Comparing counterconditioning and extinction as methods to the reduce fear of movement-related pain

Ann Meulders[1,2], Petra A. Karsdorp[4,5], Nathalie Claes[1,3], & Johan W.S. Vlaeyen[1,2,5]

[1]Research Group on Health Psychology, University of Leuven, Leuven, Belgium

[2]Center for Excellence on Generalization in Health and Psychopathology, University of Leuven, Leuven, Belgium

[3]Department of Experimental, Clinical and Health Psychology, Ghent University, Belgium

[4]Clinical and Health Psychology, Utrecht University, Utrecht, The Netherlands

[5]Department of Clinical Psychological Science, Maastricht University, The Netherlands

Key words: fear of movement-related pain; fear learning; extinction; counterconditioning; chronic pain; fear-avoidance

Correspondence concerning this article should be addressed to Ann Meulders, Ph.D, Department of Psychology, University of Leuven, Tiensestraat 102, box 3726, 3000 Leuven, Belgium. E-mail: ann.meulders@ppw.kuleuven.be, T: +32 (0)16 32 60 38, F: +32 (0)16 32 61 44.

Disclosures

AM is a postdoctoral researcher of the Research Foundation – Flanders (FWO-Vlaanderen), Belgium (grant ID: 12E33714N). This study was also supported by an EFIC-Grünenthal Research Grant to AM (E-G-G ID: 169518451). The contribution of PAK was supported by a Veni Grant (grant ID: 453-04-003) provided by the Netherlands Organization for Scientific Research. The contribution of NC was supported by a research grant of the Research Foundation –Flanders (FWO-Vlaanderen), Belgium (grant ID: G091812N) . The contribution

of JWSV was supported by the Odysseus Grant ‘‘*The Psychology of Pain and Disability Research Program’’* funded by the Research Foundation Flanders (FWO-Vlaanderen), Belgium (grant ID: G090208N). The authors report no conflict of interest.

Abstract

Cognitive-behavioral treatments for chronic pain typically target pain-related fear – exposure in vivo is a common treatment focusing on disconfirming harm expectancy of feared movements. Exposure therapy is tailored on Pavlovian extinction; an alternative fear reduction technique that also alters stimulus valence is counterconditioning. We compared both procedures to reduce pain-related fear using a Voluntary Joystick Movement Paradigm. Participants were randomly allocated to the Counterconditioning or Extinction Group. During fear acquisition, moving the joystick in two directions (CS+) was followed by a painful electrocutaneous stimulus (pain-US), while moving the joystick in two other directions was not (CS-). During fear reduction, one CS+ was extinguished, but another CS+ was still followed by pain in the Extinction Group; in the Counterconditioning Group one CS+ was extinguished and followed by a monetary reward-US, and another CS+ was followed by both USs (pain-US and reward-US). Results indicate that counterconditioning effectively reduces pain-related fear but that it does not produce deeper fear reduction than extinction. Adding a reward-US to a painful movement did neither attenuate fear nor the intensity/unpleasantness of the pain itself. Both procedures changed stimulus valence. We contend that changing the affective valence of feared movements might improve fear reduction and may prevent relapse.

Perspective: This article reports no immediate differences between counterconditioning and extinction in reducing pain-related fear in the lab. Unexpectedly, both methods also altered stimulus valence. We cautiously suggest however that methods explicitly focusing on altering the affective valence of feared movements may improve long-term effectiveness of fear reduction and prevent relapse.

1. Introduction

Pain is considered an unconditioned stimulus (US) that demands for instantaneous defensive action such as the withdrawal from the nociceptive stimulus[21, 57]. Additionally, neutral movements (conditioned stimulus, CS) that are associated with pain come to elicit fear and tend to be avoided (conditioned response, CR). Recent experimental research indeed demonstrated the involvement of associative learning in the acquisition of fear of movement-related pain[38, 39, 41].

In the same vein, models of classical conditioning predict that fear of movement-related pain can be reduced using an *extinction procedure*, that is, exposure to the CS without presenting the US[3, 11]. Graded exposure in vivo (GEXP) is the clinical analogue of Pavlovian extinction: chronic pain patients are gradually exposed to feared movement(s) without experiencing the expected bodily damage[32, 40, 62]. As a result, patients' catastrophic representation of pain associated with the feared activity is challenged and disconfirmed. Although GEXP is an effective approach to reduce pain-related fear[2, 17-20], there is room for improvement. What patients learn during exposure often does not sufficiently generalize to other situations and contexts[15, 26]. In fact, human fear conditioning models predict this relapse. Particularly, with the study of return-of-fear phenomena such as renewal (i.e. return of fear after a context switch), reinstatement (i.e. return of fear after unpredictable USs), Bouton[4, 5] showed that conditioned fear can reemerge after extinction, thus demonstrating that the original CS-US association was not erased, but that extinction memory is context-dependent.

One possible source of relapse is the lingering *negative affective valence* of feared movements after exposure therapy. That is, patients may still find a certain movement unpleasant, although they no longer avoid it because they learned that the movement will not

provoke bodily harm. Dirikx and colleagues[22] indeed showed that negative stimulus valence plays a role in fear reinstatement after successful extinction.

A counterconditioning procedure can be used to change the stimulus valence. During counterconditioning, a CS is paired with another US of opposing valence[16, 27, 30]. As a result, the CS will start to elicit conditioned responses in correspondence with the second US, different from its first-learned conditioned response. Raes and De Raedt[44] showed that counterconditioning, in contrast to extinction, can alter the negative stimulus valence of a CS that was previously followed by an aversive US. Following this reasoning, feared movements may no longer elicit fear and avoidance and even lose their negative valence when paired with a non-painful approach-related stimulus.

We compared both extinction and counterconditioning as procedures to reduce fear of movement-related pain using a Voluntary Joystick Movement (VJM) Paradigm[39] with arm movements as CSs and a painful electrocutaneous stimulus as the negative valenced US (pain-US). We operationalized the positive valenced US as a monetary reward (reward-US) – in humans, money is considered a salient secondary US that has received its positive valence by cultural transmission. Participants were randomly allocated to the Counterconditioning (COUNTER) Group or the Extinction (EXT) Group. In both groups, two CS+ movements were followed by the pain-US, while two CS- movements were not followed by pain during fear acquisition. Then, one CS+ was extinguished, but another CS+ was still followed by pain in the EXT Group. In the COUNTER Group, one CS+ was followed by the reward-US (i.e. counterconditioning), and another CS+ was followed by both USs (i.e. competition). We hypothesized that: (a) counterconditioning is effective in reducing pain-related fear and (b) leads to deeper fear reduction than extinction, (c) a concurrent reward-US during a painful movement attenuates pain-related fear, (d) a concurrent reward-US attenuates intensity and

unpleasantness of a painful stimulus, (e) counterconditioning but not extinction renders the valence of the CSs more positive.

2. Methods

2.1. Participants

Fifty healthy individuals (21 males en 29 females; mean ± SD age = 23 ± 5.27 years) participated in this study and were reimbursed in two ways: (a) 3 first-year psychology students received 1.5 course credits, and (b) the 47 other volunteers received €12. Exclusion criteria were: pregnancy; past or current severe medical conditions, psychiatric disorders or chronic pain; having received the advice to avoid stressful situations from a GP; cardiac pacemaker or presence of any other medical device; acute pain or impairment at the dominant hand or wrist; uncorrected hearing problems. The study was approved by the Ethics Committee of the Faculty of Psychology and Educational Sciences of the University of Leuven (registration number: S-55375). All participants signed the informed consent form, which emphasized that they could withdraw from the study at any time. Participants were randomly assigned to one of the two experimental groups (EXT or COUNTER Group).

2.2.Stimulus material

Four proprioceptive stimuli (i.e. moving a Logitech Attack3 joystick upwards, downwards, to the left, and to the right) were used as CSs. Participants performed the movements by manipulating the joystick with their dominant hand. The first US was an electrocutaneous stimulus (duration of 2 ms), administered by a commercial stimulator (DS7A; Digitimer, Welwyn Garden City, England) through surface Sensormedics electrodes (8 mm) filled with K-Y gel which were attached to the wrist of the dominant hand. The pain-US intensity level was individually selected during a pre-experimental calibration procedure. During this procedure, participants received a series of pain-USs of increasing intensity.

After each stimulus presentation, they rated the intensity of that stimulus on a rating scale from 1 to 10, with 1 meaning, "*You feel something, but this is not painful; it is merely a sensation*"; up to 10, meaning, "*This is the worst pain you can imagine.*" Participants indicated if they did not want to receive a stimulus of higher intensity or if they wanted the intensity to be set back at a lower level, yet they were asked to do some effort to select a significantly painful and unpleasant stimulus. We targeted a pain-US of a subjective intensity of 8, which corresponds to a stimulus that is "*significantly painful and demanding some effort to tolerate*". During the entire experiment, the pain-US intensity remained unchanged. The second US we used was a monetary reward. The reward-US was represented by an €-symbol on the computer screen. Participants received written instructions explaining that the presentation of an €-symbol on the computer screen (i.e. reward-US) during a given trial represented an extra monetary profit of €0.50. In total the reward-US was presented on 32 trials in the COUNTER Group . That way participants in that group were led to believe they could earn a total amount of €16 in addition to the promised (financial) reimbursement.

2.3.Software

The entire experiment was run on a Windows XP computer (Dell Optiplex 755) with 2 GB RAM, an Intel Core2 Duo processor at 2.33 GHz and an ATI Radeon 2400 graphics card with 256 MB of video RAM. The experiment was programmed using the free software package Affect 4.0[49].

