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Attentional control and the competition between nonpain goals and the threat of pain

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Abstract

Background: Fully understanding attention to pain requires taking into account the motivational context. Both pain- and (nonpain) goal-related information attracts attention. An intriguing question is which attentional bias prevails when pain- and goal-related information co-occurs? Reduced attentional bias towards pain- and goal-related information was predicted when the other competing information was presented simultaneously. Moreover, trait attentional control was predicted to be associated with stronger attentional bias towards goal-related information particularly in the presence of pain-related information.
Methods: Attentional competition between pain- and (nonpain) goal-related information was measured in ninety participants using a dot-probe task presenting two stimuli (pain-related, goal-related or neutral) simultaneously. Reaction time was the dependent variable. Dot-probe trials alternated with goal trials to induce a temporary goal. Trait attentional control was measured with the attentional control scale.
Results: For pain-related neutral stimulus pairs, participants responded fastest when probes appeared on the same, compared to the opposite, location as the pain-related stimulus. For pain-goal-related stimulus pairs, responses were fastest when probes appeared on the same, compared to the opposite, location as the goal-related stimulus. Higher trait attentional control was associated with faster responding when probes appeared on the same, compared to the opposite, location as the goal-related stimulus. Unpredicted, this effect was irrespective of the co-occurring stimulus (neutral vs. pain-related).
Conclusions: The findings suggest that the unintentional allocation of attention towards events related to a temporary (nonpain) goal prevails over attentional bias to events predicting pain. Trait attentional control predicts stronger attentional allocation towards events related to a temporary goal.
Significance: These findings indicate that treatment interventions facilitating goal pursuit in patients with chronic pain are beneficial in reducing attentional biases towards pain-related events.

For this article, a commentary is available at the Wiley Online Library

1. Introduction

Pain is an evolutionarily acquired alarm signal of bodily threat (Eccleston and Crombez, 2007). Orienting attention towards pain signals facilitates pain anticipation and avoidance. Biased attention to pain signals may enhance chronic pain (Pincus and

Morley, 2001; Eccleston and Crombez, 2007; Van Ryckeghem et al., 2013). Healthy individuals and patients with chronic pain selectively attend to pain-related information (Roelofs et al., 2002; Schoth et al., 2012; Crombez et al., 2013). However, the effect sizes of these biases are small to medium (Crombez et al., 2013) suggesting the involvement of moderator variables. Fully understanding attention to pain requires considering the motivational context in which pain occurs (Van Damme et al., 2010). People with pain experience conflicts between pain-avoidance and nonpain goals, such as completing tasks satisfactorily. Research has demonstrated that (nonpain) goal commitment leads to an attentional prioritization of goal-related information even without the intention to attend to this information (Moskowitz, 2002; Ansorge et al., 2009; Vogt et al., 2013). An intriguing question is which attentional bias prevails when pain- and goal-related information co-occurs. Research has demonstrated that performing nonpain tasks inhibits attention to pain signals (Schrooten et al., 2012). In this study, attention to goal-related information was instrumental for goal achievement. It is unknown whether attention to goal-related information that is noninstrumental for goal achievement, and therefore is unintentional (Vogt et al., 2013), reduces attention to pain-related information. Additionally, research on the interruptive effect of pain-related information on the attentional processing of goal-related information is fairly absent. Therefore, research is required testing whether pain-related information reduces unintentional allocation of attention to goal-related information.

Trait attentional control may be involved in the resolution of attentional conflicts (Moskowitz, 2002; McNaughton and Corr, 2004). Higher attentional control is associated with stronger activation of goal representations in memory (Posner et al., 2002; Peers et al., 2013) and increased ability to direct attention away from interfering threat-related information (Derryberry and Reed, 2002) towards goal-related information (Peers et al., 2013). To our knowledge, research considering the role of attentional control in attentional conflicts between pain- and goal-related information is absent. Attentional control may be associated with enhanced attentional allocation towards goal-related information, but away from conflicting pain-related information. As trait attentional control is involved in automatic attentional processes (Bardeen and Orcutt, 2011; Kiefer, 2014), it possibly increases attention towards competing goal-related information even without the intention of attending.

The present study aimed to establish whether (1) unintentional attention towards goal-related stimuli would reduce attention towards pain-related information, whether (2) pain-related information interrupts attention to goal-related information and whether (3) trait attentional control moderates these effects. A dot-probe paradigm (MacLeod et al., 1986) was employed presenting a pair of stimuli from a set of three stimuli: pain-related, (nonpain) goal-related and neutral (pain/goal-unrelated), followed by a probe. Selective attention was characterized by faster responses to probes at the location previously occupied by the attended stimulus than unattended stimulus. Dot-probe trials were alternated by separate goal trials inducing a temporary nonpain goal (Vogt et al., 2013). Attending to the goal-related stimulus during dot-probe trials was not instrumental for goal achievement. It was predicted that (1) attention would be selectively allocated to pain- and goal-related stimuli as compared to neutral stimuli, (2) selective attention towards pain- and goal-related stimuli would be reduced when goal- and pain-related stimuli were presented simultaneously, relative to when presented with neutral stimuli, and (3) trait attentional control would be associated with a stronger attentional bias towards goal-related stimuli, particularly when goal-related information co-occurred with pain-related stimuli (high goal conflict) versus neutral stimuli (low goal conflict).

