No differences in return of pain-related fear after extinction and counterconditioning

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Abstract

Extinction-based protocols such as exposure-in-vivo successfully reduce pain-related fear in chronic pain conditions, but return of fear and clinical relapse often occur. Counterconditioning is assumed to attenuate return of fear, likely through changing the negative affective valence of the conditioned stimulus (CS). We hypothesized that counterconditioning would outperform extinction in mitigating return of pain-related fear, and decrease CS negative affective valence. Healthy participants performed a conditioning task, in which two joystick movements (CSs+) were paired with a painful electrocutaneous stimulus (unconditioned stimulus; pain-US), whereas two other movements (CSs-) were not. Subsequently, in the extinction group, one CS+ was extinguished (pain-US omission) and the other not, whereas in the counterconditioning group, one CS+ was presented with a US of opposite valence (reward-US) and the other was paired with both USs. We tested reinstatement of pain-related fear after two unsignalled pain-US presentations. Results showed no group differences in fear reduction and no differences in CS affective valence changes between the extinguished and counterconditioned CS. Remarkably, none of the groups showed reinstatement. Overall, counterconditioning did not appear to be more effective than extinction in reducing pain-related fear and its return.

Keywords: extinction, counterconditioning, pain-related fear, reinstatement, return of fear

Introduction

Ample evidence confirms that fear of movement-related pain can be acquired through classical conditioning (Meulders, 2020). As a salient biological warning signal, pain can be considered an unconditioned stimulus (US) eliciting protective responses (e.g., fear and escape; Meulders, 2020; Vlaeyen, 2015). After (repeated) pairings with pain, initially neutral movements (conditioned stimuli; CSs) may come to signal pain and elicit fear themselves (conditioned response; CR) (Meulders, 2020). Learning to predict pain is adaptive and enables one to take protective action, but when pain becomes chronic, and thus a false alarm, continued fear and avoidance may compromise daily functioning (Vlaeyen, 2015).

Subsequently, conditioned fear of movement-related pain can be reduced using *Pavlovian extinction*, that is, presenting the CS+ without the pain-US (Meulders, 2020). Exposure-in-vivo is the clinical analogue of extinction (Vervliet, Craske, & Hermans, 2013), and the gold standard to tackle catastrophic harm expectancies that underlie chronic pain disability (e.g. if I lift a crate, my spine will snap; den Hollander et al., 2010). Exposure has been proven effective for chronic pain (e.g., Glombiewski et al., 2018), but relapse often occurs, leaving room for improvement.

Full-blown relapse may follow the post-extinction return of fear (Bouton, 2002; Vervliet et al., 2013). Contemporary learning theory conceptualises extinction not as “unlearning” the original CS-US association, but as learning a new (CS-noUS) association that inhibits the retrieval and behavioural expression of the former (Bouton, 2002). Extinction is context-dependent and therefore fragile; release from inhibition may thus lead to return of fear (Bouton, 2002). Unexpected encounters with the US, e.g. when a person with chronic pain experiences a pain flare-up after successful treatment, is one mechanism that may make fear re-emerge (*reinstatement;* Bouton, 2002; Haaker, Golkar, Hermans, & Lonsdorf, 2014; Meulders, 2020).

An alternative procedure to reduce fear is *counterconditioning*, which involves pairing the CS+ with a US of opposite valence (Keller, Hennings, & Dunsmoor, 2020). Counterconditioning is thought not only to reduce US-expectancy, but also change the CS affective valence (Engelhard, Leer, Lange, & Olatunji, 2014; Hermans, Vansteenwegen, Crombez, Baeyens, & Eelen, 2002). Residual CS negative valence presumably underlies the return of fear (Dirikx, Hermans, Vansteenwegen, Baeyens, & Eelen, 2004). Therefore, reducing CS negative valence may also reduce return of fear. There is some experimental evidence for attenuated return of fear after counterconditioning compared to extinction (Kang, Vervliet, Engelhard, van Dis, & Hagenaars, 2018), though opposite findings have also been reported (van Dis, Hagenaars, Bockting, & Engelhard, 2019).

One study to date has compared extinction and counterconditioning in reducing fear of movement-related pain (Meulders, Karsdorp, Claes, & Vlaeyen, 2015). In that study, participants performed a conditioning task, in which two joystick movements (CSs+) were associated with the pain-US, whereas two others (CSs-) were not. Subsequently, one CS+ was extinguished, i.e. the pain-US was omitted, or counterconditioned, i.e. followed by monetary reward (between-subjects). No differences between extinction and counterconditioning were observed at immediate test, but the authors suggested that such differences may manifest after return of fear manipulations (cf. Dirikx et al., 2004; Kang et al., 2018) Therefore, the present study aimed to compare reinstatement of fear of movement-related pain after extinction and counterconditioning. Using an adjusted version of the Voluntary Joystick Movement paradigm of Meulders and colleagues (2015) we tested whether counterconditioning would generate (1) less reinstatement of fear of movement-related pain, and (2) larger decrease in CS negative valence compared to extinction.

Methods

Participant

Seventy-four healthy adults were randomly allocated to the Extinction (EXT; *n*=39) or the Counterconditioning (COUNTER; *n*=35) group. Sample size was larger compared to the previous study of Meulders et al. (2015), in order to account for the additional experimental phase of reinstatement, and sufficed for the detection of a moderate-to-large effect, as calculated with G*Power 3.1.9.2 (Faul, Erdfelder, Lang, & Buchner, 2007). Six participants were excluded (5 due to technical problems, 1 was later revealed to meet exclusion criteria), leaving 68 participants (EXT: *n*=36; COUNTER: *n*=32) for statistical analyses. Participants were recruited via the KU Leuven online recruitment system, advertisements, and word-of-mouth. Exclusion criteria were: pregnancy; acute pain or impairment at the dominant hand/wrist; presence of cardiac pacemaker or other medical device; uncorrected hearing problems; past or current severe medical conditions, psychiatric disorders or chronic pain; and medical advice to avoid stressful situations. The Social and Societal Ethics Committee of the KU Leuven approved the study protocol (G-201512426).

Stimulus material

Conditioned stimuli (CSs) were four proprioceptive stimuli, namely moving an Attack™ 3 Joystick (Logitech International S.A., Lausanne, Switzerland) upward, downward, to the left, and to the right. One movement in the vertical plane and one in the horizontal plane were the CSs+ (counterbalanced across participants). The other movements were the CSs-. The *painful unconditioned stimulus* (pain-US) was a 2-ms square-wave electrocutaneous stimulus generated by a DS7A constant current stimulator (Digitimer Limited, Hertfordshire, UK) and delivered on

the dominant wrist via two 0.8mm Ag/AgCl surface electrodes (SensorMedics Corp., Yorba Linda, CA, USA) filled with K-Y gel (Johnson & Johnson, New Brunswick, NJ). Pain-US intensity was individually calibrated to be "significantly painful and demanding some effort to tolerate", according to the procedure of Meulders et al. (2015). The mean physical intensity was 31.1mA (*SD*=20.6, range=8.0-99.9), and corresponded to a self-reported intensity of 8.1 (*SD*=0.3, 8-9) on the 0-10 pain calibration scale. There were no group differences in either the physical, $F(1, 66) = 0.13$, $p = .724$, or the self-reported pain-US intensity, $F(1, 66) = 1.06$, $p = .308$, as these were rated at the end of the calibration phase. The *reward-US* was an image of two lottery tickets, increasing the chance to win a prize of approximate value of €100. At the start of the study, participants were told that they had already received ten lottery tickets merely by participating, but that they would have the opportunity to win more lottery tickets throughout the experiment, thus increasing their chance of winning. To increase reward-US motivation, participants selected their prize of choice from a pre-set list (cf. Claes, Crombez, Meulders, & Vlaeyen, 2016; Claes, Crombez, & Vlaeyen, 2015).

Measures

We assessed *fear of movement-related pain* by asking "To what extent were you afraid to perform the left/right/upward/downward movement?", and *pain-US expectancy* by asking "To what extent did you expect an electrical stimulus when you moved the joystick to the left/right/upward/downward?". Participants responded on an 11-point Likert scale ranging from "not at all" to "very much". Furthermore, we assessed *CS valence* with the affective valence subscale of the Self-Assessment Manikin (Bradley & Lang, 1994) scale, accompanied by the question "How did you feel during moving the joystick to the left/right/upward/downward?".