2.4.Procedure

This experiment was conducted during a 1-hour session using the Voluntary Joystick Movement (VJM) task[39] consisting of a preparation phase, a practice phase, an acquisition phase and a fear reduction phase (see Table 1). We used a between-subjects design comprising two experimental groups; participants were randomly allocated to either the

COUNTER Group or the EXT Group. During fear acquisition, all groups received a pain-US after two CS+ movements (A_1+ and A_2+), but not after two CS- movements (B_1- and B_2-). Note that the direction of joystick movement that served as CS+ and CS- was counterbalanced across participants (one in the CS+ and CS- in the horizontal plane, i.e. moving to the left/right, and one CS+ and CS- in the vertical plane, i.e. moving up/down). During the fear reduction phase in the EXT, one CS+ movement was no longer followed by the pain-US (A_2-), but a control CS+ movement was still followed by the pain-US (A_1+). The latter is a typical control stimulus for non-associative decreases in conditioned responding, i.e. habituation. In the COUNTER Group, one CS+ movement was followed by the reward-US (A_2-€; i.e. counterconditioning), and the other CS+ movement was followed by both the pain-US and the reward-US (A_1+€; i.e. competition). The prospect of the positive reward-US –and the resulting approach tendencies– compete with the negative pain-US –and the resulting avoidance tendencies–, therefore we refer to this movement as a "competition" trial. Experimental research on goal competition rendered inconsistent results so far, showing that adding a reward attenuated avoidance behavior/decision-making, although pain-related fear remained unaltered[8, 9]. In order to further our understanding about the effect of competing outcomes/motivations on pain-related fear and pain, we included this competition movement in the Counterconditioning Group. Note that the experimental procedure also included the placement of three facial electrodes and the presentation of auditory startle probes related to the measurement of fear-potentiated eyeblink startle. For the sake of readability and brevity, we decided to omit the description of the startle measure and all related aspects because of technical failure of this measurement rendering the data unreliable. For more information on the startle-related procedure used in this study, see Meulders et al.[39].

Preparation phase. Upon arrival at the laboratory, participants first filled out the checklist of exclusion criteria (see section "*2.1. Participants*"). In the framework of a separate

research question, the inhibitory capacity of the participants was measured using the Stop Signal Task (SST)[34] and the heart rate variability (HRV) protocol described by Smets et al.[47]. For the latter purpose, three electrodes were placed on the chest of the participant. When participants had completed the SST task, they received information (orally and in writing) about the use of short loud noises (startle probes) and painful electrocutaneous stimuli (pain-USs) during the experiment. They were told that the goal of the study was to investigate the effect of these distractors (loud noises and painful stimuli) on the performance of a motor task i.e. moving a joystick in different directions. After signing the informed consent form, the electrodes for administration of the pain-US were attached. Subsequently, the intensity level of the pain-US was selected using the aforementioned calibration procedure.

Practice phase. Participants received the written instructions of their main task on the computer screen (see online supplementary material for the verbatim instructions given before the practice and acquisition phase). They were requested to move the joystick to the left, right, upwards or downwards as quickly and accurately as possible after seeing the starting signal "+" (i.e. a fixation cross presented in the middle of the screen). The movement directions that were allowed were indicated by counter bars, each divided into four segments, presented respectively on the left, right, top and bottom of the screen (see Figure 1). The practice phase consisted of one block of 16 trials, that is, four movements in each direction. Participants could choose the order in which they performed the different movements themselves. When they performed the movement correctly, a segment of the corresponding counter bar was colored blue. This way, participants received feedback about how many movements in each direction still ought to be carried out. During the practice phase, valid target regions were colored green and invalid target regions red and visual feedback about the movement of the joystick was given by linking it to the movement of the cursor on the screen; if participants moved into the invalid target regions, an error message was shown, the trial was aborted

immediately, and a new trial started. During this phase, no pain-USs or reward-USs were presented. At the end of this phase, participants were asked to rate the retrospective affective valence of each movement using the Self-Assessment Manikin scale (SAM[6]).

Fear acquisition phase. The procedure in the fear acquisition phase was almost identical to the practice phase, except that (a) valid/invalid regions were no longer colored green/red and no on-screen error messages were given; (b) the movement of the joystick was no longer visualized by the path of the cursor on the screen; (c) pain-USs were delivered; and (d) this phase consisted of two blocks of 16 trials.

The duration of the CS movement itself depended upon the participants' movement speed. The intertrial interval (ITI) consisted of a pre-CS interval of 3.5 s, after which the starting signal appeared. This was followed by the movement and a post-CS interval of 8 ± 2 s. During each block, the participant was requested to perform each movement four times. Two movements (one in the horizontal, and one in the vertical plane) were always followed by a pain-US (CS+, i.e. A_1+ and A_2+), whereas the other two movements (one in the horizontal, and one in the vertical plane) were never followed by a pain-US (CS-; i.e. B_1- en B_2-). The pain-US was delivered immediately after the CS+ movements. Which movements served as the CS+ and CS- was counterbalanced across participants. After each conditioning block, pain-US intensity, pain-US unpleasantness, fear of movement-related pain, pain-US expectancy and reward-US expectancy were assessed via a rating scale shown on the computer screen (see section "*2.5. Measures*").

Fear reduction phase. This phase was different for the two groups. Participants underwent either an extinction or a counterconditioning phase. Each group received four blocks of 16 trials, in which each movement had to be performed four times. In the EXT Group, one CS+ movement was no longer followed by the pain-US (A_2-), while the other CS+ movement was still followed by the pain-US (A_1+). In the COUNTER Group, both CS+

movements were paired with the reward-US; one CS+ movement was no longer followed by the pain-US, but was followed by the reward-US alone (A_2-€), whereas the other CS+ movement (A_1+€) was followed by both the pain-US and the reward-US.

After each conditioning block, pain-US intensity, pain-US unpleasantness, fear of movement-related pain, pain-US expectancy and reward-US expectancy were assessed via a rating scale shown at the bottom of the computer screen. After this last phase, participants rated the retrospective affective valence of each movement on the SAM scale.

Questionnaires. Immediately after the experiment, participants completed four psychological trait questionnaires to control for individual differences in positive and negative affect (PANAS; the Positive and Negative Affect Schedule[23, 61]), fear of pain (FPQ; Fear of Pain Questionnaire[37, 45]), pain catastrophizing (PCS; Pain Catastrophizing Scale[50, 51]) and trait anxiety (STAI-T; trait version of the State-Trait Anxiety Inventory[48]), using a web survey tool. When the questionnaires were completed, participants were debriefed about the deception regarding the reward-US and remunerated for their participation. Note that in reality all participants were maximally paid €12 or received 1.5 course credits.

2.5.Measures

2.5.1. Self-reported measures

Fear of movement-related pain. After each conditioning block, participants were asked to answer to following question: "*How fearful were you to perform the left/right/upward/downward movement?*" on an 11-point Likert scale with the labels "not fearful at all" and "very fearful" at the extremes.

Concurrent pain-US and reward-US expectancy. At the end of each conditioning block, participants were asked to indicate for each movement how much they expected the pain-US and reward-US to occur on an 11-point Likert scale with labels "not at all" to "very much".

Pain intensity and pain unpleasantness. After each conditioning block, participants answered the questions "*How painful did you find the electrocutaneous stimulus in the previous block?*" and "*How unpleasant did you find the electrocutaneous stimulus in the previous block?*" on an 11-point Likert scale, with labels "not at all" and "very much" at the extremes.

Retrospective affective valence of the CSs. Before and after the experiment, the affective valence of the CS movements was measured using the Self-Assessment Manikin (SAM) scale[6], which consists of five pictographs of humanlike figures–Manikins. These Manikins gradually differ in emotional expression from happy to sad. Participants indicated the Manikin that matched best how they felt when performing the respective movements. Responses were scored from 1 to 5 (happy – sad).

2.6.Experimental setting

Participants were seated in an armchair (0.6 m screen distance) in a sound-attenuated and dimmed experimental room, adjacent to the experimenter's room. Further verbal communication was possible through an intercom system; the experimenter observed the participants by means of a closed-circuit TV installation.

2.7. Data analysis overview

A series of repeated measures ANOVAs were carried on the different dependent variables, followed by planned contrasts to further test our a priori hypotheses. Data from the practice phase were excluded from the statistical analyses. The α level was set at .05. In testing our a priori hypotheses, a Bonferroni correction was applied when using multiple planned comparisons. Greenhouse-Geisser corrections are reported when appropriate. Uncorrected degrees of freedom and corrected *p*-values are reported together with ε and the effect size indication, generalized eta squared, $\boldsymbol{\eta_g^2}$ [1, 31, 43] Statistical analyses for all dependent measures were conducted using Statistica 12 (StatSoft, Inc, Tulsa, OK).

3. Results

3.1. Descriptive characteristics pain-US and questionnaires

Overall, the selected pain-US intensity (mean ± SD) was 28.64 ± 15.12 mA (ranging from 8-68), participants rated this stimulus as a 8.18 ± 0.48 (ranging from 7-9); this score corresponds to a stimulus that is "painful and demands some effort to tolerate". There were no differences in the physical intensity of the pain-US chosen by the EXTGroup (29.12 ± 15.83 mA) and the COUNTER Group (28.16 ± 14.68 mA), $t(48) = -0.22$, $p = .83$. Furthermore, this stimulus was rated as equally painful in both the EXT Group (8.12 ± 0.44) and the COUNTER Group (8.24 ± 0.52), $t(48) = -0.88$, $p = .38$. Table 2, displays the questionnaire scores per group; independent *t*-tests revealed that there were no group differences with respect to these psychological trait questionnaires.

3.2.Manipulation checks

3.2.1. Acquisition effects

First, we checked whether we successfully induced fear of movement-related pain using separate 2 x 2 x 4 [Block (ACQ1-2) x Group (COUNTER/EXT) x Stimulus Type ($A_1/A_2/B_1/B_2$)] repeated measures ANOVAs on both the fear of movement-related pain ratings and the expectancy ratings. The analysis run on the fear of movement-related pain ratings (see Figure 2) revealed a significant main effect for Stimulus Type, $F(3,144) = 93.90$, $p < .0001$, $\varepsilon = 0.60$, $\eta_g^2 = .38$, and Block, $F(1,48) = 15.68$, $p < .001$, $\eta_g^2 = .02$. As expected there was no main effect for Group, $F < 1$, because during acquisition all groups received the same treatment. None of the other interactions with Group were significant, all *F*s < 1.59. Most importantly, there was a significant Stimulus Type x Block interaction, $F(3, 144) = 15.29$, $p <$

.0001, ε = 0.66, η_g^2 = .04, suggesting that differences in fear of movement-related fear between the different stimuli emerged across blocks. Within-group comparisons further showed that by the end of the acquisition phase, participants were more afraid of the painful A movements than of the non-painful B movements, EXT Group, $F(1, 48) = 63.10$, $p < .0001$, as well as COUNTER Group, $F(1, 48) = 63.10$, $p < .0001$. These results confirm that both groups learned to be more afraid of the movements that were followed by pain compared to the movements that were not followed by pain.

