaneous stimulation (*no-pain cue*). On one-third of the trials in which the pain cue appeared, the electrocutaneous stimulus was delivered at cue offset (acquisition by partial reinforcement). The test phase was immediately preceded by a short acquisition phase (see paragraph 2.3.) during which the electrocutaneous stimulus was delivered at cue offset each time the pain cue appeared (acquisition by full reinforcement). Colour of pain cue and no-pain cue was counterbalanced between participants. Participants were informed that one of the colours (but not which colour) would predict the occurrence of the electrocutaneous stimulus.

Biases in attention to pain signals are reflected in larger cue validity effects for pain cues than for no-pain cues (e.g., [13,46]). The size of attentional bias effects as measured with the spatial cueing task is in the order of milliseconds.

2.2.4. Non-Pain Goal Task

Spatial cueing task trials were intermixed with digit trials. Digit trial configuration was similar as for cueing task trials, except that also a black digit (7 mm) appeared for 50 ms at central fixation, replacing the cross. Digits were randomly selected from 1 to 9 and appeared throughout the trial (but not simultaneously with the target or with responses to the target, for technical reasons) as well as during the inter-trial interval. Participants' task

with regard to targets ('/'or '\) was the same as on cueing task trials. Participants' task with regard to digits depended on the group they were assigned to.

The *goal group* was instructed to read aloud each digit as quickly and accurately as possible. To enhance motivational salience of this *non-pain goal task*, the goal group was told that digit naming performance would influence monetary compensation for their participation. It was explained that they would gain one point for each fast and accurate response, but lose one point for each slow, inaccurate, or missed response. Digit naming responses were categorized as fast or slow based on a criterion that was adjusted after each response. Using this floating criterion, an equivalent proportion of relatively fast and slow responses was established throughout the task. Intermediate scores were not presented to the participant following each digit, but during regular task breaks (see paragraph 2.3.). Instead of the individual's end score, an end score equal to 0 was given to all participants. The task started with a score of 0 (at start of baseline phase; see paragraph 2.3.). At the start of the session, participants assigned to the goal group received 2 €5-vouchers and were told that their compensation would depend on their end score (at the end of the test phase). They would receive €15 compensation (i.e., €5 gain) with a positive end score, €5 compensation (i.e., €5 loss) with a negative end score, and €10 compensation (i.e., no gain, no loss) with an end score of 0. Because cueing task and goal task required different responses to different stimuli, the tasks were independent. So, the non-pain goal manipulation had no direct effect on cueing task performance, from which attentional bias to pain signals was derived. This is important in order to allow firm conclusions about effects of competing goals on pain-related attentional bias.

The *control group* received no instruction to respond to digits. They were informed that the digits were presented as an additional aid to focus on central fixation. Pilot testing indicated that undergraduates considered this a plausible explanation.

Because digit trials were also presented to the control group, perceptual load of the task was equal for both groups.

2.2.5. Apparatus

Task presentation and response registration (latency and accuracy) were controlled by a Dell Optiplex GX 620 computer that was running Presentation software (Neurobehavioral Systems, Albany, CA) and that was connected to two 19-inch Samsung Syncmaster 940 BF LCD monitors (one for the participant and one for the experimenter). In the goal group, verbal response latency was registered via a Sennheiser HMD/HME 25-1 microphone / headphone combination connected to a voice key. In order to record verbal response accuracy, the experimenter manually entered the corresponding digit (or 0 in case of missing) at the end of each digit trial (numeric keypad). In order to establish comparable testing conditions for both groups, also the control group wore the microphone / headphone combination (supposedly as part of the intercom system and as to attenuate distracting noise).

2.3. Procedure

Participants were tested individually at a viewing distance of about 60 cm from the computer screen in a dimly lit, sound-attenuated room designed for psycho-physiological experiments. They were video-monitored and could communicate with the experimenter (in a separate room) through an intercom. They were informed that the study investigated the relationship between concentration and performance and that during the computer task sensory stimuli would be delivered through electrodes on their ankle; that these stimuli feel like pinpricks, stimulate pain nerves, and are perceived by

the majority as unpleasant. The true purpose was explained after all participants had been tested.