2. Methods

2.1 Participants

Ninety-five participants (70 women, 25 men; M_{age} [*SD*] = 24.12 [8.87] years) were recruited through advertisement at Maastricht University (faculties of Health Science, Psychology or Medicine). Exclusion criteria were: (1) age younger than 18 years or older than 65 years, (2) self-reported chronic pain problems, (3) pregnancy, (4) uncorrected vision, (5) colour blindness and (6) electronic implants (such as a pacemaker). Three participants were excluded because of technical errors during data acquisition. Moreover, two participants were excluded because their proportion of errors (no response or wrong button press) and outliers (reaction times < 150 ms or > 1000 ms) on the test phase of the dot-probe task (see 2.2.5) was more than 3 *SD* (95% and 55%) than the mean proportion of errors [*M* (*SD*) = 6% (12)]. The final sample size consisted of 90 participants (66 women, 24 men; M_{age} [*SD*] = 23.93 [8.62] years). None of the participants indicated that

they were aware of the hypothesis of the experiment. The ethical committee of the Psychology department of the Maastricht University approved the study and the procedures followed were in accordance with the Helsinki Declaration (6th revision, Seoul 2008). The participants provided written informed consent.

2.2 Instruments

2.2.1 Attentional control

To measure trait executive control over attention, the Dutch translation (Verwoerd et al., 2007) of the Attentional Control Scale (ACS; Derryberry and Reed, 2002) was used. The ACS is a 20-item self-report measure that assesses one's ability to maintain attention despite distractors, and the ability to shift attention from one task to another. Items are scored on a 4-point Likert scale ranging from 1 (almost never) to 4 (always). Total scores range from 20 to 80, with high scores indicating high attentional control. Examples of items are: 'When I need to concentrate and solve a problem, I have trouble focusing my attention' and 'It is easy for me to alternate between two different tasks.' The psychometric properties (reliability and validity) of the ACS are satisfactory (Derryberry and Reed, 2002; Judah et al., 2014). Scores on the ACS have been shown to be associated with performance on cognitive tasks that require executive, attentional control, and more specifically, the extent to which participants allocate attention to threat information (Derryberry and Reed, 2002; Judah et al., 2014). The internal consistency of the attentional control scale in the present study was satisfactory: Cronbach's $\alpha = 0.78$.

2.2.2 Apparatus

Task presentation and response registration (latency and accuracy) were controlled by a Dell Optiplex GX 755 (Dell, Round Rock, TX, USA) computer that was connected to two 19-inch Samsung Syncmaster 931 BF LCD (Samsung, Ridgefield Park, NJ, USA) monitors (one for the participant and one for the experimenter). The experiment was programmed using Presentation software (Neurobehavioral Systems, Albany, CA, USA).

2.2.3 Electrocutaneous stimuli

Electrocutaneous stimuli (bipolar sinus waveform; 400-ms duration) were administered by a constant current stimulator with 50-Hz internal frequency (DS5, Digitimer, Hertfordshire, United Kingdom) through 2 8-mm stainless steel electrodes filled with hypertonic gel. The electrodes were vertically attached to the external side of the left ankle with 1-cm inter-electrode distance. Stimulus intensity was individually determined using a work-up procedure starting with the lowest intensity of 1 mA and maximally 20 mA. After each stimulus, participants rated its intensity on a scale ranging from 0 (not at all painful) to 10 (the worst pain imaginable). The individual stimulus intensity level that was rated an '8' (M [SD] = 8.28 [3.41] mA, range 3-18 mA) was selected during this calibration procedure (Meulders et al., 2011). After the work-up procedure, the threat value of the electrocutaneous stimulus was increased as pain-related attentional bias has been demonstrated particularly for highly threatening stimuli (Crombez et al., 1999). Participants were led to believe that the electrocutaneous stimuli of a higher intensity than selected would be presented occasionally during the test phase (Schrooten et al., 2012). In reality, no stimuli of higher intensity were delivered during the experiment.