Second, a similar analysis was run on the pain-US expectancy ratings during acquisition (see Figure 3). This analysis showed significant main effect for Stimulus Type, $F(3,144) = 185.01$, $p < .0001$, ε = 0.54, η_g^2 = .66, and Block, $F(1,48) = 9.60$, $p < .01$, η_g^2 = .01. Again, as expected there was no main effect for Group, $F < 1$, and none of the other interactions with Group were significant, all *F*s < 1.41.The crucial Stimulus Type x Block interaction, $F(3, 144) = 19.41$, $p < .0001$, ε = 0.72, η_g^2 = 0.08, was significant indicating that pain-US expectancy ratings developed differently across blocks depending on stimulus type. Within-group comparisons further showed that by the end of the acquisition phase, participants expected the pain-US to occur more after the painful A movements than after the non-painful B movements, EXT Group, $F(1, 48) = 180.08$, $p < .0001$, as well as COUNTER Group, $F(1, 48) = 223.36$, $p < .0001$. The results of the US-expectancy ratings corroborate the data pattern observed in the fear of movement-related pain ratings and show that both groups learned to expect pain-US after the movements that were paired with the painful stimulus, but not after the movements that were not associated with the painful stimulus.

Third, we repeated this analysis for the reward-US expectancy ratings during acquisition (see Figure 4). This analysis yielded no significant main effects for Stimulus Type, Group, nor Block, all *F*s < 2.73. Because during the acquisition phase, no reward-USs were presented, no differences between groups or stimulus types are anticipated at this point.

Indeed, there was no significant Stimulus Type x Block interaction, $F(3, 144) = 1.66$, $p = .18$, $\varepsilon = 0.64$, $\eta_g^2 = .004$, and no significant three-way interaction, $F < 1$. These results confirm that both groups learned not to expect a reward-US after any of the movements..

3.2.2. Reward-US expectancy during the reduction phase

We conducted a 2 x 4 x 5 [Group (COUNTER/EXT) x Stimulus Type ($A_1/A_2/B_1/B_2$) x Block (ACQ2, RED1-4)] repeated measures ANOVA on the reward-US expectancy ratings during the reduction phase (see Figure 4). This analysis yielded significant main effects for Stimulus Type, $F(3, 72) = 117.16$, $p < .0001$, $\varepsilon = 0.61$, $\eta_g^2 = .41$, Block, $F(4, 96) = 10.65$, $p < .0001$, $\varepsilon = 0.55$, $\eta_g^2 = .04$, and Group, $F(1, 48) = 84.40$, $p < .0001$, $\eta_g^2 = .28$. There was a significant Stimulus Type x Block interaction, $F(12, 576) = 23.08$, $p < .0001$, $\varepsilon = 0.41$, $\eta_g^2 = .13$, indicating that the reward-US expectancy ratings increased during the reduction phase depending on stimulus type, and this effect was modulated by Group, $F(12, 576) = 25.67$, $p < .0001$, $\varepsilon = 0.41$, $\eta_g^2 = .14$. Further, also the Block x Group interaction, $F(4, 192) = 39.79$, $p < .0001$, $\varepsilon = 0.55$, $\eta_g^2 = .36$, and the Stimulus Type x Group interaction, $F(3, 144) = 88.91$, $p < .0001$, $\varepsilon = 0.61$, $\eta_g^2 = .34$, were significant. Planned comparisons further confirmed that reward-US expectancies increased significantly more for both A movements than for both B movements from the end of the acquisition phase to the end of the reduction phase in the COUNTER Group, $F(1, 48) = 141.25$, $p < .0001$, but not in the Extinction Group, $F < 1$. These results confirm that participants in the COUNTER Group learned to expect the reward-US after the movements that were paired with the reward, but not after movements that were not. This differential reward-expectancy learning was not observed in the EXT Group.

3.3.Can fear of movement-related pain be reduced using a counterconditioning procedure?

We conducted two separate 4 x 5 [Stimulus Type ($A_1/A_2/B_1/B_2$) x Block (ACQ2, RED1-4)] repeated measures ANOVAs on the fear and expectancy ratings of the COUNTER

group alone to test whether counterconditioning is an effective strategy to reduce fear of movement-related pain.

First, the analysis run on the fear of movement-related pain ratings (see Figure 2) yielded significant main effects of both Stimulus Type, $F(3,72) = 42.47$, $p < .0001$, $\varepsilon = 0.62$, $\eta_g^2 = .39$, and Block, $F(4, 96) = 12.21$, $p < .0001$, $\varepsilon = 0.62$, $\eta_g^2 = .05$. More importantly, there was a significant Stimulus Type x Block interaction, $F(12, 288) = 10.69$, $p < .0001$, $\varepsilon = 0.32$, $\eta_g^2 = .07$, indicating that over time the fear ratings evolved differently depending on stimulus type. Planned comparisons further confirmed that fear reported in response to the A_2 movement was significantly reduced as compared to the A_1 movement from the end of acquisition (ACQ2) to the end of the reduction phase (RED4), $F(1, 24) = 23.85$, $p < .0001$. Whereas participants showed similar levels of fear of movement-related pain at the end of acquisition to both pain-associated A movements, $F(1, 24) = 1.15$, $p = .29$, they reported significantly more fear in response to the A_1 movement than to the A_2 movement by the end of the reduction phase, $F(1, 24) = 23.61$, $p < .0001$. Moreover, at the end of the reduction phase, the previously painful A_2 movement did not elicit more fear than the non-painful B movements, $F(1, 24) = 4.59$, $p = .04$ (after Bonferroni corrections, this difference was no longer statistically significant; $p < .0125$). These results provide evidence for the hypothesis that counterconditioning (i.e. replacing a negative outcome by a positive outcome) significantly reduces fear of movement-related pain in response to a movement that was previously followed by pain.

Second, from a similar analysis on the pain-US expectancy ratings (see Figure 3) during the reduction phase significant main effects emerged for Stimulus Type, $F(3,72) = 138.44$, $p < .0001$, $\varepsilon = 0.56$, $\eta_g^2 = .70$, and Block, $F(4, 96) = 50.50$, $p < .0001$, $\varepsilon = 0.60$, $\eta_g^2 = .14$. More importantly, the Stimulus Type x Block interaction was significant, $F(12, 288) =$

24.41, p <.0001, ε = 0.35, η_g^2 = .26. Planned comparisons further confirmed that participants expected the pain-US to occur less after the A_2 movement than after the A_1 movement at the end of the reduction phase (RED4) as compared with the end of acquisition (ACQ2), $F(1, 24) = 71.84$, p <.0001. Although participants had similar pain-US expectancy ratings for both painful A movements at the end of acquisition, $F(1, 24) = 2.31$, p = .14, they reported significantly higher pain-US expectancies in response to the A_1 movement than to the A_2 movement by the end of the reduction phase, $F(1, 24) = 88.38$, p<.0001. Moreover, at the end of the reduction phase, the A_2 movement that was no longer followed by the pain-US did not elicit higher pain-US expectancy ratings than the non-painful B movements, $F(1, 24) = 5.19$, p =.03 (after Bonferroni corrections, this difference was no longer statistically significant; p < .0125). The results of the US-expectancy ratings mirror our findings in the fear of movement-related pain ratings, that is, the expectancy of the occurrence of the pain-US is significantly reduced for the counterconditioning movement.

3.4.Does counterconditioning lead to more profound fear reduction than extinction (i.e. omitting the pain-US) alone?

We conducted a series of 2 x 4 x 5 [Group (COUNTER/EXT) x Stimulus Type (A_1/A_2/B_1/B_2) x Block (ACQ2, RED1-4)] repeated measures ANOVAs on the fear and expectancy ratings to test whether counterconditioning is a more effective strategy to reduce fear of movement-related pain than extinction.

First, the analysis run on the fear of movement-related pain ratings (see Figure 2) showed significant main effects for Stimulus Type, $F(3,144) = 92.16$, p <.0001, ε = 0.67, η_g^2 = .39, and Block, $F(4, 192) = 21.28$, p <.0001, ε = 0.68, η_g^2 = .04, but not for Group, F < 1. Again, there was a significant Stimulus Type x Block interaction, $F(12, 576) = 18.78$, p <.0001, ε = 0.44, η_g^2 = .07, but this effect was not moderated by Group, three-way interaction:

$F < 1$. Basically, these results indicate that counterconditioning, and more specifically replacing the pain-US by a reward-US is as effective to reduce fear of movement-related pain as extinction alone (i.e. omitting the pain-US). Thus, we could not confirm any added value of the reward-US on *immediate* fear reduction.

Second, we ran a similar analysis on the pain-US expectancy ratings (see Figure 3). This analysis revealed main effects for Stimulus Type, $F(3,144) = 250.64$, $p < .0001$, $\varepsilon = 0.70$, $\eta_g^2 = .69$, and Block, $F(4, 192) = 50.51$, $p < .0001$, $\varepsilon = 0.72$, $\eta_g^2 = .10$, but not for Group, $F < 1$. Again, there was a significant Stimulus Type x Block interaction, $F(12, 576) = 47.16$, $p < .0001$, $\varepsilon = 0.47$, $\eta_g^2 = .24$, but this effect was not moderated by Group, three-way interaction: $F < 1$. In essence, these results indicate that counterconditioning is as successful to decrease pain-US expectancies as extinction alone. Hence, we could not confirm any added value of the reward-US on decreasing pain-US expectancy.

3.5.Does a concurrent reward-US attenuates pain-related fear of a painful movement?