Participants responded on the 5-point scale, with anchors “very happy” and “very unhappy”, and the middle point labelled as “neutral”. As a manipulation check, we assessed *reward-US expectancy* with the question “To what extent did you expect a lottery ticket when moving the joystick to the left/right/upward/downward?”, on an 11-point Likert scale ranging from “not at all” to “very much”. Participants rated fear of movement-related pain, pain-US and reward-US expectancy at the end of each block of 16 trials, and CS valence at the end of each experimental phase (see *Procedure*). Furthermore, participants filled in online (LimeSurvey Project Team & Schmitz, 2012) a series of *psychological trait questionnaires* assessing fear of pain (Fear of Pain Questionnaire-III; McNeil & Rainwater, 1998; Roelofs, Peters, Deutz, Spijker, & Vlaeyen, 2005), pain catastrophizing (Pain Catastrophizing Scale; Sullivan, Bishop, & Pivik, 1995; Van Damme, Crombez, Bijttebier, Goubert, & Van Houdenhove, 2002), positive and negative affect (Positive and Negative Affect Schedule; Engelen, De Peuter, Victoir, Van Diest, & Van Den Bergh, 2006; Watson, Clark, & Tellegen, 1988), and trait anxiety (State-Trait Anxiety Inventory, trait version; Spielberger, 1983; Van der Ploeg, 1980), to map potential group differences and ensure successful randomization.

Procedure

Participants performed an adapted version of the Voluntary Joystick Movement (VJM) task (see *Figure 1*) used by Meulders et al. (2015), with the following methodological improvements. *First,* we used a partial reinforcement schedule, preventing rapid extinction, likely allowing potential differences in the speed or magnitude of fear reduction to materialize. *Second,* we used a personally relevant reward-US, in order to increase its motivational value. *Third,* we assessed CS valence more frequently, in order to gain a better understanding of its changes across time.

The task consisted of the following phases: practice, fear acquisition, fear reduction, reinstatement, and test.

Participants were told that the experiment regarded the effects of distractors on motor performance, and were tested individually in a session lasting approximately 2 hours. The lab session also included assessments of inhibitory capacity, in the context of a separate research question not further discussed. For the part that is of interest here, exclusion criteria were checked by means of self-report and participants provided informed consent. Subsequently, the experimenter attached electrodes for the administration of the pain-US and the measurement of the eyeblink startle reflex. Due to technical problems that rendered the startle measurement unreliable, however, we omit it from the description of the procedure and results.

Pain-US and reward-US selection. The pain-US intensity was individually determined (see *Stimulus material*), and participants selected their preferred prize from a pre-set list. Participants received 10 lottery tickets at the start of the experiment. Although only COUNTER group participants received additional lottery tickets during the experiment, in reality this did not affect their chance of winning (cf. Claes et al., 2015).

Practice. To get familiarized with the task, participants performed 16 joystick movements (4 in each direction). A counter bar divided into four segments was presented at each of four locations (top, bottom, left and right) on a black background, providing visual feedback about the number of movements participants were required to perform in each direction (upward, downward, to the left and to the right, respectively). Each trial began with a pre-CS intertrial interval (ITI) of 5000ms, followed by a white cross presented in the middle of the screen, probing the start of the joystick movement. Participants moved as fast and accurately as possible, in the direction of their choice. The cross remained on the screen until movement onset. Upon

movement completion, one of the counter bar segments at the corresponding location turned blue, and a post-CS ITI of 5000ms started. During practice, performance feedback was provided. First, the joystick cursor was shown, visualizing the movement. Second, the valid movement regions were coloured green, whereas the invalid ones were coloured red. Third, the experimenter provided oral feedback. No pain-US or reward-US was presented.

Fear acquisition. This phase (3 blocks of 4 movements in each direction) was the same as practice, apart from the following. *First*, two movements (one in the horizontal and one in the vertical plane; counterbalanced) were followed by a pain-US, thus serving as CSs+ ($CS+_1$ and $CS+_2$). The pain-US was administered upon movement offset on 75% of CSs+ trials. The other two movements were never followed by a pain-US, thus serving as CSs- ($CS-_1$ and $CS-_2$). The $CS-_1$ was in the same movement plane as $CS+_1$, whereas the $CS-_2$ was in the same movement plane as the $CS+_2$. *Second*, there was a pre-CS ITI of 5000ms and a post-CS ITI of 9000ms.

Fear reduction. This phase comprised 4 blocks of 4 movements in each direction, differing for the two groups. For the EXT group, one CS+ was extinguished (i.e., pain-US omitted; $CS+_1$), whereas the other one ($CS+_2$) remained 75% reinforced. For the COUNTER group, one CS+ was counterconditioned (i.e., 75% reinforced with the reward-US; $CS+_1$), whereas the other one ($CS+_2$) was followed by both USs on 75% of the trials. $CS-_1$ and $CS-_2$ were never reinforced.

Reinstatement. On the 2000^{th} and the 12000^{th} ms of the first ITI after fear reduction, and whilst the counter bars were still visible, participants received two unsignalled pain-USs. No joystick movements were made during this phase (total duration=14000ms).

Test. Participants performed 4 movements in each direction, with the same reinforcement schedule as during fear reduction.

After the experiment, participants completed the psychological trait questionnaires and were debriefed about the lottery manipulation. Full debriefing occurred upon completion of data collection.

Statistical analyses

For sample characteristics, we computed descriptive statistics and compared the two groups by means of a series of ANOVAs and χ^2-tests. For manipulation checks, we report planned contrasts on reward-US expectancy, and fear acquisition and reduction, which are prerequisites to investigate return of fear. We also report planned contrasts for our main hypotheses that counterconditioning reduces (1) differential fear reinstatement, and (2) negative CS valence compared to extinction. To correct for multiple testing, we applied Holm-Bonferroni correction. For the sake of completeness, we also performed a series of Repeated Measures (RM) ANOVAs with group as between-subjects factor, and block and stimulus as within-subjects factors. The full ANOVA results are in line with these of the planned contrasts, and can be found in the supplementary material. Analyses were performed with SPSS 24.0 (IBM, Armonk, NY: IBM Corp).

Results

Sample characteristics

The two groups did not differ in sex ratio, mean age, or mean questionnaire scores (see Table 1).

Manipulation checks

Reward-US expectancy. Figure 2 indicates that the COUNTER group expected the reward-US more for the CSs+ and less for the CSs-, whereas the EXT group reported low reward-US expectancies for all CSs throughout the fear reduction phase. Planned comparisons confirmed that at the end of the reduction phase, COUNTER group participants expected a reward-US more than the EXT group participants after the two CSs that were indeed followed by the reward-US, i.e. the $CS+_1$, $\Delta_{CS+1 \text{ at } RED4(COUNTER-EXT)} = 5.8$, 95%CI [4.7, 7.0], $t(65.72) = 10.25$, $p < .001$, and the $CS+_2$, $\Delta_{CS+2 \text{ at } RED4(COUNTER-EXT)} = 5.8$, 95%CI [4.5, 7.1], $t(48.02) = 8.87$, $p < .001$. As expected, the two groups reported similar reward-US expectancy for the $CS-_1$, $\Delta_{CS-1 \text{ at } RED4(COUNTER-EXT)} = -1.0$, 95%CI [-2.05, 0.04], $t(58.85) = -1.92$, $p = .60$, and the $CS-_2$, $\Delta_{CS-2 \text{ at } RED4(COUNTER-EXT)} = -0.2$, 95%CI [-1.3, 1.0], $t(66) = -0.28$, $p = .780$. Thus, COUNTER, but not EXT, participants expected a reward-US after the CSs+, indicating that our manipulation was successful.