2.2.4 Visual stimuli

The visual stimuli used in the goal task and dot-probe task were three coloured patches (yellow, orange and pink). The patches were rectangles (6.1 cm high, 4.6 cm wide). The patches were used as the goal-related, pain-related or neutral (pain/goal-unrelated) stimulus. The meaning of the colour was randomized across participants. Additionally, 12 filler stimuli were used in the goal task, to reduce the proportion of the three relevant stimuli. These filler stimuli were three shades of green, blue, brown and grey. All visual stimuli were matched on luminance and presented against a black background.

2.2.5 Dot-probe task

Each trial in the *dot-probe task* started with the presentation of a black fixation cross (5 × 5 mm) in a white square in the middle of the screen. Participants were encouraged to fixate their eyes on the cross during the experiment. Two white rectangles (6.1 cm high, 4.6 cm wide) were displayed left and right of the fixation cross (see Fig. 1). The middle of each of these peripheral rectangles was 4.6 cm from the fixation cross. After 500 ms, two coloured patches (representing goal-related, pain-related or neutral cues in the test phase) filled the left and right frame for 250 ms. Immediately after cue offset,

a back slash or forward slash (font size 8) appeared (probe) in either the left or right frame. Participants' task was classifying the probe by pressing a left key labelled '\' or a right key labelled '/' with the index finger of respectively the left or right hand. The probe disappeared after a response was registered or 1500 ms had elapsed since the onset of the probe. No electrocutaneous stimuli were presented during the dot-probe task.

2.2.6 Goal task

Each trial in the goal task started with the appearance of a colour patch (6.1 cm × 4.6 cm) in the middle of the screen for 250 ms, after which it was replaced by a red question mark (font size 5). Participants' task was pressing a button with the thumb when the goal-related colour patch was presented. The button was located below the two buttons of the dot-probe task. When a pain-related stimulus was presented an electrocutaneous stimulus (400 ms) was given in 50% of the trials (12 trials) at the start of the red question mark, irrespective of the response of the participant. These electrocutaneous stimuli were presented to avoid extinction. The trial ended with a response or when 2000 ms had elapsed since the onset of the question mark. Correct reactions to the goal-related colour patch were followed by a feedback screen for 200 ms consisting of the word 'correct' in green (in Dutch 'goed', font size 24). Incorrect reactions (i.e. no reaction) to the goal-related colour patch and incorrect reactions to the other colour patches (i.e. pressing of the button) were followed by error feedback for 200 ms consisting of the word 'wrong' in red (in Dutch 'fout,' font size 24).

2.3 Procedure

Figure 2 shows a schematic overview of the procedure. At step 1, participants were told that the study was about the relationship between motivation and performance. After signing informed consent, participants completed the ACS and biographical questions regarding their age, gender, pain symptoms, pregnancy, eyesight and colour blindness.

At step 2, participants performed the dot-probe trials during a practice (12 trials) and baseline phase (144 trials). The baseline dot-probe task was administered to check whether there was no attentional prioritization of specific colour patches before the acquisition phase. Randomization of stimulus pair, cue type, cue-probe location was similar to the dot-probe task in the test phase.

At step 3, one of the coloured patches was paired with the electrocutaneous stimulus (acquisition). Participants were instructed that only one of the coloured patches would sometimes be followed by the electrocutaneous stimulus whereas the other coloured patches would never be followed by the electrocutaneous stimulus. Participants' task was to find out which coloured patch would be followed by the electrocutaneous stimulus. The acquisition phase consisted of eight trials presenting two of the three coloured patches (yellow, orange or pink), representing the pain-related and neural stimulus, one at a

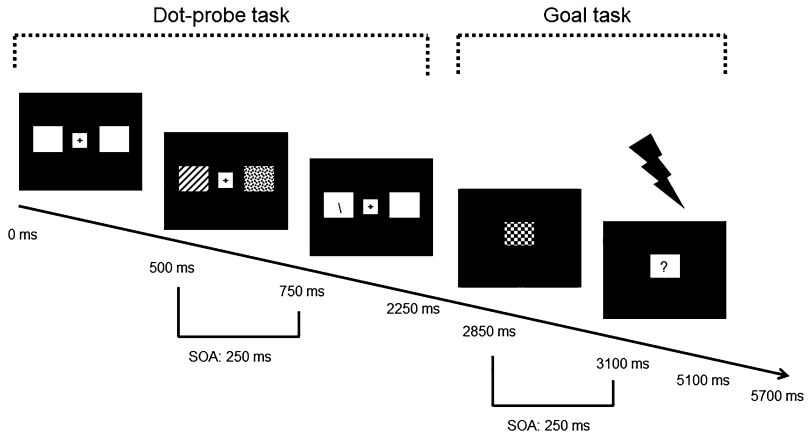

Figure 1 Schematic overview of a trial of the test phase, in which the dot-probe task and goal task are combined. The first three boxes depict the dot-probe task in which the presentation of two cues (pain-related, goal-related or neutral) was followed by a probe (forward or backward slash) that had to be localized by pressing one of two horizontally oriented response keys. The last two boxes display the goal task in which the presentation of a single stimulus (pain-related, goal-related, neutral or filler) was followed by the appearance of a question mark. When the stimulus of the goal task was pain-related, an electrocutaneous shock (400 ms) was presented on 50% of the trials. Participants had to press a third central response key when the single stimulus of the goal task was the goal-related stimulus.