We conducted a 2 x 4 x 4 [Group (COUNTER/EXT) x Stimulus Type ($A_1/A_2/B_1/B_2$) x Block (RED1-4)] repeated measures ANOVA on the fear of movement-related pain ratings to test whether a movement followed by competing outcomes (i.e. monetary reward-US = positive; pain-US = negative) elicits less fear than a movement that is followed by the pain-US alone. This analysis showed significant main effects for Stimulus Type, $F(3, 144) = 77.45$, $p < .0001$, $\varepsilon = 0.65$, $\eta_g^2 = .40$, and Block, $F(3, 144) = 16.70$, $p < .0001$, $\varepsilon = 0.63$, $\eta_g^2 = .03$, but not for Group, $F < 1$. There was a significant Stimulus Type x Block interaction, $F(9, 432) = 4.44$, $p < .0001$, $\varepsilon = 0.49$, $\eta_g^2 = .01$, indicating that fear of certain movements developed differently across blocks, but this effect was not modulated by Group, $F(9, 432) = 1.39$, $p = .23$, $\varepsilon = 0.49$, $\eta_g^2 = .004$. In contrast to what we expected, fear of movement-related pain was

not reduced in response to a "competition" movement that was followed by pain but also by a reward (i.e. both positive and negative outcomes).

3.6.Does a concurrent reward-US reduce the intensity and unpleasantness of a painful stimulus?

We conducted two separate 2 x 4 [Group (COUNTER/EXT) x Block (RED1-4)] repeated measures ANOVAs on the pain intensity and pain unpleasantness ratings (see Figure 5). The first analysis showed no significant main effects for Group nor Block, both *F*s < 1. The two-way interaction also failed to reach significance, $F(3, 144) = 1.45$, $p = .24$, $\varepsilon = 0.77$, $\eta_g^2 = .005$.

The analysis ran on the pain unpleasantness data largely corroborated the findings in the pain intensity ratings. No significant main effects of Group, $F < 1$, or Block, $F(3, 144) = 1.49$, $p = .23$, $\varepsilon = 0.81$, $\eta_g^2 = .004$, emerged. Also the two-way interaction failed to reach significance, $F < 1$. Taken together, the results indicate that pain unpleasantness and intensity was not reduced for the "competition" movement (followed by pain and reward) as compared to the movement that was only followed by pain. Thus, adding a reward to a painful movement does not seem to reduce pain intensity/unpleasantness.

3.7. Does counterconditioning but not extinction, render the valence of the CSs more positive?

We checked whether we successfully reduced the negative affective valence (see Figure 6) of the A_2 movement after the reduction phase using a 2 x 2 x 4 [Time (pre/post) x Group (COUNTER/EXT) x Stimulus Type ($A_1/A_2/B_1/B_2$)] repeated measures ANOVA. This analysis showed significant main effects for Time, $F(1,48) = 9.10$, $p < .01$, $\eta_g^2 = .02$, and Stimulus Type, $F(3, 144) = 19.27$, $p < .0001$, $\varepsilon = 0.90$, $\eta_g^2 = .08$, but not for Group $F(1, 48) = 1.83$, $p = .18$, $\eta_g^2 = .01$. Further there was a significant Time x Group interaction, $F(1, 48) =$

4.40, p <.05, η_g^2 = .41, as well as a significant Time x Stimulus Type, $F(3, 144) = 9.15$, p <.0001, ε = 0.85, η_g^2 = .05. Although, the three-way interaction was not significant, we further tested whether counterconditioning led to a stronger reduction of negative affective valence of the A_2 movement than extinction. Planned comparisons revealed the expected data pattern, that is, the affective valence of the A_2 movement was rated as more positive from pre to post in the Counterconditioning Group than in the Extinction Group, but the statistical test failed to reach significance, $F(1, 48) = 3.09$, p =.085. Taken together, these results only provide partial support for the hypothesis that counterconditioning changes the negative affective valence of a stimulus more than extinction alone does.

4. Discussion

Graded in vivo exposure therapy has a strong pedigree as one of the most potent cognitive-behavioral treatments to reduce disabling fear, and has recently been applied in chronic pain[2, 13, 17-20, 24, 32, 55, 56, 59]. A substantial proportion of patients do not remain symptom-free but demonstrate (partial) return-of-fear at some point after successful treatment[33]. An alternative fear reduction technique based on learning principles is counterconditioning, in which not only the harm expectancy but also the affective valence of a painful movement/activity is changed. This counterconditioning approach closely relates to cognitive-behavioral treatments that not only focus on pain reduction but aim to reintroduce values-based actions such as returning to work or engaging in social activities[7, 14, 52, 58]. Examples of such interventions focusing both on the pursuit of pain and normal life goals are motivational interviewing[28, 29], contextual cognitive-behavioral treatment[36, 46, 60] or treatments aimed at improving daily functioning despite pain while assisting patients to achieve valuable life goals (e.g., graded activity, exposure in vivo)[25, 32, 35].

The primary goal of this study was to compare counterconditioning and extinction as a method to reduce fear of movement-related pain. As secondary goal, we wanted to investigate the possible attenuating effects of a concurrent reward on pain-related fear as well as on intensity and unpleasantness of the painful stimulus.

Two possible mechanisms might contribute to hypothesized differences between counterconditioning and extinction[44]. The *first mechanism* is the reduction of uncertainty of the CS outcome. That is, when the CS after conditioning is paired with a positively valenced stimulus it is clear that the CS is now followed by another outcome (reward-US) that is opposite to the pain-US, whereas during extinction there is no stimulus following the CS, so disconfirmation of the original painful outcome is less clear. A *second mechanism* is that the presentation of an opposite US might facilitate the inhibition of the original pain-US memory representation. Hence, presenting a new, opposite US might be more efficient in the formation of a new CS representation than not presenting any US.

In the COUNTER Group, fear and pain-US expectancy ratings for the A_2 movement were significantly reduced as compared with those for the A_1 movement, confirming our *first hypothesis* that counterconditioning indeed is effective in reducing fear of movement-related pain. Interestingly, at the end of the reduction phase, the counter-conditioned A_2 movement did not elicit more fear or pain-US expectancy than the B movements, suggesting that counterconditioning rendered the A_2 movement completely safe.

In contrast with our *second hypothesis*, we could not confirm that counterconditioning leads to more profound (short-term) fear reduction than extinction. In the EXT Group, fear and pain-US expectancy ratings for the A_2 movement were also significantly lower than for the A_1 movement by the end of the fear reduction phase. Again, verbal ratings for the A_2 movement were not different from the B movements. These findings corroborate the results of

Raes and De Raedt[44] who observed no group differences in the fear and US-expectancy ratings, but did report differences in skin conductance between both procedures. Therefore, the lack of effects on the verbal measures might not be so surprising. Previous research indeed has shown that extinction itself is quite successful in reducing US-expectancy[42, 54] and self-reported fear[42]. Given that psychophysiological measures usually are more sensitive to pick up group differences, we expected the most pronounced effects in our eyeblink startle measure, which unfortunately was not reliable due to a technical failure. Based on previous studies using return-of-fear paradigms, it is plausible that the superiority of counterconditioning as a fear reduction method compared to extinction is not portrayed *immediately* but is rather expressed in lesser relapse in the future. This means that less *fear expression* at one moment (e.g. within-session habituation during exposure) does not necessarily relate to deeper *fear* extinction *learning* when tested at another moment (e.g. between-session habituation during exposure)[12]. Future research can test this intriguing hypothesis by adding a reinstatement phase to the current design.

No evidence was found to support our *third hypothesis*, that is, adding a reward-US to a painful movement did not attenuate pain-related fear. This finding is in line with a recent study demonstrating that offering a monetary reward does not decrease pain-related fear ratings[9]. In their study, Claes et al.[9] investigated the effect of competing goals on pain-related fear and avoidant decision making behavior; they used a slightly different operationalization of the approach-related US, namely they used lottery tickets as a proxy for possible monetary gain. More specifically, participants could earn lottery tickets when performing a painful movement (i.e. experimental group). With each earned lottery ticket, the odds of winning €50 at the end of the experiment increased. The results showed that offering a concurrent reward reduced avoidant decision-making; participants were less hesitant to perform painful movements. In contrast, self-reported fear of the CS+ movement in the experimental group

was not significantly lower than in the control group (receiving only a painful stimulus after the CS+).

Regarding our *fourth hypothesis*, we could not demonstrate an attenuating effect of the reward-US on the intensity or unpleasantness of the pain-US. A possible explanation may be that a concurrent reward-US can influence approach tendencies independent of altering the intensity and unpleasantness of the pain-US[53]. Given this post-hoc interpretation, future research should include response latencies as an additional outcome measure to map approach-avoidance tendencies and to determine whether response latencies are sensitive enough to render effects on actual behavior despite being afraid of the movements.

Finally, we found partial evidence in support of our *fifth hypothesis*, that is, the valence of the A_2 movement was borderline significantly more positive after counterconditioning than after extinction as compared with the beginning of the experiment. Adding a positively valenced reward-US to a previously painful movement seemed to have a different effect on evaluative conditioning than only extinguishing the fear of the painful movement, but this effect just failed to reach significance. This is in contrast with the findings of Kerkhof et al.[30], who demonstrated in a picture-taste paradigm that counterconditioning was able to change the negative valence of a picture compared to further conditioning and extinction trials which both were ineffective in eliminating the previously acquired picture evaluations. A possible explanation why our results diverge from those of Kerkhof et al. is that we used a more stringent definition of change in valence. In our study, the stimulus valence was measured before and after the entire experiment. Judgments made at the end of a complete experiment tend to be integrative[10]. This means that participants might have collapsed information of both the acquisition and the reduction phase when completing this rating. If this is the case, valence ratings for the A_2 movement might be contaminated with the negative stimulus valence that was acquired during acquisition and thus the change is valence might be underestimated.

Moreover, we did not assess the *negative stimulus valence* of the A_2 movement after acquisition, because procedural interruptions (e.g. intermediate questions that are not part of the procedure during acquisition) tend to cause *context changes,* which might affect extinction learning. Hence, we compared changes from *neutral stimulus valence* to *positive stimulus valence* from the beginning to the end of the experiment (pre-post measures). These procedural details together with a possible lack of statistical power might contribute to the absence of significant group differences.