Fear acquisition. Figure 3 suggests that throughout the acquisition phase, fear of movement-related pain and pain-US expectancy increased for the two CSs+, but remained stably low for the two CSs-. For *fear of movement-related pain* (Figure 3a), planned contrasts confirmed that, at the end of the acquisition phase, participants of both groups were more afraid of $CS+_1$ compared to the $CS-_1$, EXT: $\Delta_{CS+1–CS-1} = 3.0$, 95%CI [2.0, 4.0], $t(35) = 6.02$, $p < .001$; COUNTER: $\Delta_{CS+1–CS-1} = 2.5$, 95%CI [1.4, 3.6], $t(31) = 4.57$, $p < .001$. In addition, both groups reported more fear for the $CS+_2$ compared to $CS-_2$, EXT: $\Delta_{CS+2–CS-2} = 2.0$, 95%CI [0.6, 3.4], $t(35) = 2.98$, $p = .005$; COUNTER: $\Delta_{CS+2–CS-2} = 1.9$, 95%CI [0.4, 3.5], $t(31) = 2.59$, $p = .015$. In both groups, however, participants were similarly afraid of the two CSs+, EXT: $\Delta_{CS+1–CS+2} = 0.4$, 95%CI [-0.7, 1.5],

$t(35) = 0.73$, $p = .470$; COUNTER: $\Delta_{CS+1–CS+2} = 0.1$, 95%CI [-0.6, 0.9], $t(31) = 0.34$, $p = .739$. Similar planned contrasts on the *pain-US expectancy* ratings (Figure 3b) indicated that at the end of the acquisition phase, participants of both groups expected pain to occur more after $CS+_1$ compared to $CS-_1$, EXT: $\Delta_{CS+1–CS-1} = 6.1$, 95%CI [4.6, 7.5], $t(35) = 8.7$, $p < .001$; COUNTER: $\Delta_{CS+1–CS-1} = 5.7$, 95%CI [4.3, 7.1], $t(31) = 8.3$, $p < .001$, and after $CS+_2$ compared to $CS-_2$, EXT: $\Delta_{CS+2–CS-2} = 6.4$, 95%CI [5.1, 7.7], $t(35) = 10.2$, $p < .001$; COUNTER: $\Delta_{CS+2–CS-2} = 5.0$, 95%CI [3.5, 6.5], $t(31) = 6.9$, $p < .001$. Both groups, however, expected pain after the two CSs+ to a similar degree, EXT: $\Delta_{CS+1–CS+2} = -0.5$, 95%CI [-1.1, 0.1], $t(35) = -1.6$, $p = .127$; COUNTER: $\Delta_{CS+1–CS+2} = 0.5$, 95%CI [-0.1, 1.2], $t(31) = 1.6$, $p = .117$. Taken together, these findings confirm that differential fear acquisition occurred successfully in both groups.

Fear reduction. Figure 3 suggests that, throughout the fear reduction phase, fear of movement-related pain and pain-US expectancy for the CS+ that was extinguished or counterconditioned ($CS+_1$) steadily decreased, whereas for the movement that was still paired with pain ($CS+_2$) remained stably high or even slightly increased. Planned contrasts confirmed that, from the end of the acquisition phase to the end of the reduction phase, *fear of movement-related pain* (Figure 3a) reduced more for $CS+_1$ than for $CS+_2$. This was the case for both groups, EXT: $\Delta_{(CS+1 \text{ at ACQ3-CS+1 at RED4})–(CS+2 \text{ at ACQ3-CS+2 at RED4})} = 3.6$, 95%CI [2.4, 4.7], $t(35) = 6.37$, $p < .001$; COUNTER: $\Delta_{(CS+1 \text{ at ACQ3-CS+1 at RED4})–(CS+2 \text{ at ACQ3-CS+2 at RED4})} = 3.3$, 95%CI [2.3, 4.3], $t(31) = 6.93$, $p < .001$. Furthermore, in both groups the reduction was greater for the extinguished or counterconditioned movement, compared to its counterpart CS-, EXT: $\Delta_{(CS+1 \text{ at ACQ3-CS+1 at RED4})–(CS-1 \text{ at ACQ3-CS-1 at RED4})} = 2.8$, 95%CI [1.4, 4.1], $t(35) = 4.07$, $p < .001$; COUNTER: $\Delta_{(CS+1 \text{ at ACQ3-CS+1 at RED4})–(CS-1 \text{ at ACQ3-CS-1 at RED4})} = 1.7$, 95%CI [0.4, 2.9], $t(31) = 2.75$, $p = .010$. There was a larger difference in fear

ratings for the movement that was still paired with pain compared to its counterpart CS-, but only in the COUNTER group, $\Delta_{(CS+2 \text{ at ACQ3-CS+2at RED4})–(CS-2 \text{ at ACQ3-CS-2 at RED4})} = -1.8$, 95%CI [-2.7, -0.9], $t(31) = -4.03$, $p < .001$. The same did not hold for the EXT group, $\Delta_{(CS+2at \text{ ACQ3-CS+2at RED4})–(CS-2 \text{ at ACQ3-CS-2 at RED4})} = -0.8$, 95%CI [-2.0, 0.4], $t(35) = -1.35$, $p = .185$. Overall, the two groups reported a similar decrease in fear for the $CS+_1$, $\Delta_{EXT(CS+1 \text{ at RED4-CS+1 at ACQ3})– \text{ COUNTER}(CS+1 \text{ at RED4-CS+1 at ACQ3})} = 0.7$, 95%CI [-0.8, 2.1], $t(66) = .91$, $p = .365$. Similar analyses showed that *pain-US expectancy* (Figure 3b) for $CS+_1$ was more reduced compared to $CS+_2$ in both the EXT group, $\Delta_{(CS+1 \text{ at ACQ3-CS+1 at RED4})–(CS+2 \text{ at ACQ3-CS+2 at RED4})} = 5.0$, 95%CI [3.8, 6.1], $t(35) = 8.9$, $p < .001$, and the COUNTER group, $\Delta_{(CS+1 \text{ at ACQ3-CS+1 at RED4})–(CS+2 \text{ at ACQ3-CS+2 at RED4})} = 4.1$, 95%CI [2.6, 5.6], $t(31) = 5.6$, $p < .001$. In both groups, pain-US expectancy for $CS+_1$ was more reduced compared to $CS-_1$, EXT: $\Delta_{(CS+1 \text{ at ACQ3-CS+1 at RED4})–(CS-1 \text{ at ACQ3-CS-1 at RED4})} = 3.9$, 95%CI [2.6, 5.3], $t(35) = 5.9$, $p < .001$; COUNTER: $\Delta_{(CS+1 \text{ at ACQ3-CS+1 at RED4})–(CS-1 \text{ at ACQ3-CS-1 at RED4})} = 2.2$, 95%CI [0.8, 3.5], $t(31) = 3.2$, $p = .003$. Again, there was a larger change in pain-US expectancy for the $CS+_2$ compared to the $CS-_2$ in the COUNTER group, $\Delta_{(CS+2at \text{ ACQ3-CS+2at RED4})–(CS-2 \text{ at ACQ3-CS-2 at RED4})} = -1.6$, 95%CI [-2.9, -0.3], $t(31) = -2.49$, $p = .019$, but not in the EXT group, $\Delta_{(CS+2at \text{ ACQ3-CS+2at RED4})–(CS-2 \text{ at ACQ3-CS-2 at RED4})} = -0.9$, 95%CI [-2.1, 0.3], $t(35) = -1.6$, $p = .123$. As above, the two groups reported a similar decrease in pain-US expectancy for the $CS+_1$, $\Delta_{EXT(CS+1 \text{ at RED4-CS+1 at ACQ3})– \text{ COUNTER}(CS+1 \text{ at RED4-CS+1 at ACQ3})} = 1.4$, 95%CI [-0.2, 3.0], $t(66) = 1.74$, $p = .087$. Taken together, these results demonstrate that both extinction and counterconditioning were effective in reducing fear of pain and pain-US expectancy, but to a similar degree.

Comparing the effect of reinstatement between extinction and counterconditioning

Does counterconditioning generate less return of fear of movement-related pain and pain-US expectancy than extinction?