Upon arrival in the lab, participants were randomly assigned to the goal group or the control group. Following electrocutaneous stimulus selection, both groups performed the computer task consisting of a mixture of cueing task trials and digit trials. Task trials were the same for both groups, but instructions differed. Whereas the goal group was instructed to respond manually to targets ('/'or '\') on every trial and verbally to digits that appeared on 25% of the trials, the control group had only to respond to targets. Because the configuration of cueing task trials and digit trials was the same, except for the occurrence of digits, digits were expected to appear throughout cueing task trials. So, for the goal group, stimuli for the additional goal task were also expected on trials on which attentional bias to pain signals was measured. The goal group received 2 vouchers worth €5 each before computer task performance. These vouchers remained visible throughout the session. For both groups, the computer task consisted of the following phases:

Practice phase. The goal group practiced the cueing task, first without (32 cueing task trials) and then in combination with the digit naming task (16 cueing task trials; 16 digit trials). The control group practiced the cueing task (2 x [16 cueing task trials; 16 digit trials]). No electrocutaneous stimuli were delivered and participants were informed about this. Following practice, all participants assigned to the goal group were able to repeat the rules for gaining/losing points and money.

Baseline phase. The baseline phase consisted of 96 cueing task trials and 32 digit trials. The goal group performed the cueing task in combination with the digit naming task; the control group performed only the cueing task. No electrocutaneous stimuli were delivered and participants were informed about this.

Acquisition phase. The acquisition phase consisted of 8 cueing task trials (no digit trials) and was immediately followed by the test phase (no break in between). The goal group performed the cueing task in combination with the digit naming task; the control group performed only the cueing task. Spatial cues were differentially conditioned. On all 4 trials that a pain cue appeared, the electrocutaneous stimulus was delivered; on the other 4 trials, a no-pain cue was presented, never followed by the electrocutaneous stimulus.

Test phase. The test phase consisted of 144 cueing task trials and 48 digit trials. The goal group performed the cueing task in combination with the digit naming task; the control group performed only the cueing task. Spatial cues were differentially conditioned. On one-third of the trials that a pain cue appeared (24 cueing task trials; 8 digit trials), the electrocutaneous stimulus was delivered; on the other trials, no electrocutaneous stimuli were delivered.

During practice, baseline and test phase, cueing task trials and digit trials were presented in a different random order for each participant. During the whole task, incorrect and premature responses to targets ('/'or '\') were indicated by a short beep along with the display of an error message at screen centre for 500 ms (+ 1000 ms pause). Missed responses to these targets were also followed by a visual message lasting 500 ms (+ 1000 ms pause). Performance feedback was given (at screen centre) every 32 trials during short breaks terminated by the participant: mean RT and number of incorrect responses with regard to manual responses to targets and, to the goal group, intermediate score on the digit naming task.

Following computer task performance, electrodes were detached and participants indicated on 11-point Likert rating scales (0 = 'no at all'; 10 = 'to a very large extent' or 'extremely') to what extent they expected green and pink cues to be followed by sensory stimulation, how fearful they were when green and pink cues were presented, how painful

and unpleasant they perceived the sensory stimulation during task performance. Finally, all participants received 2 vouchers worth €5 each. Each session took about 55 minutes to complete.

2.4. Design

This experiment employed a 2 (valid cueing vs. invalid cueing) x 2 (pain cue vs. no-pain cue) x 2 (goal group vs. control group) factorial design with reaction time (RT) to targets as main dependent variable. Attentional bias for pain signals is reflected in differential cue validity effects for pain cues and no-pain cues during the test phase. The test phase was preceded by a baseline phase, without differential conditioning of the spatial cues, in order to assess whether cue validity effects do not differ as a function of distinctive visual features of the cues, independent of their conditioned signal value.

2.5. Data Analysis

Attention effects were derived from performance on cueing task trials on which no electrocutaneous stimulus was delivered. Outlier participants who were slow or inaccurate on these trials during baseline and/or test phase were identified separately for each group (> 2.5 *SD* above group mean) and were excluded from the analyses.

To examine whether the final groups differed in demographic variables and debriefing scores, χ^2 tests and independent *t* tests were conducted. To determine whether differential conditioning had occurred, analyses of variance (ANOVAs) were conducted with cue identity (pain cue vs. no-pain cue) as within-subjects factor, group (goal group vs. control group) as between-subjects factor, and self-reported fear when the cue was presented or expectancy of electrocutaneous stimulation following the cue as dependent variable.