Some limitations should be outlined as well. First, we could only rely on the verbal ratings, because the startle data were not reliable due to a hardware failure and we had no behavioral avoidance measure (e.g., response latencies) . These verbal ratings might not be sensitive enough to detect group differences. Second, using a 100% reinforcement scheme as we did, usually leads to rapid extinction because disconfirmation of the CS-US association occurs on the first trial that the CS+ is not followed by the pain-US. This might explain the lack of differences in counterconditioning and extinction learning. Moreover, a 100% reinforcement schema does not represent the clinical reality very well (i.e. sometimes certain movements increase pain in chronic pain patients, but sometimes they do not), and thus has limited ecological validity. Future research should use a partial reinforcement schedule. Third, the credibility of our manipulation of the positive reinforcer may have been limited. After debriefing, a small number of participants reported that they did not believe they would get more money when the reward-US was presented. Additionally, it is possible that the reward-US was not a strong incentive for all participants. Future research should assess the subjective appreciation of the reward post-experimentally to guide the search for more potent reward types.

To summarize, this study was the first to demonstrate fear of movement-related pain reduction using counterconditioning. However, we were unable to confirm that

counterconditioning leads to deeper fear reduction than extinction. However, we contend that procedures targeting not only the change of harm expectancy but also the change in affective valence of feared movements might offer a valuable approach to reduce fear of movement-related pain more profoundly and especially to prevent relapse.

5. Acknowledgments

The authors would like to thank Marijke Ruytings for her assistance in the data collection.

6. References

1. Bakeman R. Recommended effect size statistics for repeated measures designs. *Behav Res Methods.* 37:379-384, 2005

2. Boersma K, Linton S, Overmeer T, Jansson M, Vlaeyen J, de Jong J. Lowering fear-avoidance and enhancing function through exposure in vivo. A multiple baseline study across six patients with back pain. *Pain.* 108:8-16, 2004

3. Bouton ME. Context and ambiguity in the extinction of emotional learning: Implications for exposure therapy. *Behaviour Research and Therapy.* 26:137-149, 1988

4. Bouton ME. A learning theory perspective on lapse, relapse, and the maintenance of behavior change. *Health Psychology.* 19:57-63., 2000

5. Bouton ME. Context, ambiguity, and unlearning: sources of relapse after behavioral extinction. *Biological Psychiatry.* 52:976-986, 2002

6. Bradley MM, Lang PJ. Measuring emotion: The self-assessment manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychiatry.* 25:49-59, 1994

7. Christiansen S, Oettingen G, Dahme B, Klinger R. A short goal-pursuit intervention to improve physical capacity: a randomized clinical trial in chronic back pain patients. *Pain.* 149:444-452, 2010

8. Claes N, Crombez G, Vlaeyen JWS. Pain-avoidance versus reward-seeking: An experimental investigation. *Pain.* 156:1449-1457, 2015

9. Claes N, Karos K, Meulders A, Crombez G, Vlaeyen JWS. Competing Goals Attenuate Avoidance Behavior in the Context of Pain. *The Journal of Pain.* 15:1120–1129, 2014

10. Collins D, Shanks D. Momentary and integrative response strategies in causal judgment. *Memory & Cognition.* 30:1138-1147, 2002

11. Craske MG, Hermans D, Vansteenwegen D: *Fear and learning: From basic processes to clinical implications* American Psychological Association: Washington, DC, 2006.

12. Craske MG, Kircanski K, Zelikowsky M, Mystkowski J, Chowdhury N, Baker A. Optimizing inhibitory learning during exposure therapy. *Behav Res Ther.* 46:5-27, 2008

13. Craske MG, Wolitzky-Taylor KB, Labus J, Wu S, Frese M, Mayer EA, Naliboff BD. . A cognitive-behavioral treatment for irritable bowel syndrome using interoceptive exposure to visceral sensations. *Behav Res Ther.* 49:413-421, 2011

14. Crombez G, Eccleston C, Van Damme S, Vlaeyen JW, Karoly P. Fear-avoidance model of chronic pain: the next generation. *Clinical Journal of Pain.* 28:475-483, 2012

15. Crombez G, Eccleston C, Vlaeyen JW, Vansteenwegen D, Lysens R, Eelen P. Exposure to physical movements in low back pain patients: restricted effects of generalization. *Health Psychol.* 21:573-578, 2002

16. De Houwer J, Thomas S, Baeyens F. Association learning of likes and dislikes: A review of 25 years of research on human evaluative conditioning. *Psychological bulletin.* 127:853, 2001

17. de Jong JR, Vangronsveld K, Peters ML, Goossens MEJB, Onghena P, Bulté I, Vlaeyen, JWS. Reduction of pain-related fear and disability in post-traumatic neck pain: a replicated single-case experimental study of exposure in vivo. *J Pain.* 9:1123-1134, 2008

18. de Jong JR, Vlaeyen JW, Onghena P, Cuypers C, den Hollander M, Ruijgrok J. Reduction of pain-related fear in complex regional pain syndrome type I: the application of graded exposure in vivo. *Pain.* 116:264-275, 2005

19. de Jong JR, Vlaeyen JW, Onghena P, Goossens ME, Geilen M, Mulder H. Fear of Movement/(Re)injury in Chronic Low Back Pain: Education or Exposure In Vivo as Mediator to Fear Reduction? *Clin J Pain.* 21:9-17, 2005

20. de Jong JR, Vlaeyen JW, van Eijsden M, Loo C, Onghena P. Reduction of pain-related fear and increased function and participation in work-related upper extremity pain (WRUEP): Effects of exposure in vivo. *Pain.* 153:2109-2118, 2012

21. den Hollander M, de Jong JR, Volders S, Goossens ME, Smeets RJ, Vlaeyen JW. Fear reduction in patients with chronic pain: a learning theory perspective. *Expert Rev Neurother.* 10:1733-1745, 2010

22. Dirikx T, Hermans D, Vansteenwegen D, Baeyens F, Eelen P. Reinstatement of extinguished conditioned responses and negative stimulus valence as a pathway to return of fear in humans. *Learning and Memory,.* 11:549–554, 2004

23. Engelen U, De Peuter S, Victoir A, Van Diest I, Van Den Bergh O. Verdere validering van de Positive and Negative Affect Schedule (PANAS) en vergelijking van twee Nederlandstalige versies. [Further validation of the Positive and Negative Affect Schedule (PANAS) and comparison of two Dutch versions]. *Gedrag & Gezondheid: Tijdschrift voor Psychologie en Gezondheid.* 34:89-102, 2006

24. Flink IK, Nicholas MK, Boersma K, Linton SJ. Reducing the threat value of chronic pain: A preliminary replicated single-case study of interoceptive exposure versus distraction in six individuals with chronic back pain. *Behav Res Ther.* 47:721-728, 2009

25. Gatzounis R, Schrooten MG, Crombez G, Vlaeyen JW. Operant learning theory in pain and chronic pain rehabilitation. *Current pain and headache reports.* 16:117-126, 2012

26. Goubert L, Francken G, Crombez G, Vansteenwegen D, Lysens R. Exposure to physical movement in chronic back pain patients: no evidence for generalization across different movements. *Behav Res Ther.* 40:415-429., 2002

27. Hofmann W, De Houwer J, Perugini M, Baeyens F, Crombez G. Evaluative conditioning in humans: a meta-analysis. *Psychological bulletin.* 136:390, 2010

28. Jensen MP, Nielson WR, Kerns RD. Toward the development of a motivational model of pain self-management. *J Pain.* 4:477-492, 2003

29. Jones KD, Burckhardt CS, Bennett JA. Motivational interviewing may encourage exercise in persons with fibromyalgia by enhancing self efficacy. *Arthritis care & research.* 51:864-867, 2004

30. Kerkhof I, Vansteenwegen D, Baeyens F, Hermans D. Counterconditioning: an effective technique for changing conditioned preferences. *Experimental psychology.* 58:31, 2011

31. Lakens D. Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. *Frontiers in psychology.* 4, 2013

32. Leeuw M, Goossens ME, van Breukelen GJ, de Jong JR, Heuts PH, Smeets RJ, Koke AJ, Vlaeyen JWS. Exposure in vivo versus operant graded activity in chronic low back pain patients: Results of a randomized controlled trial. *Pain.* 138:192-207, 2008

33. Linton SJ, Boersma K, Jansson M, Overmeer T, Lindblom K, Vlaeyen JW. A randomized controlled trial of exposure in vivo for patients with spinal pain reporting fear of work-related activities. *European journal of pain (London, England).* 12:722-730, 2008