Figure 3 indicates that, contrary to our expectation, fear and pain-US expectancy ratings did not increase from the end of the fear reduction phase to test, for either of the two groups. Planned comparisons on *fear of movement-related pain* (Figure 3a) confirmed this visual impression. Specifically, they yielded no group differences in return of fear for the $CS+_1$, $\Delta_{EXT(CS+1\text{ at TEST-CS+1 at RED4})-\text{ COUNTER}(CS+1\text{ at TEST-CS+1 at RED4})} = 0.05$, 95%CI [-0.7, 0.8], $t(66) = 0.13$ $p = .894$, the $CS+_2$, $\Delta_{EXT(CS+2\text{ at TEST-CS+2 at RED4})-\text{ COUNTER}(CS+2\text{ at TEST-CS+2 at RED4})} = -0.1$, 95%CI [-0.8, 0.5], $t(66) = -0.46$, $p = .646$, the $CS-_1$, $\Delta_{EXT(CS-1\text{ at TEST-CS-1 at RED4})-\text{ COUNTER}(CS-1\text{ at TEST-CS-1 at RED4})} = 0.07$, 95%CI [-0.7, 0.8], $t(66) = .18$, $p = .857$, or the $CS-_2$, $\Delta_{EXT(CS-2\text{ at TEST-CS-2 at RED4})-\text{ COUNTER}(CS-2\text{ at TEST-CS-2 at RED4})} = 0.4$, 95%CI[-0.3, 1.2], $t(66) = 1.17$, $p = .246$. Similar planned contrasts on *pain-US expectancy* (Figure 3b) showed that, in both groups, pain-US expectancies remained similar from the end of the fear reduction phase to test. This was the case for all stimuli, i.e. for the $CS+_1$, $\Delta_{EXT(CS+1\text{ at TEST-CS+1 at RED4})-\text{ COUNTER}(CS+1\text{ at TEST-CS+1 at RED4})} = 0.2$, 95%CI [-0.6, 1.0], $t(66) = .51$, $p = .615$, the $CS+_2$, $\Delta_{EXT(CS+2\text{ at TEST-CS+2 at RED4})-\text{ COUNTER}(CS+2\text{ at TEST-CS+2 at RED4})} = -0.2$, 95%CI [-0.6, 0.2], $t(66) = -0.9$, $p = .362$, the $CS-_1$, $\Delta_{EXT(CS-1\text{ at TEST-CS-1 at RED4})-\text{ COUNTER}(CS-1\text{ at TEST-CS-1 at RED4})} = 0.1$, 95%CI [-0.7, 0.9], $t(66) = 0.15$, $p = .883$], as well as the $CS-_2$, $\Delta_{EXT(CS-2\text{ at TEST-CS-2 at RED4})-\text{ COUNTER}(CS-2\text{ at TEST-CS-2 at RED4})} = 0.2$, 95%CI [-0.6, 1.0], $t(66) = .53$, $p = .597$. Taken together, these findings indicate that the reinstatement manipulation did not result in return of fear or pain-US expectancy for the CS that had been extinguished or counterconditioned, or for any other of the CSs, that is, that there was no differential fear reinstatement in either of the two groups.

Does counterconditioning reduce CS negative valence more than extinction?

Figure 4 shows a larger decrease in negative valence of the $CS+_1$ compared to the $CS+_2$ throughout the fear reduction phase. Planned contrasts showed that CS valence ratings decreased in a similar manner for the two groups. This was the case for all stimuli, i.e. the $CS+_1$, $\Delta_{EXT(CS+1\text{ at RED-CS+1 at ACQ})– COUNTER(CS+1\text{ at RED-CS+1 at ACQ})} = 0.05$, 95%CI [-0.5, 0.6], $t(66) = 0.16$, $p = .870$, the $CS+_2$, $\Delta_{EXT(CS+2\text{ at RED-CS+2 at ACQ})– COUNTER(CS+2\text{ at RED-CS+2 at ACQ})} = 0.4$, 95%CI [0.02, 0.9], $t(66) = 2.08$, $p = .042$ (but did not survive Bonferroni-Holm correction), the $CS-_1$, $\Delta_{EXT(CS-1\text{ at RED-CS-1 at ACQ})– COUNTER(CS-1\text{ at RED-CS-1 at ACQ})} = 0.1$, 95%CI [-0.3, 0.5], $t(66) = 0.40$, $p = .688$, and the $CS-_2$, $\Delta_{EXT(CS-2\text{ at RED-CS-2 at ACQ})– COUNTER(CS-2\text{ at RED-CS-2 at ACQ})} = 0.02$, 95%CI [-0.4, 0.4], $t(66) = 0.11$, $p = .913$. These results indicate that, contrary to our expectations, the affective valence of the counterconditioned CS+ did not decrease to a larger degree than that of the extinguished one.

Discussion

Fear of movement-related pain can be learned through classical conditioning, and is pivotal in the development and maintenance of chronic pain disability (Meulders, 2020; Vlaeyen, 2015). To reduce fear of movement-related pain, extinction-based protocols, such as exposure-in-vivo, are successfully applied to tackle chronic pain disability (den Hollander et al., 2010; Glombiewski et al., 2018). Exposure, however, is often followed by relapse (Bouton, 2002; Vervliet et al., 2013). Counterconditioning (i.e., pairing the fear-evoking CS with a positive US) has been suggested to reduce return of fear by virtue of its greater capacity to decrease CS negative valence (Dirikx et al., 2004; Hermans et al., 2002). We tested whether counterconditioning would lead to less return of fear of movement-related pain and a greater decrease in negative stimulus valence than extinction.

First, we replicated Meulders et al. (2015) in showing that counterconditioning and extinction were similarly effective in reducing fear of movement-related pain. Our study thus provides further evidence that counterconditioning can reduce conditioned fear of movement-related pain and pain-US expectancy. This finding is also in line with previous studies showing similar positive effects of counterconditioning in anxiety (Raes & De Raedt, 2012), and disgust (Engelhard et al., 2014). Further, the observation that counterconditioning does not outperform extinction on immediate fear reduction is also in line with previous research (Meulders, Karsdorp, et al., 2015; Raes & De Raedt, 2012).

In contrast to our expectations, participants in both groups did not show a return of differential fear of movement-related pain or pain-US expectancy at test after the reinstatement manipulation. This is in contrast to the findings of a recent experiment showing that counterconditioning outperformed extinction by decreasing, though not entirely suppressing, spontaneous recovery and reinstatement of US-expectancy (Kang et al., 2018). Our findings, though, are more similar to those of van Dis et al. (2019), who also found the effect of counterconditioning and extinction on the return of fear to be of a similar magnitude.

The lack of reinstatement in the extinction group is in contrast to previous studies that have successfully demonstrated reinstatement after extinction, using simpler variations of the VJM paradigm and smaller groups than in the present study (den Hollander, Meulders, Jakobs, & Vlaeyen, 2015; Meulders, Rousseau, & Vlaeyen, 2015; Meulders & Vlaeyen, 2013). The failure to observe reinstatement is also at odds with a large body of anxiety literature (e.g., Haaker et al., 2014; Kang et al., 2018), and may be explained by the increased complexity of our design. We used two CSs+ and two CSs-, in contrast to most other studies using only one CS+ and one CS- (e.g., Haaker et al., 2014; Kang et al., 2018). As $CS+_2$ continued being associated with the pain-

US throughout the fear reduction phase, it is likely that the *context* acquired some associative strength by virtue of mediated conditioning (cf. Ward-Robinson & Hall, 1999). In that case, the reinstatement pain-USs may have been experienced as *signalled* by the context, thus likely being less surprising. Closely related is the clinically relevant procedure of *occasionally reinforced extinction*, in which occasional CS-US pairings or US-only presentations are included in the fear extinction phase, in order to decrease the differences between acquisition and extinction context and thus the corresponding context switch (Craske, Treanor, Conway, Zbozinek, & Vervliet, 2014). The reduced context switch between acquisition and extinction is expected to facilitate retrieval of the extinction memory (Bouton, 2002). Compared to regular extinction procedures, occasionally reinforced extinction leads to less return of fear (Thompson, McEvoy, & Lipp, 2018). In addition to the context, $CS+_2$, which continued being associated with the pain-US throughout the fear reduction phase, may have also been considered a reliable predictor of the pain-US, thus attenuating the expected reinstatement effect (Rescorla & Cunningham, 1977). As both the context and the $CS+_2$ may have come to signal the pain-US, these two explanations are not mutually exclusive.