The reported RT analysis was based on *median* correct RTs to reduce the impact of outlier values.[1] All reported *p*-values are two-tailed.

In order to assess whether cue validity effects differ as a function of distinctive features of the cues, median RTs on cueing task trials during baseline phase were subjected to a mixed ANOVA with cue validity (valid vs. invalid) and cue identity (pain cue vs. no-pain cue) as within-subjects factors, and group (goal group vs. control group) as between-subjects factor. In order to assess group differences in attentional bias for pain signals (i.e., cue validity x cue identity), median RTs on cueing task trials during test phase were subjected to a mixed ANOVA with cue validity, cue identity, and group as factors. Significant interactions were broken down by using 2 x 2 ANOVAs and *t* tests, when appropriate. Magnitude of cue validity effects was calculated by subtracting median RTs on valid trials from median RTs on invalid trials; magnitude of differential cue validity effects for pain cues and no-pain cues was calculated by subtracting cue validity effects for no-pain cues from cue validity effects for pain cues.

Accuracy data (the log of percentage correct; [37]) were analysed in the same way as was done for RTs.

3. Results

3.1. Group Characteristics

In total 31 participants were assigned to the goal group and 32 to the control group. Five outlier participants who responded slowly or inaccurately were excluded, leaving 29 participants in the goal condition and 29 in the control condition. The final groups had the same gender ratio and did not differ in age (Table 1). The goal group

perceived the sensory stimulation as somewhat less unpleasant and less painful (Table 1; Cohen's d = .64 and .72, respectively).

Self-reported fear and expectancy of electrocutaneous stimulation indicated that differential conditioning had occurred. That is, as can be seen in Table 1, participants were more fearful when pain cues were presented as compared to the presentation of no-pain cues, $F(1, 56) = 90.3$, $p < .001$, $\eta_p^2 = .62$ (d = 1.73), and electrocutaneous stimulation was more often expected after pain cues than after no-pain cues, $F(1, 56) = 91.4$, $p < .001$, $\eta_p^2 = .62$ (d = 1.72). These differences in fear and expectancy ratings between pain cues and no-pain cues, reflecting differential conditioning, were smaller in the goal group (fear: $t(28) = 5.0$, $p < .001$, d = 1.33; expectancy: $t(28) = 4.5$, $p < .001$, d = 1.19) than in the control group (fear: $t(28) = 8.6$, $p < .001$, d = 2.40; expectancy: $t(28)$ =10.3, $p < .001$, d = 2.70), as indicated by significant interaction effects of cue identity and group on fear, $F(1, 56) = 4.0$, $p = .05$, $\eta_p^2 = .07$, and expectancy of electrocutaneous stimulation, $F(1, 56) = 4.2$, $p < .05$, $\eta_p^2 = .07$. The goal group, as compared to the control group, reported a somewhat higher expectation of electrocutaneous stimulation following no-pain cues (d = .59) and, though non-significantly, a somewhat higher level of fear when no-pain cues were presented (d = .48), whereas the groups did not differ in those ratings for pain cues (Table 1). Note that fear and expectancy ratings for no-pain cues were very low in either group.

3.2. Spatial Cueing Task: RTs

3.2.1. Baseline Phase

In the goal group, an average of 3.1% (SD = 2.1) of the responses on cueing task trials was incorrect; in the control group, 2.4% (SD = 1.8). Median correct RTs on cueing

task trials (Table 2, left-hand columns) were subjected to an ANOVA with cue validity, cue identity, and group as factors. Responses were faster following valid cues than following invalid cues, $F(1, 56) = 111.2$, $p < .001$, $\eta_p^2 = .67$ ($d = 2.02$). As expected, this cue validity effect (Table 2, left-hand columns) did not depend on cue identity (cue validity x cue identity: $F(1, 56) = 1.3$, $p = .25$, $\eta_p^2 = .02$; cue validity x cue identity x group: $F < 1.0$), for cue colour was not yet differentially conditioned during the baseline phase. Overall, the goal group responded somewhat faster and showed a smaller cue validity effect as compared to the control group (group: $F(1, 56) = 7.1$, $p = .01$, $\eta_p^2 = .11$ ($d = .82$); cue validity x group: $F(1, 56) = 5.9$, $p < .05$, $\eta_p^2 = .10$).