34. Logan GD, Schacar RJ, Tannock R. Impulsivity and inhibitory control. *Psychological Science.* 8:60-64, 1997
35. Macedo LG, Latimer J, Maher CG, Hodges PW, McAuley JH, Nicholas MK, Tonkin L, Stanton CJ, Stanton TR, Stafford R. Effect of motor control exercises versus graded activity in patients with chronic nonspecific low back pain: a randomized controlled trial. *Phys Ther.* 92:363-377, 2012
36. McCracken L: *Contextual Cognitive-Behavioral Therapy for Chronic Pain*, IASP Press: Seattle, 2005.
37. McNeil DW, Rainwater AJ. Development of the Fear of Pain Questionnaire--III. *Journal of behavioral medicine.* 21:389-410., 1998
38. Meulders A, Vandebroek N, Vervliet B, Vlaeyen JWS. Generalization gradients in cued and contextual pain-related fear: An experimental study in healthy participants. *Frontiers in Human Neuroscience.* 345, 2013
39. Meulders A, Vansteenwegen D, Vlaeyen JWS. The acquisition of fear of movement-related pain and associative learning: A novel pain-relevant human fear conditioning paradigm. *Pain.* 152:2460-2469, 2011
40. Meulders A, Vlaeyen JWS. Reduction of fear of movement-related pain and pain-related anxiety: An associative learning approach using a voluntary movement paradigm. *Pain.* 153:1504-1513, 2012
41. Meulders A, Vlaeyen JWS. The acquisition and generalization of cued and contextual pain-related fear: An experimental study using a voluntary movement paradigm. *Pain.* 154:272-282, 2013
42. Olatunji BO, Forsyth JP, Cherian A. Evaluative differential conditioning of disgust: A sticky form of relational learning that is resistant to extinction. *Journal of Anxiety Disorders.* 21:820-834, 2007
43. Olejnik S, Algina J. Generalized eta and omega squared statistics: measures of effect size for some common research designs. *Psychological methods.* 8:434-447, 2003
44. Raes AK, De Raedt R. The effect of counterconditioning on evaluative responses and harm expectancy in a fear conditioning paradigm. *Behav Ther.* 43:757-767, 2012
45. Roelofs J, Peters ML, Deutz J, Spijker C, Vlaeyen JW. The Fear of Pain Questionnaire (FPQ): Further psychometric examination in a non-clinical sample. *Pain.* 116:339-346, 2005
46. Schrooten M, Vlaeyen JW, Morley S. Psychological interventions for chronic pain: Reviewed within the context of goal pursuit. *Pain management.* 2:1-10, 2012
47. Smets E, Pappens M, Thayer JF, Van den Bergh O, Van Diest I: Interindividual differences in inhibitory control predict extinction of interoceptive fear. In: Psychophysiology, 2011, pp. 8.
48. Spielberger CD: *Manual for the state-trait anxiety inventory (STAI-Form Y)*, Consulting Psychology Press: Palo Alto, CA, 1983.
49. Spruyt A, Clarysse J, Vansteenwegen D, Baeyens F, Hermans D. Affect 4.0: A free software package for implementing psychological and psychophysiological experiments. *Experimental psychology.* 57:36, 2010
50. Sullivan MJ, Bishop SR, Pivik J. The pain catastrophizing scale: development and validation. *Psychol. Assess.* 7:524-532, 1995
51. Van Damme S, Crombez G, Bijttebier P, Goubert L, Van Houdenhove B. A confirmatory factor analysis of the pain catastrophizing scale: Invariant factor structure across clinical and non-clinical populations. . *Pain.* 96:319-324, 2002
52. Van Damme S, Crombez G, Eccleston C. Coping with pain: A motivational perspective. *Pain.* 139:1-4, 2008

53. Van Damme S, Van Ryckeghem DM, Wyffels F, Van Hulle L, Crombez G. No pain no gain? Pursuing a competing goal inhibits avoidance behavior. *Pain.* 153:800-804, 2012

54. Vansteenwegen D, Francken G, Vervliet B, De Clercq A, Eelen P. Resistance to extinction in evaluative conditioning. *Journal of Experimental Psychology: Animal Behavior Processes.* 32:71, 2006

55. Vlaeyen JW, de Jong J, Geilen M, Heuts PH, van Breukelen G. Graded exposure in vivo in the treatment of pain-related fear: a replicated single-case experimental design in four patients with chronic low back pain. *Behav Res Ther.* 39:151-166, 2001

56. Vlaeyen JW, de Jong J, Geilen M, Heuts PH, van Breukelen G. The treatment of fear of movement/(re)injury in chronic low back pain: further evidence on the effectiveness of exposure in vivo. *Clin J Pain.* 18:251-261, 2002

57. Vlaeyen JW, Linton SJ. Fear-avoidance model of chronic musculoskeletal pain: 12 years on. *Pain.* 153:1144-1147, 2012

58. Vlaeyen JWS, Crombez G, Linton SJ. The fear-avoidance model of pain: We are not there yet. Comment on Wideman et al. "A prospective sequential analysis of the fear-avoidance model of pain" [Pain, 2009] and Nicholas "First things first: reduction in catastrophizing before fear of movement" [Pain, 2009]. *Pain.* 146:222-222, 2009

59. Vlaeyen JWS, de Jong JR, Leeuw M, Crombez G: Fear reduction in chronic pain: graded exposure in vivo with behavioural experiments. In: Understanding and treating fear of pain.(Asmundson GJG, Vlaeyen JWS, Crombez G, Eds.), Oxford University Press, Oxford:, 2004.

60. Vowles KE, McCracken LM. Acceptance and values-based action in chronic pain: A study of treatment effectiveness and process. *Journal of Consulting and Clinical Psychology.* 76:397-407, 2008

61. Watson D, Clark LA, Tellegen A. Development and validation of brief measures of positive and negative affect: The PANAS Scales. *Journal of Personality and Social Psychology*47, 1988

62. Woods MP, Asmundson GJ. Evaluating the efficacy of graded in vivo exposure for the treatment of fear in patients with chronic back pain: a randomized controlled clinical trial. *Pain.* 136:271-280, 2008

7. Figure captions

Figure 1. Overview of the timing of an illustrative trial in **A.** the fear acquisition phase, and **B.** fear reduction phase in the Counterconditioning and the Extinction Group.

Figure 2. Mean (±SE) self-reported fear of movement-related pain per block (ACQ1-2, RED1-4) for the Counterconditioning Group and the Extinction Group separately.

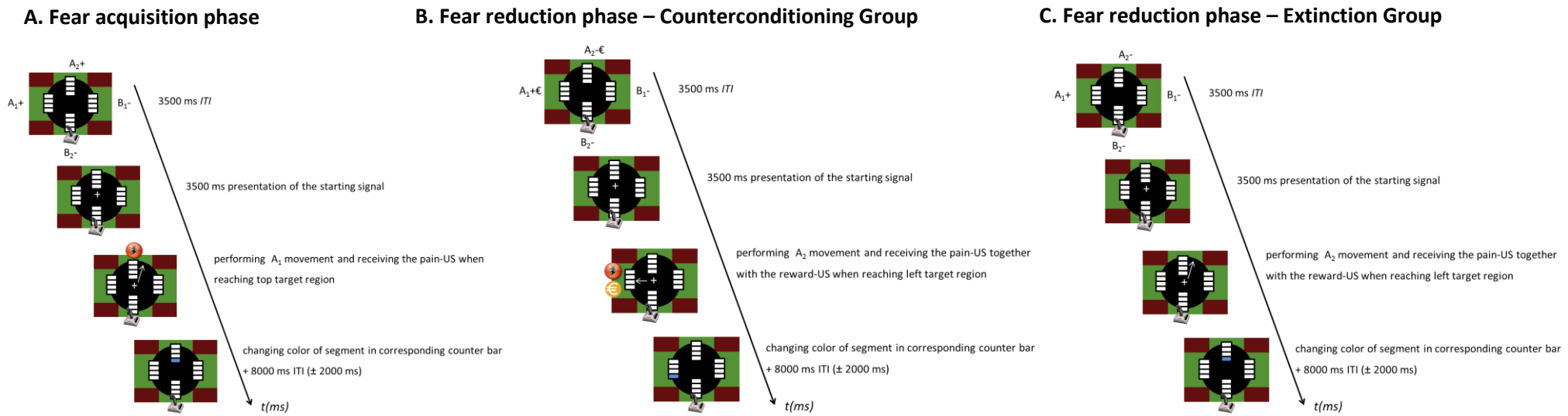
Figure 3. Mean (±SE) concurrent pain-US expectancy per block (ACQ1-2, RED1-4) for the Counterconditioning Group and the Extinction Group separately.

Figure 4. Mean (±SE) concurrent reward-US expectancy per block (ACQ1-2, RED1-4) for the Counterconditioning Group and the Extinction Group separately.

Figure 5. Mean (±SE) self-reported **A.** pain-US intensity, and **B**. pain-US unpleasantness per block (ACQ1-2, RED1-4) for both experimental groups (Counterconditioning/Extinction).

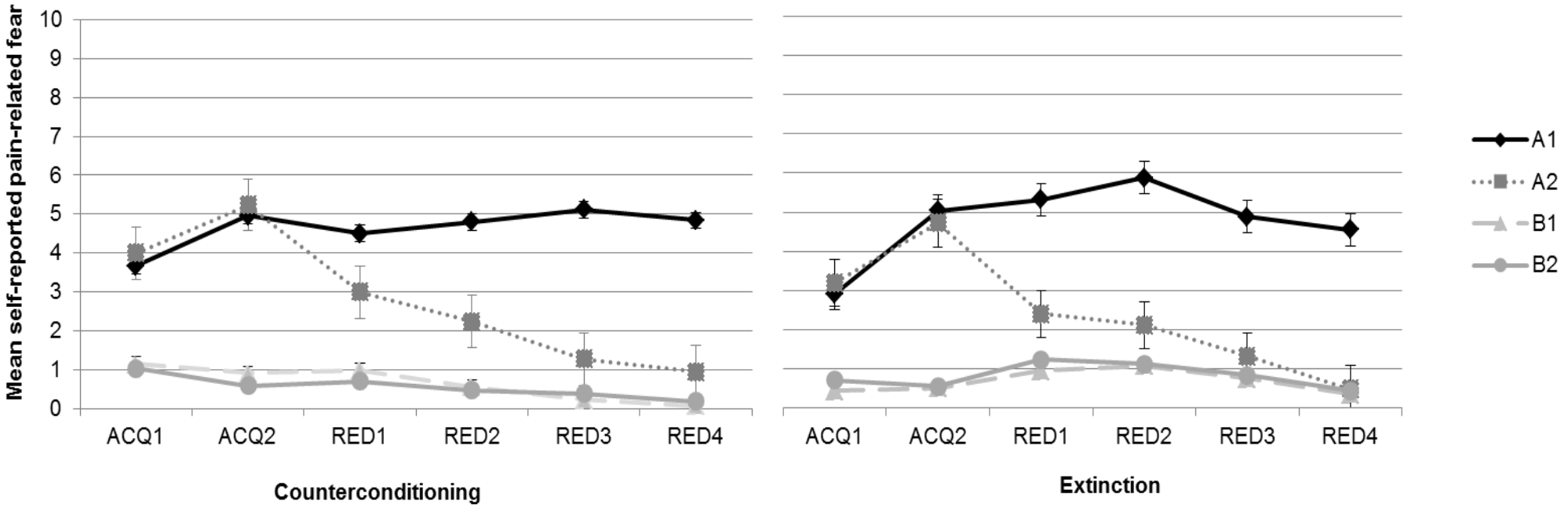
Figure 6. Mean (±SE) self-reported retrospective affective valence for all CS movements (A_1/A_2,/B_1/B_2) at the beginning (PRE) and at the end of the experiment (POST) for both experimental groups.

Figure 1.