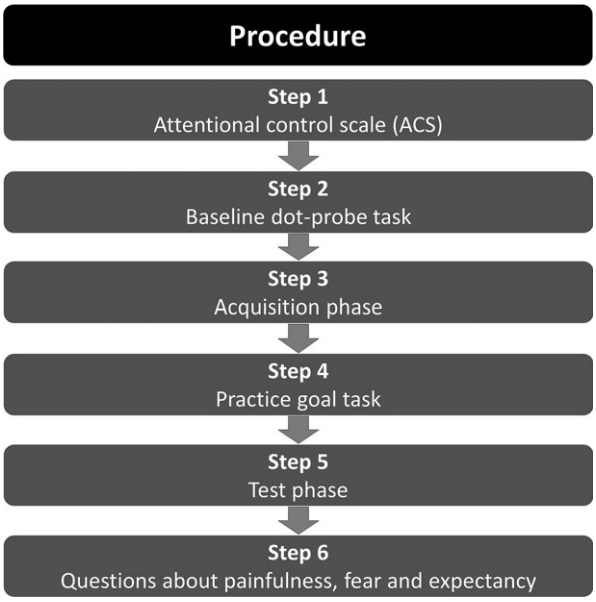

Figure 2 Schematic overview of the procedure.

time. The trial started with a fixation cross for 500 ms followed by a coloured patch in the middle of the screen for 250 ms. The trial ended when 2,500 ms had elapsed since the onset of the fixation cross. Each of the two coloured patches was presented four times in a random order, with one patch always being followed by the electrocutaneous stimulus (400 ms) (CS+), whereas the other patch was never followed by the electrocutaneous stimulus (CS-). The goal-related patch was not presented during this phase. After presentation of the acquisition trials, all the participants correctly indicated the colour that was followed by the electrocutaneaous stimulus.

Step 4 was a practice goal task. Participants were instructed to press a central key with their thumb only when the stimulus was the goal-related stimulus. The task comprised 30 trials in which either the pain-related stimulus (5 trials), neutral stimulus (5 trials), the goal-related stimulus (5 trials) or filler stimulus (15 trials) was presented in a random order. The pain-related stimulus was followed by an electrocutaneous stimulus three times.

At step 5, the test phase of the dot-probe task started. Each trial of the dot-probe task was always followed by a trial of the goal task. The dot-probe task consisted of 144 trials presenting three pairs of the relevant coloured patches (pain-related – neutral, pain-related – goal-related and goal-related – neutral). In half of the trials, each single coloured patch was presented in the left cue location and in half of the trials in the right cue location. Moreover, each stimulus pair was followed by a probe which was a forward slash or a backward slash half of the time and which was presented in the left or the right cue location half of the time. Stimulus pair, probe type, location of each relevant stimulus, and probe location were presented in a different random order for each participant. The probe could be presented on the same location as the pain-related or goal-related stimulus (respectively pain congruent or goal-congruent condition) or on the opposite location (respectively pain incongruent or goal incongruent condition). The spatial location of the pain-related, goal-related or neutral stimulus was never predictive of the spatial location of the probe. Additionally, the presentation of a pain-related stimulus in the dot-probe task was never predictive of an electrocutaneous stimulus during the subsequent goal task. Attentional allocation to the pain-related stimulus or the goal-related stimulus in the dot-probe task was not instrumental for the performance on the goal task.

Like the dot-probe task, the goal task consisted of 144 trials in total. In each trial, a goal-related stimulus (24 trials), a pain-related stimulus (24 trials), a neutral stimulus (24 trials) or one of 12 filler stimuli (72 stimuli) were presented in random order. Before the actual task started, 12 practice dot-probe and 12 goal trials were performed to practice the alternation of dot-probe and goal trials.

At step 6, after the dot-probe and goal tasks participants were asked how painful and unpleasant the electrocutaneous shock was during the goal task on a 10-point Likert scale ranging from 0 (not at all) to 10 (the worst/the most unpleasant pain imaginable). In addition, participants were asked to indicate to what extent they expected an electrocutaneous shock and how fearful they were after the presentation of the pain-related stimulus (CS+), neutral stimulus (CS-) and the goal-related stimulus on a 10-point Likert scale ranging from 0 (not at all) to 10 (very much). Moreover, participants completed an open-ended question asking about the goal of the experiment. All participants were debriefed about the design and purpose of the study immediately after the experiment. Participants received course credits for their participation or €7.50.