We also did not find that the negative valence of the counterconditioned CS+ was more reduced than that of the extinguished CS+. This is in contrast to previous research (Engelhard et al., 2014) and theoretical accounts proposing that counterconditioning relies on changing the negative stimulus valence (Hermans et al., 2002). Interestingly, however, evidence is accumulating that counterconditioning may reduce fear and US-expectancy without actually changing CS valence (Kang et al., 2018; Meulders, Karsdorp, et al., 2015). These findings likely suggest that the underlying mechanism of counterconditioning might be at least partly different than initially thought. For example, Dunsmoor and colleagues (2015) demonstrated that pairing

the CS+ with a novel, neutral (rather than opposite valenced) outcome ("novelty-facilitated extinction") was superior to regular extinction in reducing spontaneous fear recovery. According to these authors, pairing the CS+ with a surprising though mundane outcome is a more unambiguous sign of change than the mere omission of the initial (threat) US, and may thus facilitate inhibitory learning by increasing prediction error. In support of this, Raes & De Raedt (2012) also showed that counterconditioning with a positive or a neutral outcome had similar effects in subsequent implicit measurements of CS+ valence. On a similar note, US-devaluation techniques, which are assumed to decrease stimulus valence, were shown not to outperform traditional extinction in decreasing conditioned fear (Dibbets, Lemmens, & Voncken, 2018) and its return (Landkroon, Mertens, & Engelhard, 2020). Taken together, these findings indicate that additional or alternative processes than changing the affective valence of the CS+ may actually underlie counterconditioning. These processes likely relate to the maximization of expectancy violation (Craske et al., 2014; Keller et al., 2020).

The present study and hypotheses were designed from the perspective of the inhibitory learning model of extinction (Bouton, 2002). Propositional (Mitchell, De Houwer, & Lovibond, 2009) and goal-directed (Boddez, Moors, Mertens, & De Houwer, 2020) models, however, would predict that interventions providing more information about the feared CS would be more effective at reducing the return of fear compared to counterconditioning. For example, demonstrating that more threatening CSs are not followed by the pain-US is expected to lead one to infer that the same would apply to less threatening CSs as well (cf. Mertens et al., 2019; Preusser, Margraf, & Zlomuzica, 2017). Given that counterconditioning is not consistently found to be more effective than extinction in reducing the return of fear (Kang et al., 2018; van Dis et al., 2019), these emerging theoretical perspectives offer valuable alternatives for research.

Our reward manipulation entailed increasing the probability to win a future lottery prize rather than obtaining a reward with certainty. This reward manipulation has been used successfully in healthy student samples before. Specifically, Claes et al. (2016) reported moderate to high lottery ticket value, ticket pleasantness, and importance of obtaining tickets. Furthermore, our findings are in line with these of Meulders et al. (2015), who provided a reward with certainty (a € symbol on the computer screen representing an additional profit of €0.50 each time it appeared), but also found no differences in fear reduction after extinction or counterconditioning. We are thus fairly confident that our (lack of) findings is not due to the way we manipulated reward.

The present study had some limitations. First, technical problems prevented us from obtaining reliable eyeblink startle reflex measurements. Nevertheless, self-reported measures of fear such as these that we relied on are considered valid (Boddez et al., 2013). Similarly, we assessed stimulus valence by means of verbal ratings, but implicit measures (e.g., affective priming tasks; Engelhard et al., 2014) may yield different results. Second, our sample consisted of healthy volunteers, who received experimentally induced pain. Replication is thus warranted before findings are generalized to clinical populations. Third, our study was adequately powered to detect only medium-to-large effects, raising the possibility that smaller effects may have been missed. However, the reinstatement effect is routinely demonstrated with smaller samples and simpler designs (for an elaborate review, see Haaker et al., 2014; for simpler variations of the VJM paradigm, see den Hollander et al., 2015; Meulders, Rousseau, et al., 2015; Meulders & Vlaeyen, 2013), attesting to the complexity of our design as the primary plausible explanation for the lack of reinstatement effects.

A strength of this study is the use of a complex design with two CSs+, only one of which was later extinguished or counterconditioned, and two CSs-. This deviates from classic differential paradigms on counterconditioning (e.g., Engelhard et al., 2014; Kang et al., 2018; Raes & De Raedt, 2012) and human fear reinstatement (Haaker et al., 2014), which most often only use one CS+ and one CS-. Importantly, by using this design we did not replicate the well-established reinstatement effect that has been demonstrated repeatedly with one (extinguished) CS+ and one CS- joystick movement (Meulders, 2020). Our findings raise the issue of balancing experimental control and modelling real-life complexity more adequately in experimental paradigms and how this balance may affect findings. Similar suggestions have recently been made for the advancement of other experimental paradigms (e.g., for extinction; Scheveneels, Boddez, Vervliet, & Hermans, 2016).

To conclude, we showed that counterconditioning is as effective as extinction in reducing pain-related fear, but does not seem to outperform extinction when it comes to reducing the return of fear or the negative valence of the conditioned stimulus. The complexity of study designs should be considered.

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Figure captions

Figure 1. Overview of an illustrative trial in (A) the fear acquisition phase, and the fear reduction phase in (B) the EXT group and (C) the COUNTER group.

Figure 2. Reward-US expectancy ratings from the end of acquisition (ACQ) to the end of fear reduction (RED), separately per group. Error bars denote standard errors.

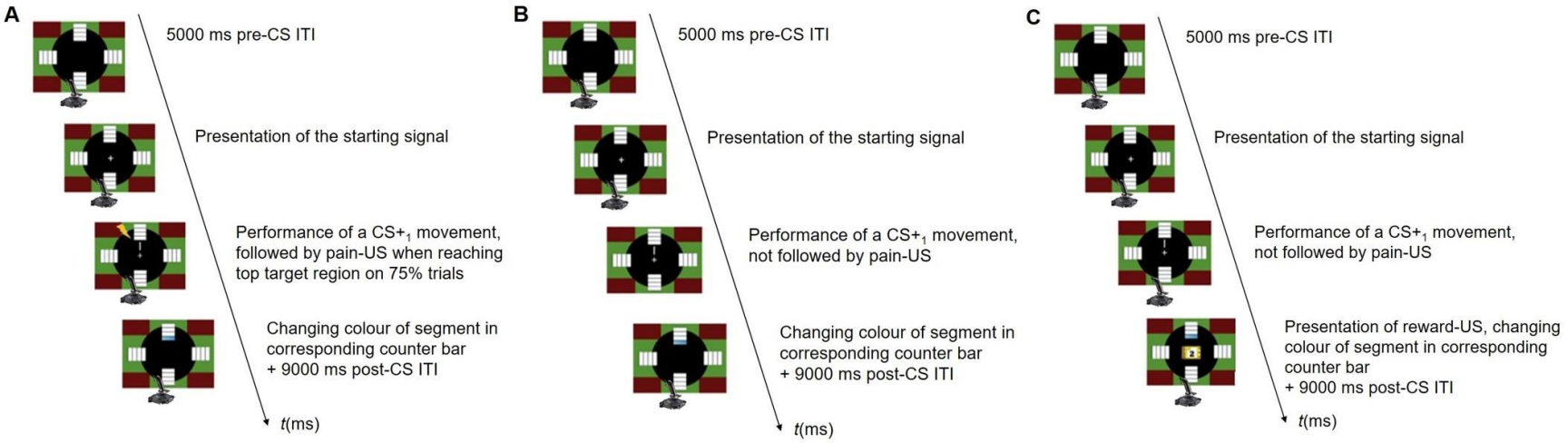
Figure 3. Fear of movement-related pain (panel a) and pain-US expectancy (panel b) ratings during the acquisition (ACQ), fear reduction (RED), and test (TEST) phases, separately per group. Error bars denote standard errors.

Figure 4. Retrospective affective valence ratings for the CSs after each experimental phase (ACQ, RED, and TEST), separately per group. Error bars denote standard errors.