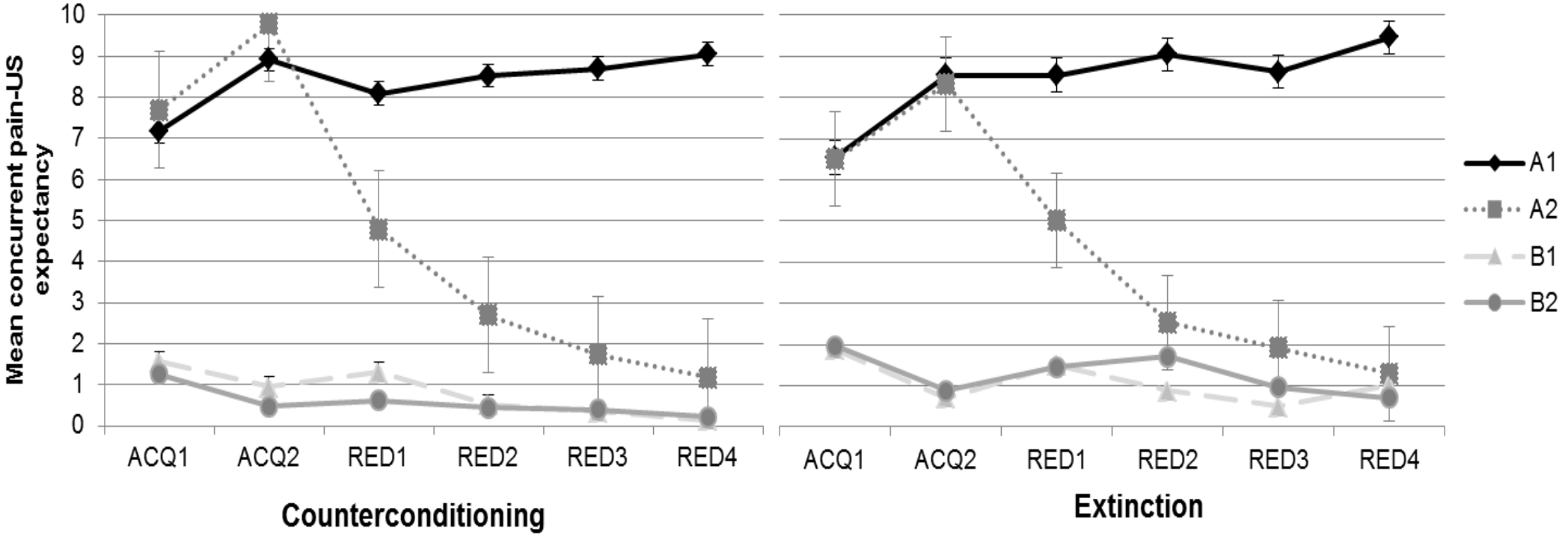
Note. The lightning bolt represents the presentation of the pain-US, the €-symbol represents the presentation of the monetary reward-US, the "+" serves as a starting signal to initiate the movement of choice, the white arrow represents the direction in which a participant moves on a certain trial, and the coloring blue of a segment of a certain counter bar indicates that a movement was successfully performed. During the fear acquisition phase, A_1 and A_2 were reinforced with the pain-US, but B_1 and B_2 were unreinforced. The acquisition phase was identical in both groups (panel A). During the fear reduction phase in the counterconditioning group (panel B), the A_1+€ movement (i.e. moving to the left) was followed both by the pain-US and the reward-US; the A_2-€ movement was followed by the reward-US but not by the pain-US (i.e. moving upward); B_1 and B_2 were unreinforced (i.e. moving to the right and downward). In the extinction group (panel C), the A_1+ movement continued to be followed by the pain-US, while the A_2- movement was extinguished (no longer followed by the pain-US).

Figure 2.



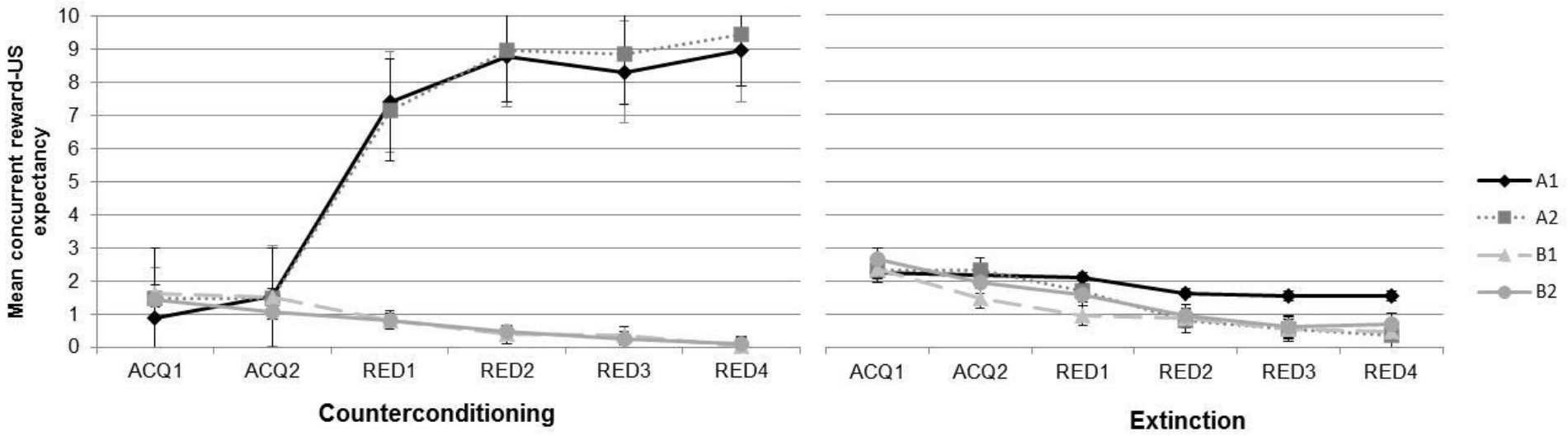
Note. 'ACQ' refers to the fear acquisition phase, whereas 'RED' refers to the fear reduction phase; the number refers to block. 'A' represents a reinforced movement, whereas 'B' indicates a non-reinforced movement. In both groups, both A_1 and A_2 were followed by a painful electrocutaneous stimulus (pain-US) during acquisition. In the fear reduction phase, A_1 was still followed by the pain-US, whereas A_2 was no longer followed by a pain-US in the Extinction Group. In the Counterconditioning Group, A_1 was both followed by the pain-US and the monetary reward (reward-US), whereas A_2 was followed by the reward-US alone. B_1 and B_2 were never followed by the pain-US, nor the reward-US.

Figure 3



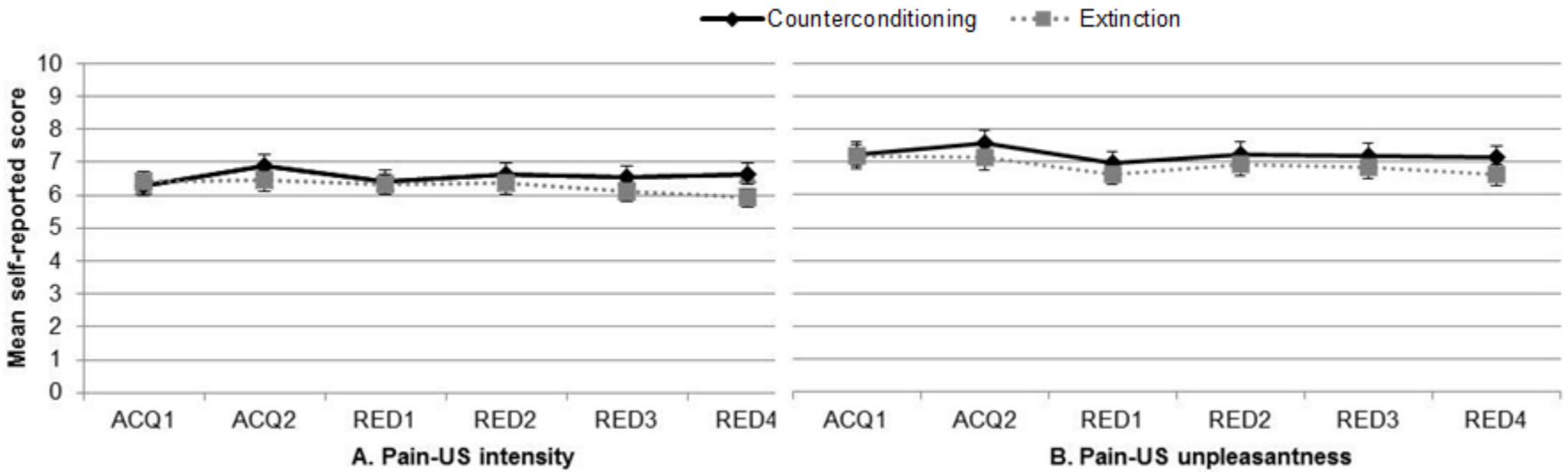
Note. 'ACQ' refers to the fear acquisition phase, whereas 'RED' refers to the fear reduction phase; the number refers to block. 'A' represents a reinforced movement, whereas 'B' indicates a non-reinforced movement. In both groups, both A_1 and A_2 were followed by a painful electrocutaneous stimulus (pain-US) in the acquisition phase. In the fear reduction phase, A_1 was still followed by a pain-US, whereas A_2 was no longer followed by a pain-US in the Extinction Group. In the Counterconditioning Group, A_1 was both followed by the pain-US and the monetary reward (reward-US), whereas A_2 was followed by the reward-US alone. B_1 and B_2 were never followed by the pain-US, nor the reward-US.

Figure 4.