2.4 Statistics

To establish whether conditioning had been successful, two analyses of variance (ANOVA) were performed with stimulus (pain-related, goal-related vs. neutral) as within-subjects factor and with either fear or expectancy of an electrocutaneous shock as dependent variables. If the effect of stimulus was

significant, post hoc pairwise comparisons were performed using simple contrasts.

To test the hypotheses of the experiment (i.e. attentional prioritization of the goal-related stimulus vs. the pain-related stimulus) two analyses of covariance (ANCOVA) were performed with spatial congruence between stimulus and probe (congruent vs. incongruent) and stimulus pair (pain-related - neutral stimulus pairs, pain-related - goal-related stimulus pairs or goal-related -neutral stimulus pairs) as within-subjects factors, the centred attentional control score as covariate and mean reaction time during dot-probe task as dependent variable. Congruence was coded as either congruent to the pain-related or the goal-related stimulus dependent on the analysis conducted. To establish attentional prioritization of the pain-related stimulus when presented concurrently with the neutral stimulus or the goal-related stimulus, congruence was coded as congruent to the pain-related stimulus (threat congruence). To test attentional prioritization of the goal-related stimulus when concurrently presented with the neutral stimulus or the pain-related stimulus, congruence was coded as congruence to the goal-related stimulus (goal congruence). The same analyses were performed for the baseline dot-probe task establishing whether there was no attentional prioritization before the acquisition phase.

Nonsignificant effects ($p > 0.05$) were deleted from the model one by one, starting with the higher order interactions. In case of a significant interaction between the stimulus pair and congruence, two ANCOVAs were conducted to test congruence effects for each stimulus pair separately. In case of a significant interaction between stimulus pair, congruence and the covariate attentional control, simple slope analyses were performed. These analyses tested the effects of congruence and stimulus pair for participants with low (M - 1 SD) and high (M + 1 SD) attentional control separately.

3. Results

3.1 Manipulation checks and goal task

Participants described the electrocutaneous shock as painful (M [SD] = 6.11 [1.74]) and unpleasant (M [SD] = 6.24 [2.34]). They reported a stronger expectation of an electrocutaneous stimulus after the appearance of a pain-related colour patch (M_{pain} [SD] = 6.82 [2.12]) than after a neutral or a goal-related colour patch ($M_{neutral}$ [SD] = 0.39 [1.22]; M_{goal} [SD] = 0.42 [1.15], pain-related vs. goal-related, $t(89) = 24.80$, $p < 0.001$; pain-related vs. neutral, $t(89) = 22.72$, $p < 0.001$). They reported higher fear during the presentation of the pain-related colour patch (M_{pain} [SD] = 5.18 [2.57]) than after a neutral or a goal-related colour patch ($M_{neutral}$ [SD] = 0.89 [0.81]; M_{goal} [SD] = 0.74 [1.39]; pain-related vs. goal-related, $t(89) = 15.56$, $p < 0.001$; pain-related vs. neutral, $t(89) = 16.89$, $p < 0.001$). This indicates that conditioning was successful. The mean percentage of errors on the goal task (M [SD] = 1.76 [2.43]%) indicated that the participants adopted the goal of the task successfully.

3.2 Data preparation of the dot-probe task

Trials with wrong button presses in the dot-probe task were removed from the data (baseline, 3.28%; test, 2.07%). Additionally, reaction times faster than 150 ms and slower than 1000 ms were considered outliers (Vogt et al., 2013) and were removed from the data (baseline, 1.92%; test 2.58%). For the analyses of the baseline and test dot-probe task, there was respectively 94.80% and 95.35% of the data left for analyses. Total number of removed trials tended to be infrequent and there was not enough variability to allow for parametric testing of accuracy data [Pain-neutral pair: $M_{\text{pain congruent}}$ (SD) = 94.62 (8.57) % correct responses and $M_{\text{pain incongruent}}$ (SD) = 95.37 (7.98); Pain-goal stimulus pair: $M_{\text{pain congruent}}$ (SD) = 95.32 (7.09) % correct responses and $M_{\text{pain incongruent}}$ (SD) = 95.69 (5.94); Goal-neutral pair: $M_{\text{goal congruent}}$ (SD) = 96.25 (5.11) % correct responses and $M_{\text{goal incongruent}}$ (SD) = 94.35 (9.50)]. The hypotheses of the present study were tested by analysing reaction times and not error rates.

3.3 Baseline dot-probe task

A series of ANCOVA's with the mean reaction time during the baseline dot-probe task as dependent variable and attentional control (ACS score) as covariate demonstrated no significant main or interaction effects of spatial congruency, stimulus pair and attentional control (ps < 0.05). This indicates that there was no attentional prioritization of specific colour patches (pain-related, goal-related, neutral) before the acquisition phase.