Table captions

Table 1. *Sex ratio, age, and psychological trait questionnaire scores (mean, with SD and range in parentheses) separately per group, and group comparisons*

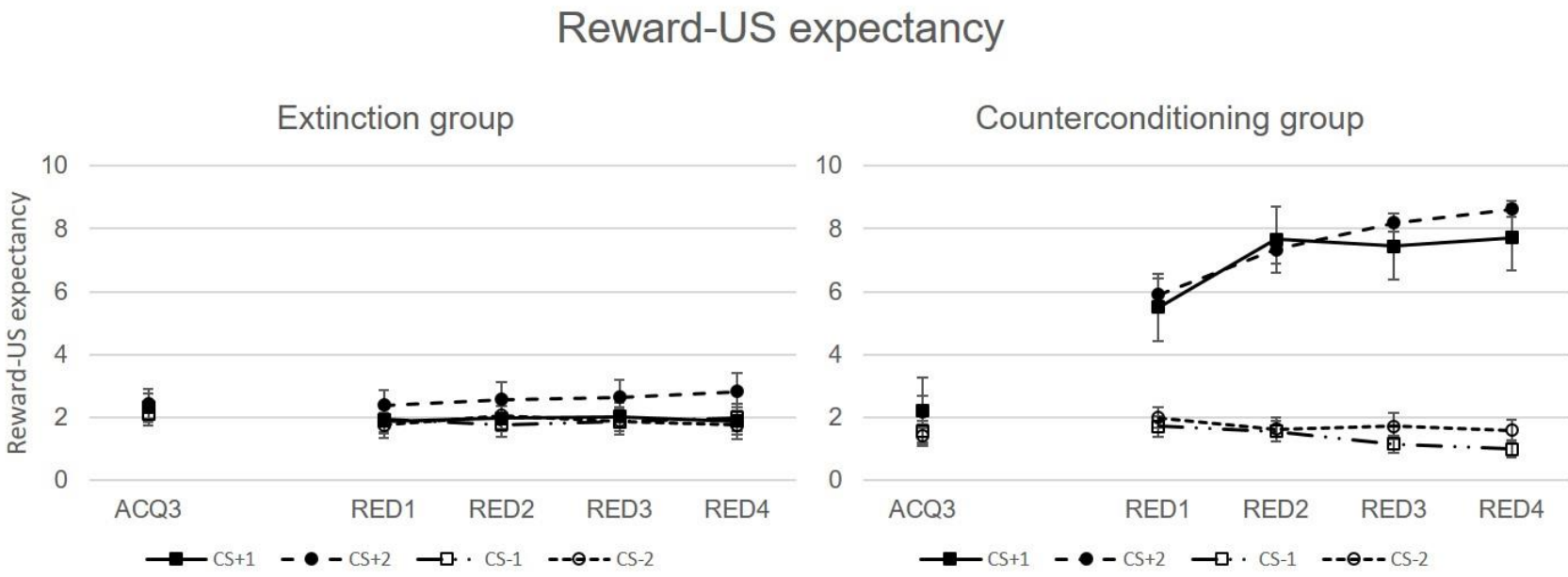
Figure 1. Overview of an illustrative trial in (A) the fear acquisition phase, and the fear reduction phase in (B) the EXT group and (C) the COUNTER group.



Note. The white cross represents the starting signal of the trial, the white arrow represents the direction of the joystick movement, the lightning bolt represents the pain-US, the yellow rectangle represents the reward-US, and the blue segment of the counter bar indicates that a movement in the corresponding direction was completed. The valid and invalid movement regions are illustrated by the green and red areas, respectively; note that these were visible to the participants only during the practice phase. During the fear acquisition phase (A), participants received a pain-US on 75% of the times that they performed a $CS+_1$ or $CS+_2$ movement. The fear acquisition phase was identical for both groups. During the fear reduction phase in the EXT group, the $CS+_1$ movement was extinguished, i.e. not paired with a pain-US (B), whereas the $CS+_2$ continued to be paired with the pain-US. During the fear reduction phase in the COUNTER group,

the $CS+_1$ movement was counterconditioned, i.e. paired with a reward-US (C), whereas the $CS+_2$ was paired with both the reward-US and the pain-US.

Figure 2. Reward-US expectancy ratings from the end of acquisition (ACQ) to the end of fear reduction (RED), separately per group. Error bars denote standard errors.



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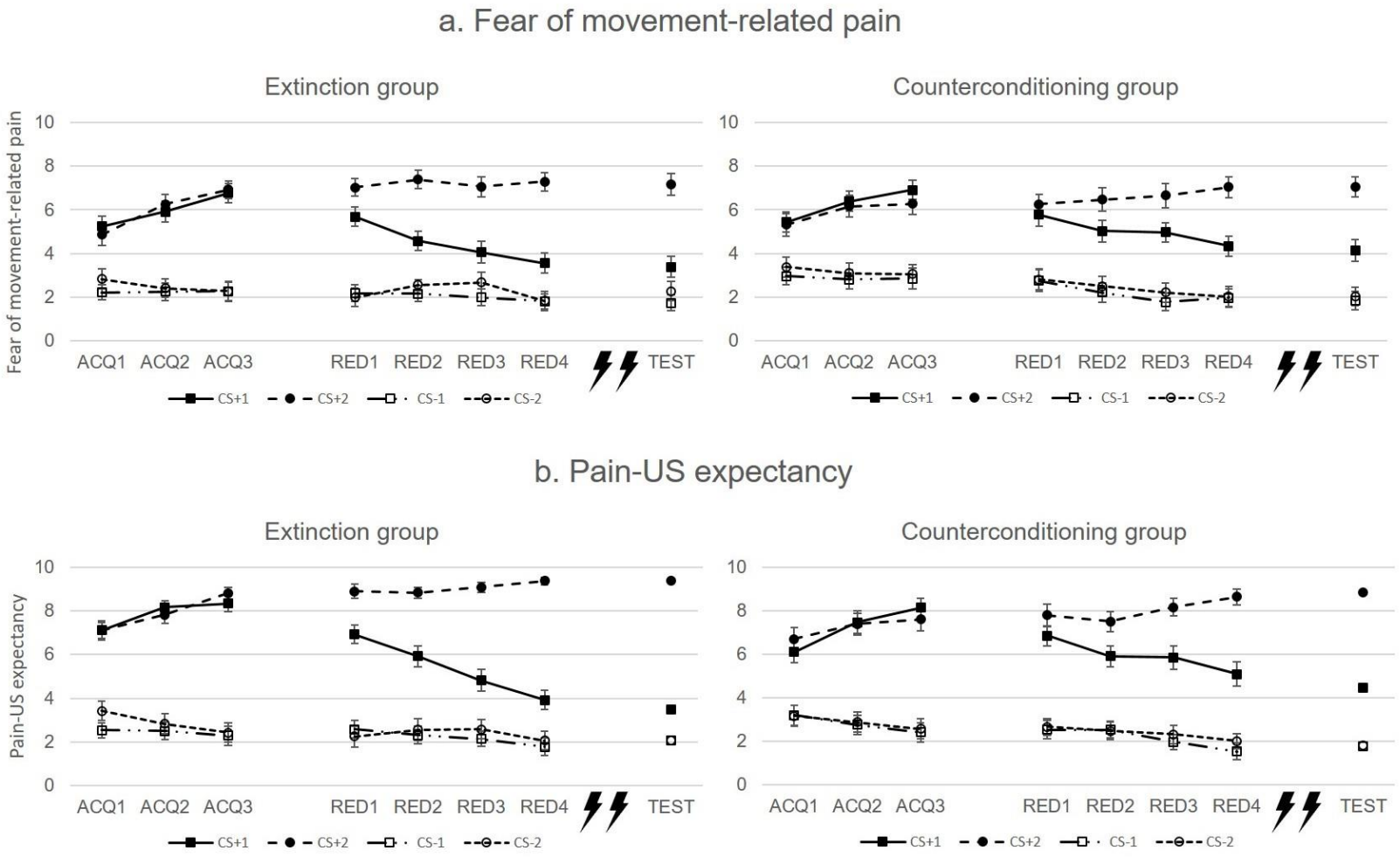