3.2.2. Test Phase

In the goal group, an average of 2.2% ($SD = 1.7$) of the responses on cueing task trials during which no electrocutaneous stimulus was delivered was incorrect; in the control group, 2.9% ($SD = 1.9$). Median correct RTs on cueing task trials during which no electrocutaneous stimulus was delivered (Table 2, right-hand columns) were subjected to an ANOVA with cue validity, cue identity, and group as factors. Responses were again faster following valid cues than following invalid cues, $F(1, 56) = 69.6$, $p < .001$, $\eta_p^2 = .55$ ($d = 1.60$). In line with our hypotheses, the magnitude of this cue validity effect (Table 2, right-hand columns; Figure 1) depended on cue identity as well as on group (cue validity x cue identity x group: $F(1,56) = 8.2$, $p < .01$, $\eta_p^2 = .13$; cue validity x cue identity: $F < 1.0$; cue validity x group: $F(1, 56) = 5.3$, $p < .05$, $\eta_p^2 = .09$), indicating a group difference in attentional bias to pain signals. There were no other significant results from the ANOVA.

For the control group, the cue validity effect was larger for pain cues than for no-pain cues (mean difference = 11.1 ms, $SD = 23.0$), indicating attentional bias for pain

signals (cue validity x cue identity: $F(1, 28) = 6.8$, $p < .05$, $\eta_p^2 = .20$; cue validity: $F(1, 28) = 37.6$, $p < .001$, $\eta_p^2 = .57$ ($d = 1.77$); cue identity: $F(1, 28) = 3.2$, $.05 < p \leq .10$, $\eta_p^2 = .10$ ($d = .50$)). In contrast, for the goal group, the cue validity effect seemed to be smaller for pain cues than for no-pain cues (mean difference = -9.2 ms, $SD = 30.6$), but this difference was not significant (cue validity x cue identity: $F(1, 28) = 2.6$, $p = .1$, $\eta_p^2 = .09$; cue validity: $F(1, 28) = 36.9$, $p < .001$, $\eta_p^2 = .57$ ($d = 1.62$); cue identity: $F < 1.0$).

For pain cues, the cue validity effect was smaller in the goal group as compared to the control group (cue validity x group: $F(1,56) = 9.9$, $p < .01$, $\eta_p^2 = .15$; cue validity: $F(1,56) = 58.1$, $p < .001$, $\eta_p^2 = .51$ ($d = 1.39$); group: $F(1,56) = 2.2$, $p = .14$, $\eta_p^2 = .04$ ($d = .39$)), but for no-pain cues, there was no significant group difference (cue validity x group: $F(1,56) = 1.1$, $p = .31$, $\eta_p^2 = .02$; cue validity: $F(1,56) = 60.4$, $p < .001$, $\eta_p^2 = .52$ ($d = 1.52$); group: $F(1,56) = 1.8$, $p = .19$, $\eta_p^2 = .03$ ($d = .35$)).

3.3. Spatial Cueing Task: Accuracy

ANOVAs of log percentage correct with cue validity, cue identity, and group as factors revealed a significant cue validity effect (i.e., more accurate on valid than invalid trials) for the baseline phase, $F(1, 56) = 17.7$, $p < .001$, $\eta_p^2 = .24$ ($d = .80$), and for the test phase, $F(1, 56) = 14.1$, $p < .001$, $\eta_p^2 = .20$ ($d = .70$). There were no other significant effects.

4. Discussion

The present experiment investigated whether attentional bias to pain signals is reduced when a pain-unrelated but salient goal is pursued. Biased attention to pain signals was assessed within a spatial cueing task whilst half of the participants were also motivated to

perform well on an independent goal task. As predicted, in participants who where motivated to engage in the goal task (goal group) attentional bias to pain signals, substantiated in a larger RT difference between valid and invalid conditions for pain cues than for no-pain cues, was smaller as compared to participants who only performed the cueing task (control group).