3.4 Attentional prioritization

3.4.1 *Attentional bias to pain-related stimuli*

A 2 Congruency (congruent vs. incongruent to the pain-related stimulus) × 2 Stimulus pair

(pain-related-neutral pairs vs. pain-goal-related pairs) ANCOVA was conducted to establish whether attention towards pain-related stimuli would be reduced in the presence of goal-related stimuli as compared to neutral stimuli, and whether this effect would be most pronounced for participants with higher attentional control. Figure 3 presents mean reaction times (with standard error bars) for pain-related with neutral and pain-related with goal-related stimulus pairs as a function of congruency.

The analysis showed a significant Congruency x Stimulus pair interaction, F (1, 88) = 11.80, $p < 0.001$, $\eta_p^2 = 0.12$ (between medium and large effect size) and a significant main effect of stimulus pair, F (1, 88) = 16.28, $p < 0.001$, $\eta_p^2 = 0.16$ (main effect of congruency, $p > 0.05$). Post hoc tests revealed a significant attentional prioritization of the pain-related stimulus over the neutral stimulus, F (1, 88) = 6.46, $p = 0.01$, $\eta_p^2 = 0.07$ (medium effect size) and a significant attentional prioritization of the goal-related stimulus over the pain-related stimulus (CS+), F (1, 88) = 4.03, $p = 0.048$, $\eta_p^2 = 0.04$ (between small and medium effect size). In line with hypothesis 1, these results indicated attentional prioritization of pain-related stimuli over neutral stimuli. In line with hypothesis 2, the attentional bias to pain-related stimuli switched to an attentional prioritization of goal-related stimuli when pain-related and goal-related stimuli were presented concurrently.

Hypothesis 3 was rejected. Higher attentional control was not associated with a stronger attentional bias towards goal-related stimuli particularly when combined with pain-related stimuli. The interaction between Congruency x Stimulus pair x Attentional control was nonsignificant, F (1, 88) = 0.93, $p = 0.34$, $\eta_p^2 = 0.01$. No other main and interaction effects of congruency, stimulus pair and attentional control reached significance ($ps < 0.05$).

3.4.2 *Attentional bias to goal-related stimuli*

A 2 Congruency (congruent vs. incongruent to the goal-related stimulus) × 2 Stimulus pair (goal-related-neutral pairs vs. goal-pain-related pairs) ANCOVA was conducted to establish whether attention towards goal-related stimuli was interrupted by pain-related stimuli as compared to neutral stimuli, and whether this interruption would be most pronounced for individuals with low attentional control. Figure 4 shows mean reaction times (with standard error bars) for individuals with low and high attentional control who responded to a probe spatially congruent versus incongruent with the goal-related stimulus.

In support of hypothesis 1, analysis showed a main effect of congruency, indicating faster reaction times in the goal-congruent than the incongruent condition, F (1, 88) = 7.18, $p = 0.01$, $\eta_p^2 = 0.08$ (medium

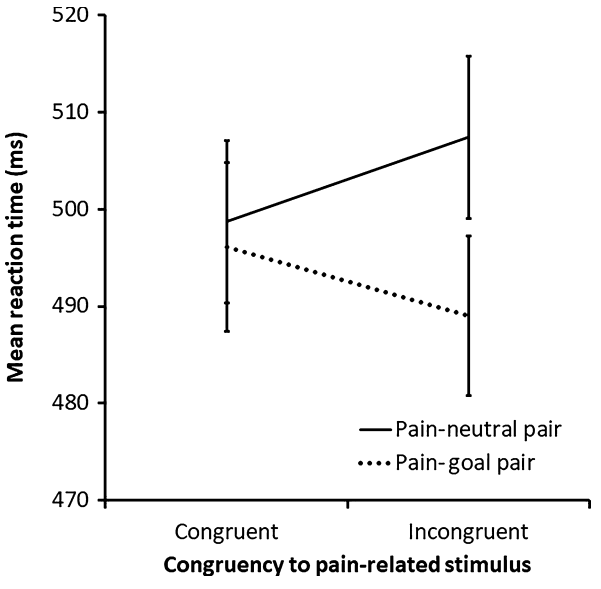

Figure 3 Mean reaction times (in ms, with standard error bars) on pain-related congruent (probe presented at same location as pain-related stimulus) and incongruent (probe presented at opposite location) trials for pain-related – neutral and pain-goal-related stimulus pairs separately.