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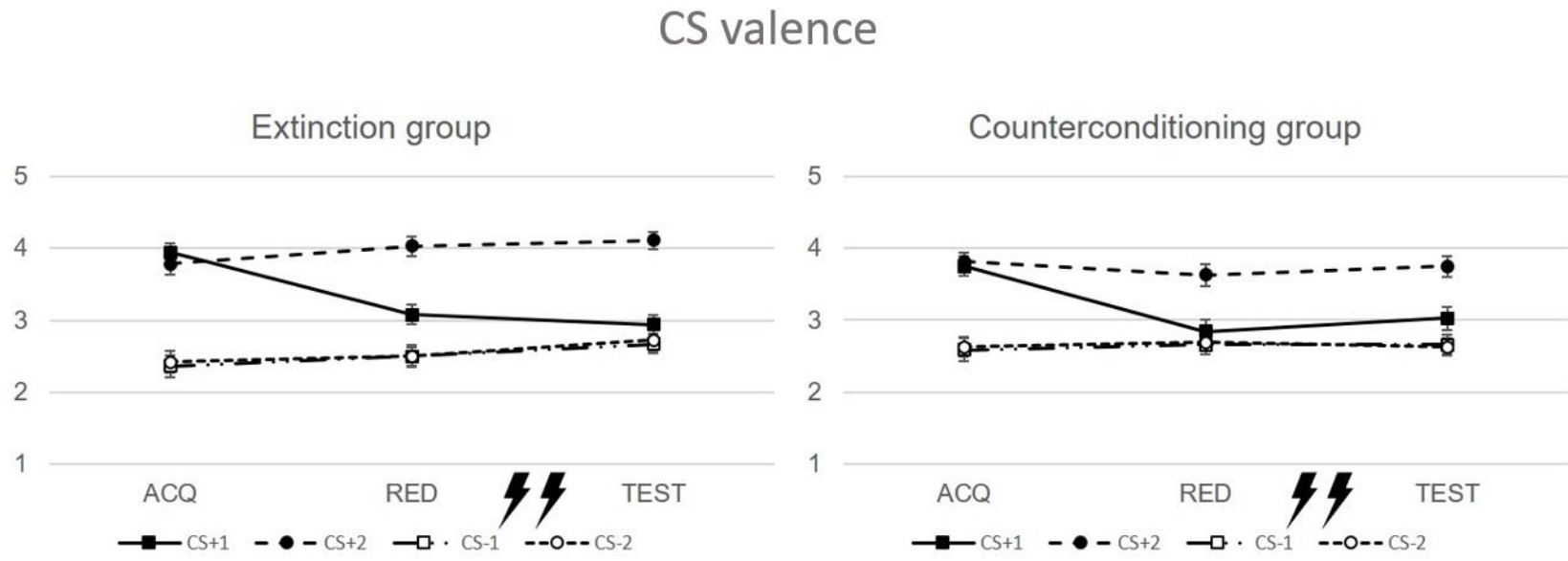

Table 1. *Sex ratio, age, and psychological trait questionnaire scores (mean, with SD and range in parentheses) separately per group, and group comparisons*

	Extinction group (*n*=36)	**Counterconditioning group (*n*=32)**	**Comparison**
Women: Men	26: 10	25: 7	$\chi^2(1) = 0.32$, $p = .575$
Age	21.2 (3.7, 18-37)	21.8 (7.2, 18-59)	$F(1, 66) = 0.21$, $p = .651$
Pain catastrophizing (PCS)	16.1 (6.6, 4.0-30.0)	17.6 (7.7, 4.0-34.0)	$F(1, 66) = 0.72$, $p = .398$
Fear of pain (FPQ)	68.7 (11.9, 39.0-92.0)	68.1 (13.9, 47.0-97.0)	$F(1, 66) = .04$, $p = .848$
Negative affect (PANAS)	18.9 (5.4, 10.0-32.0)	20.8 (6.5, 12.0-36.0)	$F(1, 66) = 1.73$, $p = .194$
Positive affect (PANAS)	34.7 (5.1, 21.0-45.0)	34.8 (6.0, 24.0-45.0)	$F(1, 66) = 0.01$, $p = .930$
Trait anxiety (STAI)	37.6 (8.4, 22.0-55.0)	39.6 (9.1, 24.0-62.0)	$F(1, 65) = 0.93$, $p = .339$

Note. PCS = Pain Catastrophizing Scale ; FPQ = Fear of Pain Questionnaire ; PANAS = Positive and Negative Affect Schedule ; STAI = State-Trait Anxiety Inventory

Supplementary Material

to the manuscript "*No differences in return of pain-related fear after extinction and counterconditioning*" by Gatzounis, R., De Bruyn, S., Van de Velde, L., & Meulders, A.

In this supplementary material we report full results of a series of Repeated Measures (RM) ANOVAs with group as the between-subjects factor, and block and stimulus as within-subjects factors, on: reward-US expectancy, and fear acquisition and reduction for our manipulation check (S.1); fear reinstatement and CS affective valence for our main hypotheses (S.2). We report univariate tests with Greenhouse-Geisser corrections where appropriate, differences between means (Δ) with 95% confidence intervals (CIs), and η_G^2 as affect size. To correct for multiple testing, we applied Holm-Bonferroni correction for planned comparisons and ANOVA effects (Cramer et al., 2016), and the more stringent Bonferroni correction for post-hoc comparisons. Adjusted α (α_{adj}) of the ANOVA effects is reported in the tables. Analyses were performed with SPSS 24.0 (IBM, Armonk, NY: IBM Corp).

S.1 Manipulation checks

S.1.1 Reward-US expectancy

We performed a 2*4*5 RM ANOVA with group (EXT, COUNTER) as the between-subjects factor and stimulus ($CS+_1$, $CS+_2$, $CS-_1$, $CS-_2$) and block (ACQ3, RED1-4) as the within-subjects factors. This analysis confirmed the visual impression given by *Figure 2* of the main article, which indicates group differences in reward-US expectancy. All effects, including the crucial group*block*stimulus interaction, were statistically significant (see Table S.1.1).

Table S.1.1. *Reward-US expectancy: Main and interaction RM ANOVA effects. Statistically significant effects are indicated in bold.*

Effect	Numerator df	Denominator df	F	p	α_{adj}	η_G^2
group	1	66	15.70	< .01	0.05	.054
block	2.1	141.5	18.69	< .001	0.025	.069
stimulus	1.8	116.9	118.18	< .001	0.00833	.323
group*block	2.1	141.5	24.20	< .001	0.01667	.088
group*stimulus	1.8	116.9	86.66	< .001	0.0125	.312
block*stimulus	6.1	402.2	30.68	< .001	0.00714	.097
group*block*stimulus	6.1	402.2	24.88	< .001	0.01	.080

S.1.2 Fear acquisition

To test for differential acquisition effects, we performed two separate 2*3*4 RM ANOVAs with group (EXT, COUNTER) as the between-subjects factor and block (ACQ1-3) and stimulus ($CS+_1$, $CS+_2$, $CS-_1$, $CS-_2$) as the within-subjects factors on the *fear of movement-related pain* (see *Figure 3a* of the main article) and *pain-US expectancy* ratings (see *Figure 3b* of the main article). Both analyses yielded significant effects of block (though for pain-US expectancy that did not survive Bonferroni-Holm correction), stimulus, and the block*stimulus interaction (see *Table S.1.2*), confirming the observation that, in both groups, participants exhibited differential fear acquisition.