Recently, researchers have called for a motivational view on attention to pain, in which the role of a person's goals is taken into account [47]. Pain and fear of pain do not occur in a motivational vacuum, but in a context of different, possibly conflicting goals (e.g., [6,16,24,51]). Efficient goal pursuit and self-regulation require that information processing can be flexibly adjusted, with attention oriented correspondingly (e.g., [9,15,25]). It would, for example, be adaptive when the activation of one's focal goal inhibits the accessibility of alternative goals and other distracting information [14,18,41]. Attention has been considered as a central process of such 'goal shielding' [15,40]. Our finding that attentional bias to pain (signals) can be influenced by the motivational context and by current goal pursuit underscores a dynamic and motivational view on attention to pain.

The observed reduction of attentional bias in the goal group as compared to the control group adds to previous findings outside the field of pain that support the modulation of attentional bias by top-down engagement (e.g., [22,27,32,33]). In addition, the present experiment extends in several ways previous studies within the field of pain that indicate that the disruption of task performance by experimentally induced pain can be modulated by the motivational salience of the task [49] and by working memory load during painful stimulation [20]. First, in the present experiment attention to signals of impending pain, rather than pain itself, was studied and attentional processing was derived from spatial cueing effects, rather than only indirectly measured via interference

effects. Second, goal pursuit was manipulated within a secondary task that was completely independent from the cueing task, measuring pain-related attentional bias. That is, the stimuli as well as response options for the goal (task) were not related to the stimuli and response options for the cueing task. By doing so, the goal manipulation had no influence on the way the cueing task was performed and group differences in attentional bias could be solely interpreted in terms of differences in pain-unrelated goal pursuit.

Besides the reduced attentional bias to pain signals in the context of non-pain goal pursuit, supporting the main hypothesis of the present study, some further aspects of the data warrant discussion. *First*, the observed reduction of cue validity effects in the goal group, during baseline and test phase, adds to previous findings showing that attention to peripheral cues which do not predict target position (so-called exogenous cues) is suppressed when attentional resources are already focused elsewhere, for example, on a demanding task or perceptual display [34]. Santangelo et al. [34] observed a suppression of exogenous cueing effects (i.e., no significant difference between performance on valid and invalid trials) when during cueing task performance participants' voluntary attention was engaged at the centre of the display — by presenting target digits (and distractor letters) at central fixation — independent of whether a response to these additional stimuli was required. These results suggest that reflexive orienting of attention is not truly automatic. In the present experiment, contrasting Santangelo et al.'s observation, cue validity effects for unconditioned exogenous cues (baseline phase) depended on whether a response to central digits was required (goal group) or not (control group). An important difference between the current task and the one applied by Santangelo et al. is that our focused attention task was motivationally enhanced. Note that because digit task trials were also presented to the control group without requiring any response to them, the

group difference in cueing effects cannot be due to a mere difference in perceptual load [19,34]. It might be valuable for future experiments to also avoid differences in attentional focus between goal conditions. Finally, Santangelo et al.'s study does not allow any conclusions about the attentional processing of affective cues in a motivational context. The current finding of a reduced cue validity effect for conditioned spatial cues in the goal group (test phase) suggests that attention to pain signals is not entirely automatic, in the sense that it can be suppressed by focusing attentional resources on a salient, demanding and potentially rewarding task.

Second, immediately after the computer task, participants in either group reported a higher expectation of electrocutaneous stimulation following pain cues than following no-pain cues as well as a higher level of fear when pain cues were presented, indicating that the cues were indeed, as expected, differentially conditioned. These differential conditioning effects were somewhat smaller for the goal group as compared to the control group. Importantly, the group difference in attentional bias to pain signals was due to a group difference in cue validity effect following pain cues for which the groups did not differ in their rating of expectancy or fear. Therefore, the group difference in attentional bias to pain signals cannot be explained in terms of the slight group difference in differential conditioning.

After the computer task, the goal group also evaluated the sensory stimulation during task performance as somewhat less unpleasant and less painful as compared to the control group. This finding is in line with previous studies showing that engagement in a more cognitively demanding task reduces pain ratings [10,38,47,49,50]. Exactly the same procedure was followed in both groups with regard to electrocutaneous stimulus selection and the above mentioned pain and cue ratings. Hence, it can be concluded that the significant group differences in retrospective self-report ratings were due to the goal

pursuit manipulation and are therefore not controlled for in the attentional bias analysis [23]. This not only holds for the pain and cue ratings, but also for the expectancy and fear ratings discussed before. Furthermore, from the present data it is not possible to discern the relative effects of dual-task performance and bias in visuospatial orienting on these ratings.