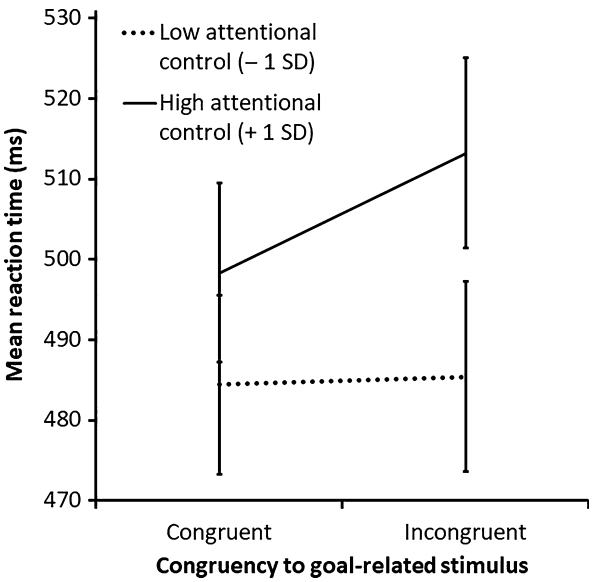

Figure 4 Mean reaction times (in ms, with standard error bars) on goal-related congruent and incongruent trials for high and low attentional control.

effect size). However, the Congruency x Stimulus pair interaction did not reach significance, F (1, 88) = 0.17, p = 0.68, $\eta_p^2 < 0.01$, indicating that, in contrast to hypothesis 2, attention to goal-related stimuli was not reduced in the presence of pain-related stimuli as compared to in the presence of neutral stimuli.

The congruency effect was moderated by attentional control, F (1, 88) = 5.43, p = 0.02, $\eta_p^2 = 0.06$ (main effect attentional control, $p > 0.05$). Simple slope analysis testing the effect of congruency for participants with low (- 1 *SD*) and high (+1 *SD*) attentional control separately, showed faster responses to congruent than incongruent trials for participants with high attentional control, F (1, 88) = 12.54, $p < 0.001$, $\eta_p^2 = 0.13$ (medium-large effect size), but not for those with low attentional control, F (1, 88) = 0.06, p = 0.81, $\eta_p^2 < 0.01$. This indicates that higher attentional control is associated with a stronger attentional bias towards goal-related stimuli. However, the Congruency x Attentional control interaction was not further modulated by stimulus pair, F (1, 88) < .01, p = 0.95, $\eta_p^2 < 0.01$, indicating, that in contrast to hypothesis 3, higher attentional control was not associated with a stronger attentional bias towards goal-related stimuli when combined with pain-related stimuli.

Finally, and of less relevance for the current focus on attention allocation, there were significant effects independent of congruency (main effect stimulus pair, F (1, 88) = 6.09, p = 0.02, $\eta_p^2 = 0.07$; Stimulus pair x Attentional control, F (1, 88) = 15.74, p = 0.02, $\eta_p^2 = 0.06$).

4. Discussion

The present study showed that attention is allocated towards pain-related and goal-related information in the presence of neutral information. However, when goal-related and pain-related information is presented simultaneously the attentional bias to pain-related information is reduced and switched towards goal-related information. Attentional bias to goal-related information was not reduced in the presence of pain-related information relative to neutral information. Moreover, higher attentional control was associated with a stronger attentional bias towards goal-related information. However, unexpectedly this relation was not most pronounced during high attentional conflict (goal-related information presented concurrently with pain-related information) as compared to low conflict (goal-related stimuli presented with neutral information).

The finding that attention is allocated towards pain-related information in the presence of neutral information (medium effect size) is in line with previous research demonstrating attentional biases of medium effect size towards signals of impeding pain (Crombez et al., 2013). These findings are in line with an evolutionary perspective suggesting the existence of a 'primitive defensive threat system' that selectively allocates attention towards potential dangers to prepare defensive actions that promote survival (LeDoux, 1996; Eccleston and Crombez, 1999; Öhman et al., 2000).

The present findings show that attentional bias to pain-related information diminishes in the presence of competing goal-related information. This observation is in line with an earlier finding that attentional bias towards pain-related information is reduced when one is motivated to pursue a concurrent salient nonpain task goal (Schrooten et al., 2012). Thus, overall, these findings provide evidence that attention to pain-related information is not solely explained by a defensive threat system, but also by an individual's current nonpain task goals (Legrain et al., 2011). The present study adds to this previous research on the impact of nonpain goal pursuit on attention to conditioned pain signals (Schrooten et al., 2012) in two important ways. Firstly, it shows that nonpain goal-related information reduces an attentional bias towards pain-related information even when attention to goal-related information is not instrumental to goal achievement and therefore is unintentional (Vogt et al., 2013). Secondly, it controls for differences in characteristics of the goal-related and pain-related information. More specifically, in previous research, pain-related stimuli were colour patches that appeared at the left or right of central fixation, whereas goal-related stimuli were digits at central fixation (Schrooten et al., 2012). In the present study, both goal-related and pain-related stimuli were colour patches that appeared at one of two similar spatial locations.