Table S.1.2. *Acquisition: Main and interaction RM ANOVA effects, separately for fear of movement-related pain and pain-US expectancy. Statistically significant effects are indicated in bold.*

Effect	Numerator df	Denominator df	*F*	*p*	α_{adj}	η_G^2
Fear of movement-related pain						
group	1	66	0.95	.334	0.0125	.002
block	1.9	128.5	8.68	< .001	0.01	.013
stimulus	2.0	131.7	63.05	< .001	0.00714	.355
group*block	1.9	128.5	0.41	.658		.001
group*stimulus	2.0	131.7	0.54	.586		.006
block*stimulus	4.6	306.0	8.54	< .001	0.00833	.026
group*block*stimulus	4.6	306.0	0.71	.603		.002
Pain-US expectancy						
group	1	66	.86	.358		.001
block	1.8	121.3	3.29	.045	0.01	.006
stimulus	1.7	111.1	129.5	< .001	0.00714	.523
group*block	1.8	121.3	.03	.964		0
group*stimulus	1.7	111.1	1.05	.344		.012
block*stimulus	4.3	284.8	9.07	< .001	0.00833	.036
group*block*stimulus	4.3	284.8	.93	.451		.004

S1.3 Fear reduction

To explore effects of counterconditioning and extinction on the reduction of fear, we performed two 2*4*5 RM ANOVAs with group (EXT, COUNTER) as the between-subjects factor, and stimulus ($CS+_1$, $CS+_2$, $CS-_1$, $CS-_2$) and block (ACQ3, RED1-4) as within-subjects factors, on *fear of movement-related pain* (see *Figure 3a* of the main article) and *pain-US expectancy* ratings (see *Figure 3b* of the main article). Both analyses yielded significant main effects of stimulus, block, and the stimulus*block interaction, but no significant group effects (see *Table S.1.3*), indicating that the counterconditioning and extinction were similarly effective in reducing pain-related fear.

Table S.1.3. *Fear reduction: Main and interaction RM ANOVA effects, separately for fear of movement-related pain and pain-US expectancy. Statistically significant effects are indicated in bold.*

Effect	Numerator df	Denominator df	*F*	*p*	α_{adj}	η_G^2
Fear of movement-related pain						
group	1	66	.06	.800		.0001
block	3.2	209.8	10.87	< .001	0.01	.020
stimulus	2.1	140.6	87.41	< .001	0.00714	.426
group*block	3.2	209.8	.52	.682		.001
group*stimulus	2.1	140.6	.96	.391		.010
block*stimulus	7.7	508.2	12.0	< .001	0.00833	.038
group*block*stimulus	7.7	508.2	1.58	.131	0.0125	.05
Pain-US expectancy						
group	1	66	.36	.552		.0004
block	2.9	194.7	14.41	< .001	0.01	.025
stimulus	1.9	124.3	170.87	< .001	0.00714	.593
group*block	2.9	194.7	.47	.699		.001
group*stimulus	1.9	124.3	1.79	.174	0.0125	.020
block*stimulus	7.2	475.4	19.22	< .001	0.00833	.068
group*block*stimulus	7.2	475.4	1.44	.183		.005

S.2 Main Hypotheses

S2.1 Reinstatement

A 2*2*4 RM ANOVA with group (EXT, COUNTER) as the between-subjects factor and block (RED4, TEST) and stimulus ($CS+_1$, $CS+_2$, $CS-_1$, $CS-_2$) as within-subjects factors, on *fear of movement-related pain* (see *Figure 3a* of the main article) yielded a significant effect of stimulus, $F(2.6, 173.1)=87.2$, $p<.001$, $\eta_G^2=.494$, but no other significant effects (see *Table S.2.1*). In line with the planned contrasts reported in the main article, the crucial three-way interaction did not emerge. Post-hoc analyses of the stimulus effect indicated that, throughout the end of fear reduction and test phase, participants were more afraid of the CS+ that was extinguished or counterconditioned compared to its respective CS-, $\Delta_{CS+1–CS-1} = 2$, 95%CI [1.1, 3.0], $p < .001$, but less than the CS+ that continued being associated with the pain-US, $\Delta_{CS+2–CS+1} = 3.3$, 95%CI [2.2, 4.3], $p < .001$.

A similar analysis on *pain-US expectancy* (*Figure 3b* of the main article) showed a significant effect of stimulus, $F(2.4, 157.8)=186.3$, $p<.001$, $\eta_G^2=.679$, but no other significant effects (see *Table S.2.1*). Post-hoc tests of the stimulus effect showed that, overall, participants were more afraid of the CS+ that was extinguished or counterconditioned compared to its counterpart, $\Delta_{CS+1–CS-1} = 2.5$, 95%CI [1.5, 3.4], $p < .001$, but less than the CS+ that continued being associated with the pain-US, $\Delta_{CS+2–CS+1} = 4.8$, 95%CI [3.7, 5.9], $p < .001$.

Table S.2.1. *Reinstatement: Main and interaction RM ANOVA effects, separately for fear of movement-related pain and pain-US expectancy. Statistically significant effects are indicated in bold.*

Effect	Numerator df	Denominator df	*F*	*p*	α_{adj}	η_G^2
Fear of movement-related pain						
group	1	66	.19	.663		.0004
block	1	66	.04	.843		0
stimulus	2.6	173.1	87.2	< .001	0.00714	.494
group*block	1	66	.17	.678		.0002
group*stimulus	2.6	173.1	.62	.584		.007
block*stimulus	2.7	179.6	1.33	.268	0.00833	.001
group*block*stimulus	2.7	179.6	.64	.576		.001
Pain-US expectancy						
group	1	66	0	.996		0
block	1	66	.26	.611		.0002
stimulus	2.4	157.8	186.3	< .001	0.00714	.679
group*block	1	66	.11	.746		.0001
group*stimulus	2.4	157.8	2.26	.098		.027
block*stimulus	2.7	178.6	4.05	.010	0.00833	.005
group*block*stimulus	2.7	178.6	.32	.789		.0004

S2.2 CS valence

To investigate whether the decrease in CS valence would be greater in the COUNTER group compared to the EXT group, we performed a 2*2*4 RM ANOVA with group (EXT, COUNTER) as the between-subjects factor, and phase (ACQ, RED) and stimulus ($CS+_1$, $CS+_2$, $CS-_1$, $CS-_2$) as within-subjects factors, on the CS valence ratings. This analysis yielded statistically significant effects of phase, $F(1.0, 66.0)=9.93$, $p=.002$, $\eta_G^2=.013$, and stimulus, $F(1.8, 119.6)=67.34$, $p<.001$, $\eta_G^2=.361$, superseded by a phase*stimulus interaction, $F(2.4, 160.1)=18.65$, $p<.001$, $\eta_G^2=.073$. There were no significant effects of group (see *Table S.2.2*). Post-hoc tests to explore the phase*stimulus effect indicated that at the end of acquisition, participants rated the two CSs+ as more negative than the two CSs-. Specifically, they rated $CS+_1$ as more negative than $CS-_1$ by approximately 1.4 points, 95%CI [0.9, 1.8], $p < .001$, and more negative than $CS-_2$ by approximately 1.4 points, 95%CI [0.9, 1.7], $p < .001$. Similarly, they rated $CS+_2$ as more negative than $CS-_2$ by approximately 1.3, 95%CI [0.9, 1.7], $p < .001$, and more negative than $CS-_1$ by approximately 1.3, 95%CI [0.9, 1.7], $p < .001$. $CS+_1$ and $CS+_2$ were rated as similarly negative at the end of acquisition, $p=1.00$, but at the end of fear reduction, participants rates $CS+_2$, which continued being paired with the pain-US, more negative than the $CS+_1$ by approximately 0.9 points, 95%CI [0.5, 1.2], $p < .001$. Indeed, participants of both groups rated the $CS+_1$ as less negative at the end of fear reduction compared to the end of acquisition, by an average of 0.9 points, 95% CI [0.6, 1.2], $p < .001$, whereas the negative valence of the other stimuli did not change significantly, $CS+_2$: $p = .768$, $CS-_1$: $p = .292$, $CS-_2$: $p = .447$. Taken together, these results indicate that the negative valence of the CS+ that was either extinguished or counterconditioned decreased throughout fear reduction phase, but, contrary to our expectation, the magnitude of the decrease was similar in both groups.

Table S.2.2. *CS valence: Main and interaction RM ANOVA effects. Statistically significant effects are indicated in bold.*

Effect	Numerator df	Denominator df	*F*	*p*	α_{adj}	η_G^2
group	1	66	0	.983		0
phase	1	66	9.93	.002	0.00833	.013
stimulus	1.8	119.6	67.34	< .001	0.00625	.361
group*phase	1	66	1.81	.183		.002
group*stimulus	1.8	119.6	2.18	.122		.025
phase*stimulus	2.4	160.1	18.65	< .001	0.00714	.073
group*phase*stimulus	2.4	160.1	.79	.477		.003