Our finding that attentional bias to pain signals can be reduced in the context of non-pain goal pursuit may have clinical implications. Pain management programs that focus on the pursuit of valued, but pain-unrelated, goals may help reducing attention to pain and bodily threat, consequently improving daily functioning. It has been suggested that cognitive-behavioural therapies that promote the pursuit of daily life goals and the engagement in valued activities would be effective for treatment of chronic pain as well (e.g., [3,36,44]). Without further research, our findings with pain-free volunteers and experimentally induced pain cannot simply be generalized to chronic pain (or other populations). Indeed, chronic pain, as well as various forms of psychopathology, have been thought to be characterized by inflexible, maladaptive goal pursuit, associated with a rigid attentional bias and weakened executive functioning (e.g., [3,8,20,33,44]). If so, within a context of multiple goal pursuit chronic pain might be associated with a reduced inhibition of attentional bias to pain.

Some study limitations should be acknowledged. First, this experiment is first in its kind and replication is needed. Second, clinical variables or variables affecting overall response speed and/or general motivation (e.g., fatigue, alcohol, caffeine) were not systematically assessed. However, participants were randomly assigned to groups, which helps to ensure that there were no systematic group differences regarding such additional variables at the onset of the experiment. Future studies may benefit from more explicit consideration of these variables. Third, in order to address the main objective of this

experiment, we induced concurrent non-pain goal pursuit by requiring participants to perform an additional task, the affective-motivational value of which was increased by associating task performance with monetary incentives; the control group was not instructed to perform an additional task. Therefore, the specific effects of additional task performance (cf. working memory load) and motivation manipulation cannot be disentangled with the present experimental design. It would be interesting for further research on pain-related attention to further examine the differential effect of affective-motivational and cognitive aspects or to focus on the impact of different goal orientations and goal task characteristics (cf. [31,32,47]). Fourth, no cues were included predicting the occurrence of non-painful somatosensory stimulation or the occurrence of another aversive outcome. So, it is not clear whether the observed effects are specific to pain. Prior research with a similar paradigm as the one applied in the present experiment to measure attentional orienting, but also including cues predicting non-painful vibrotactile stimulation, has suggested that the modulation of attentional disengagement is pain-specific [43]. An interesting avenue would be to examine attentional bias to pain cues, relative to cues that are associated to non-pain goals (cf. [53,54]).

Acknowledgments

The contribution of Martien Schrooten and Johan Vlaeyen was supported by the NWO Social Sciences Research Council of The Netherlands, Grant No. 453-04-003. Stefaan van Damme is supported by an IASP Early Career Research Grant and by the Research Foundation – Flanders (FWO – Vlaanderen). Julia Vogt is a Postdoctoral Fellow of the Research Foundation – Flanders (FWO – Vlaanderen). The authors have no conflicts of interest with regard to the study described in this manuscript. The authors thank Ron Hellenbrand for technical support and Rena Gatzounis for help in data acquisition.

Footnotes

[1] The same pattern of results was obtained with *mean* correct RTs, also after exclusion of responses deviating more than 2.5 SDs from the mean latency per condition.

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Figure Caption

Figure 1. Mean cue validity effects of the goal group (n = 29) and the control group (n = 29) for pain cues and no-pain cues during the test phase. Magnitude of cue validity effects was calculated by subtracting median RTs on valid trials from median RTs on invalid trials. Error bars indicate the SE of the group average of cue validity effects in each condition.

Figure Caption

Figure 1. Mean cue validity effects of the goal group (n = 29) and the control group (n = 29) for pain cues and no-pain cues during the test phase. Magnitude of cue validity effects was calculated by subtracting median RTs on valid trials from median RTs on invalid trials. Error bars indicate the SE of the group average of cue validity effects in each condition.

Figure 1.