Unexpectedly, the attentional allocation to goal-related information was not interrupted by the presence of pain-related information. This finding corroborates a previous study showing that attentional bias to goal-related information was not interrupted by the threat valence of a co-occurring (nonpain) stimulus (Vogt et al., 2013). However, this finding contrast research demonstrating that pain interrupts nonpain task performance (Buhle and Wager, 2012; Moore et al., 2013). Several mechanisms may explain these differential findings. Firstly, the threat value of signals of impeding pain that

were used in the present study, may have been too low and weaker than the threat of actual pain. Secondly, commitment to the task goal may have been stronger in the current study, decreasing the interruptive effects of pain-related information. Thirdly, the absence of an opportunity to respond to pain-related information (i.e. to prevent a painful shock) in the present study, may have reduced the interruptive effect of pain-related information. Finally, it is possible that attention to the nonpain task goal was not interrupted by pain-related information because the nonpain task goal was a relatively easy and low cognitively demanding task. Research has shown that threatening stimuli attracted greater attention when cognitive control resources were depleted by additional cognitive demands (e.g. high working memory load) (Holmes et al., 2014). Future research may examine these possible mechanisms.

In line with previous research (Peers and Lawrence, 2009; Peers et al., 2013) the present study demonstrated that people with higher attentional control showed a stronger attentional prioritization of goal-related stimuli than people with lower attentional control. Moreover, in line with previous research (Bardeen and Orcutt, 2011; Kiefer, 2014), attentional control positively influenced attention towards goal-related information, even when there was no intention of attending to this information. An explanation for this finding is that people with high attentional control actively maintain and implement task representations in memory (Posner et al., 2002; Peers et al., 2013) which automatically and unintentionally guide attention to goal-related stimuli (Moskowitz, 2002; Ansorge et al., 2009; Vogt et al., 2013) and reduce (attentional) interference from task irrelevant information (Miller and Cohen, 2001).

It was hypothesized that attentional control would come into play particularly when attentional conflict was high (i.e. when pain- and goal-related information co-occurred). In contrast to this hypothesis, high attentional control predicted increased attention towards goal-related information, but this was irrespective of the valence of the co-occurring stimulus (pain-related or neutral). Moreover, attentional control was not predictive of the degree to which goal-related information, relative to neutral information, reduced the attentional allocation towards pain-related information. These findings contrast previous research showing that higher attentional control is associated with increased attentional disengagement from threat (Derryberry and Reed, 2002; Lonigan and Vasey, 2009; Bardeen and Orcutt, 2011) and reduced task interference by threatening information (Peers and Lawrence, 2009; Peers et al., 2013). These differential finding may be explained by some methodological differences. Firstly, previous research measured an attentional bias towards threat when threat competed with safety information rather than with goal-related information (Derryberry and Reed, 2002; Lonigan and Vasey, 2009). It is possible that attention to goal-related information more strongly draws attention away from threatening information than safety information, reducing the additional effect of trait attentional control. Secondly, previous research used other paradigms than dot-probe tasks (e.g. a modified version of a 2-target attentional dwell task, Peers et al., 2013) that do not solely measure attentional processes. Thirdly, some studies included trait anxiety measures and suggested that the combination of high trait anxiety and low attentional control resulted in a difficulty to disengage from threatening information (Derryberry and Reed, 2002; Lonigan and Vasey, 2009; Bardeen and Orcutt, 2011). Recently, a meta-analysis demonstrated that trait anxiety or pain-related fear, as main effects, poorly predict pain-related attentional biases (Crombez et al., 2013). Future research may establish whether the combination of high trait pain-related fear and low attentional control explains attentional biases towards pain signals.

A limitation of the present study is that findings only generalize to healthy individuals. It has been suggested that patients with chronic pain have lower attentional control (Moriarty et al., 2011). In future, it would be worthwhile to examine whether goal-related information reduces attentional bias towards pain signals in patients with chronic pain. Moreover, in the present study, attentional control was assessed with a widely used self-report questionnaire, i.e. the Attentional Control Scale (Derryberry and Reed, 2002). Further studies may want to include performance-based measures of (executive) attentional control, such as the Stop Signal Task (Logan et al., 1984), which may be less prone to response bias. In sum, the present study showed that the unintentional and relatively fast allocation of attention towards events relevant to a temporary goal outweighs attentional bias to events predicting pain. Moreover, trait attentional control predicted a stronger allocation of attention towards events relevant to a temporary goal. These findings may indicate the mechanisms that explain why treatment interventions that facilitate goal pursuit in patients with chronic pain (McCracken et al., 2005; Christiansen et al., 2010; Wicksell et al., 2013) are beneficial in reducing attentional bias towards pain-related events.

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Author contributions

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