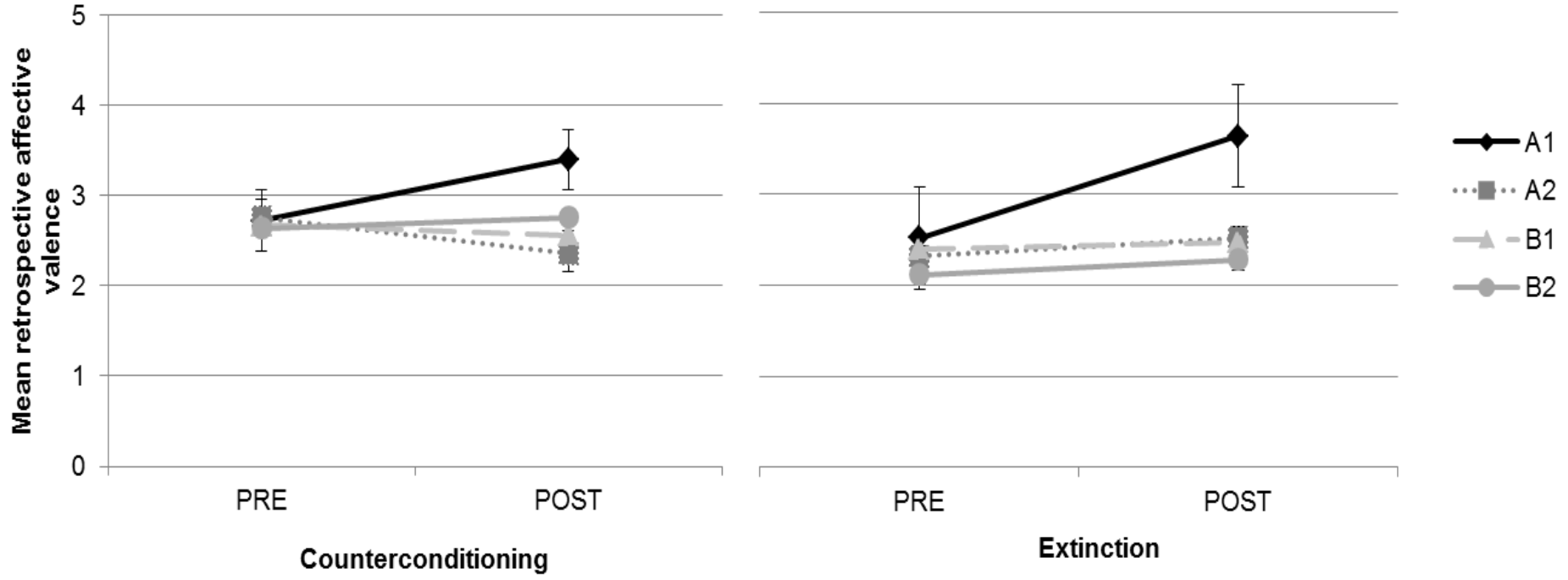
Note. 'ACQ' refers to the fear acquisition phase, whereas 'RED' refers to the fear reduction phase; the number refers to block. 'A' represents a reinforced movement, whereas 'B' indicates a non-reinforced movement. In both groups, both A_1 and A_2 were followed by a painful electrocutaneous stimulus (pain-US) in the acquisition phase. In the fear reduction phase, A_1 was still followed by a pain-US, whereas A_2 was no longer followed by a pain-US in the Extinction Group. In the Counterconditioning Group, A_1 was both followed by the pain-US and the monetary reward (reward-US), whereas A_2 was followed by the reward-US alone. B_1 and B_2 were never followed by the pain-US, nor the reward-US.

Figure 5.



Note - 'ACQ' refers to the fear acquisition phase, whereas 'RED' refers to the fear reduction phase; the number refers to block. In panel A, the pain-US intensity ratings can be found, and in panel B the pain-US unpleasantness ratings can be found for both the Counterconditioning Group and the Extinction Group.

Figure 6.



Note. 'PRE' indicates the rating at the beginning of the experiment, whereas 'POST' refers to the rating at the end of the experiment. 'A' represents a reinforced movement, whereas 'B' indicates a non-reinforced movement. In both groups, both A_1 and A_2 were followed by a painful electrocutaneous stimulus (pain-US) in the acquisition phase. In the fear reduction phase, A_1 was still followed by a pain-US, whereas A_2 was no longer followed by a pain-US in the Extinction Group. In the Counterconditioning Group, A_1 was both followed by the pain-US and the monetary reward (reward-US), whereas A_2 was followed by the reward-US alone. B_1 and B_2 were never followed by the pain-US, nor the reward-US.

Table 1

Experimental design

Group	Practice phase	Fear acquisition phase	Fear reduction phase
Counterconditioning			4 (4 A_1+€, 4 A_2-€, 4 B_1-, 4 B_2-)
	4 A_1, 4A_2, 4B_1, 4B_2	2 (4 A_1+, 4 A_2+, 4 B_1-, 4B_2-)	
Extinction			4 (4 A_1+, 4 A_2-, 4 B_1-, 4 B_2-)

Note. A = reinforced conditioned stimulus; B = unreinforced conditioned stimulus; During the practice phase, none of the movements were reinforced. In the fear acquisition and fear reduction phases, a "+" indicates that the movement was followed by a painful electrocutaneous stimulus (pain-US), a "-" indicates that the movement was not followed by the pain-US. In the fear reduction phase, a "€" indicates that a movement was followed by the monetary reward (reward-US).

Table 2. *Descriptive statistics and independent samples T-tests for the questionnaires scores, the HRV data and the SST data of both the Counterconditioning Group (n = 25) and the Extinction Group (n = 25) separately.*

Total	Counterconditioning	Extinction		
N = 50	*M* (*SD*)	*M* (*SD*)	*t*(48)	*p*
Age	23.32 (5.11)	22.48 (5.50)	-0.56	.578
Pain-US (in mA)	28.16 (14.68)	29.12 (15.83)	-0.22	.825
Self-reported pain-US intensity (ranging from 1-10)	8.12 (0.44)	8.24 (0.52)	-0.88	.384
FPQ – total	68.32 (9.04)	66.68 (15.01)	-0.47	.642
FPQ – medical pain	21.68 (4.88)	20.96 (6.54)	-0.44	.661
FPQ – minor pain	15.16 (3.98)	16.52 (4.18)	1.18	.245
FPQ – severe pain	31.48 (4.96)	29.20 (7.68)	-1.25	.220
PCS – total	15.72 (8.42)	15.52 (7.37)	-0.09	.929
PCS – magnification	3.16 (2.41)	2.92 (2.33)	-0.36	.722
PCS – rumination	7.00 (3.67)	7.48 (3.34)	0.48	.631
PCS – helplessness	5.56 (3.90)	5.12 (2.92)	-0.45	.653
PANAS – negative affect	19.12 (5.56)	19.00 (5.68)	-0.08	.940
PANAS – positive affect	33.96 (6.01)	35.04 (4.08)	0.74	.461
STAI-T – total	39.12 (8.77)	36.16 (9.67)	-1.14	.261
HRV – RMSSD	58.97 (41.92)	69.34 (57.09)	0.71[a]	.483
SST – SSRT	220.74 (53.08)	236.95 (48.85)	1.09[a]	.282

Note. FPQ= Fear of Pain Questionnaire; PCS= Pain Catastrophizing Scale; PANAS= Positive and Negative Affect Schedule; STAI-T= Trait version of the State-Trait Anxiety Inventory; HRV= Heart Rate Variability; RMSSD = Root Mean Square of Successive Differences; SST = Stop Signal Task; SSRT = Stop Signal Reaction Time. *M* = mean, *SD* = standard deviation. *t* = Student's *t* statistic; df = degrees of freedom.

[a] df = 45

Online Supplementary Material

INSTRUCTIONS BEFORE THE PRACTICE PHASE

Screen 1

Dear participant,

Your task in this experiment is to move a joystick a number of times to the left, to the right, upwards and downwards. The experiment consists of several movement blocks, and each block comprises 16 movements (i.e. 4 in each movement direction). You can chose the order in which you perform these movements yourself. Counter bars will appear on the left, right, top and bottom of the computer screen and each time you perform a movement correctly, a segment of the corresponding counter bar will color blue. In other words, if you move to the left, a segment of the left counter bar will be colored blue, and when you move to the right a segment of the right counter bar will be colored blue, and so on. This way, you will get visual feedback about the number of movements that still need to be carried out in each movement direction per block.

Screen 2

Please note that you can only start moving the joystick when a start signal, i.e. fixation cross '+' appears in the middle of the screen. You suppose to respond as quickly and accurately as possible once this start signal appears.

Before the actual experiment starts, you will go through a practice phase in which we will provide you with extra feedback about your movement performance. In this phase, you will get extra visual support to teach you what a valid/correct movement to the left/right/top/bottom exactly is.

The valid movement areas are colored green on the screen, whereas invalid movement areas are colored red on the screen. In addition, you will able to track your own movement in real-life via the cursor on the screen. When you use the joystick properly/accurately, and the cursor enters the green area, a segment of the corresponding counter bar will be colored blue. When the segments of all counter bars are colored blue, a new movement block will start.

Screen 3

Beware to keep your hand on the joystick at all times! If you have any questions or if you do not completely understand the instructions, please notify the experimenter now.

INSTRUCTIONS BEFORE THE EXPERIMENTAL PHASES

Screen 1

Now the actual experiment will start. We briefly repeat your task.

In each movement block, you will have to move 4 times to the left, 4 times to the right, 4 times upwards, and 4 times downwards as quickly and accurately as possible. You can chose the order in which you perform these movements yourself, but make sure to wait until the start signal, i.e. a fixation cross '+' appears in the middle of the screen before starting to move the joystick. Beware to keep your hand on the joystick at all times!

Screen 2

Each time you perform a correct movement, a segment of the corresponding counter bar will be colored blue. That way, you can assess how many movements in each direction still need to be carried out.

From now on, there are a couple of important changes in the procedure. First, you will not be able to track your own movement on the computer screen: the cursor will be hidden. Second, the green/valid and red/invalid areas will no longer be indicated: the background color of the screen will be black. Third, during the experiment short loud noises and electrical stimuli and rewards can be presented. If you receive a reward, a € symbol will be presented on the computer screen. Every time this symbol is presented your (financial) compensation at the end of the experiment will increase with 50 cents.

Screen 3

At the end of a movement block, we will ask you a couple of questions about how you experienced these electrical stimuli and the movements that you performed. You can answer these questions by moving cursor with the joystick along the rating scale and click on the "shooting button" of the joystick to confirm your answer. If you have any questions or if you do not completely understand the instructions, please notify the experimenter now.