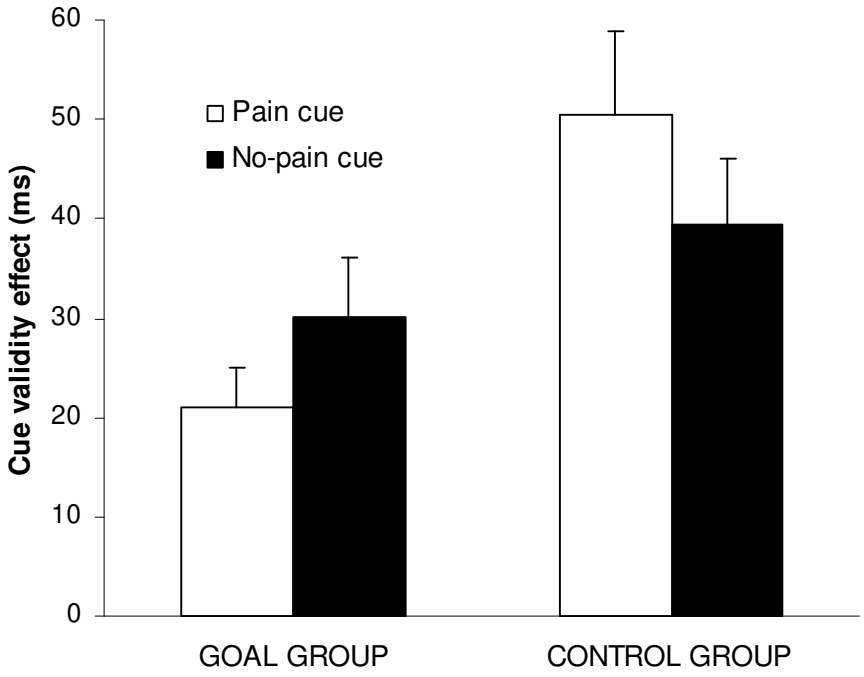
60
50
40
30
20
10
0
Cue validity effect (ms)
Pain cue
No-pain cue
GOAL GROUP
CONTROL GROUP

Table 1

Group sizes, mean age, and mean total scores (SD in brackets) on debriefing questions (11-point Likert scales) at the end of the session, immediately after the computer task.

	Group			
	Goal group	Control group		
	n = 29 (5 men)	*n* = 29 (5 men)	*t*[a]	*df*
Age (in years)	20.1 (1.6)	21.1 (2.5)	1.8[#]	56
Unpleasantness sensory stimulation?	5.0 (1.8)	6.2 (2.1)	2.4[*]	56
Painfulness sensory stimulation?	3.6 (1.9)	5.2 (2.5)	2.7[**]	56
Expectancy sensory stimulation after pain cue?	5.6 (3.1)	6.3 (2.1)	1.1	49.33[b]
Expectancy sensory stimulation after no-pain cue?	2.0 (2.3)	.9 (1.5)	-2.2[*]	48.21[b]
How fearful when pain cue?	3.8 (2.9)	4.8 (2.9)	1.4	56
How fearful when no-pain cue?	.8 (1.5)	.3 (.6)	-1.8[#]	36.36[b]

[a]Independent *t* test. [b]Equality of variances could not be assumed (Levene's test). [**] $p \leq .01$ [*] $p \leq .05$ [#] $.05 < p \leq .10$

Table 2

Median correct RTs (in ms; SD in brackets) on cueing task trials during which no electrocutaneous stimulus was delivered, as a function of cue validity, cue identity, and group (baseline phase and test phase). Magnitude of cue validity effects was calculated by subtracting median RTs on valid trials from median RTs on invalid trials.

		Baseline phase			Test phase		
		Valid	Invalid	Cue validity effect	Valid	Invalid	Cue validity effect
Goal group	Pain cue	411.4 (46.7)	442.9 (50.6)	31.5 (32.3)	404.7 (43.1)	425.6 (44.5)	21.0 (22.2)
	No-pain cue	411.4 (44.6)	437.4 (47.9)	26.0 (22.3)	397.4 (41.8)	427.6 (50.0)	30.2 (31.7)
Control group	Pain cue	429.3 (31.3)	477.8 (50.2)	48.5 (36.4)	406.0 (32.8)	456.5 (56.2)	50.5 (45.3)
	No-pain cue	434.2 (36.9)	477.5 (49.4)	43.3 (35.7)	406.5 (29.2)	445.9 (47.0)	39.4 (36.4)