Observational Learning and Pain-related Fear:

An Experimental Study with Colored Cold Pressor Tasks

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Abstract

The primary aim of the current study was to experimentally test whether pain-related fear can be acquired through observational learning, whether extinction occurs after actual exposure to the aversive stimulus, and whether pain-related fear was associated with increased pain ratings. During an observation phase, female volunteers watched a video showing models performing cold pressor tasks (CPT), of which the color served as a conditioned stimulus (CS). In a differential fear conditioning paradigm, each of two colors were either paired with models' painful (CS+) or neutral (CS-) facial expressions. Exposure consisted of participants performing CPTs of both colors (10°C). Self-reported fear of pain, and expected pain ratings were obtained after the observation period, while actual pain and avoidance measures were obtained during and after exposure. Results show that after observing another person performing the CPT associated with the painful faces, subjects report more fear of pain and expect more intense and unpleasant pain as compared to the CPT associated with the neutral faces. This effect of observational learning on pain-related fear persisted until after exposure. During and after exposure no stimulus type effect for pain ratings was found. This study provides preliminary evidence for observational learning of pain-related fear in humans.

Perspective:

Fear of pain can be more disabling than pain itself, and is a risk factor for chronic pain. Knowledge about the acquisition of pain-related fear may help developing novel pain management programs. This study is one of the first to demonstrate the effects of observational learning on pain-related fear.

Key words: Observational learning, pain-related fear, facial expressions

1 Introduction

Modern psychological theories of pain emphasize the importance of negative emotions in the individual's experience and response to pain [16, 44]. In the last decades, researchers started focusing on the reciprocal relationship between pain and anxiety/fear. For instance, pain-related anxiety was found to amplify subjective pain experience, and to predict pain behavior [14, 28]. Likewise, Litt [26] demonstrated that perceived or anticipated pain increases anxiety. A major breakthrough was the introduction of the Fear Avoidance (FA) model of chronic pain, which presents a plausible pathway by which people get caught in a downward spiral of increasing avoidance, disability, and pain [4, 20, 24, 25, 49].

Although there is accumulating research evidence supporting the FA model, there are some unresolved issues. To date, it remains unclear how exactly pain-related fear develops. Fear learning in general depends on the formation and evaluation of propositions between stimuli [31]. Propositions are statements about the way in which objects or events are related, e.g. stimulus A might *cause* stimulus B [10]. In the literature, three pathways to acquire knowledge about these propositions have been proposed [21, 30]. First, people can learn from direct experiences. After a traumatic experience, someone can develop a fear with regard to that particular object or situation [39]. Second, emotional information can be obtained through verbal instructions [32, 35]. Negative information increases fear responses, while positive information might decrease fear. Third, fear can be learned indirectly through observing others in pain [2, 3]. Bandura [5] defined this latter type of learning as *'changes in patterns of behavior that are a consequence of observing others' behaviors'*.

In the context of pain, studies concerning observational learning have mainly focused on the influence of modeling on pain intensity, threshold, and tolerance [7, 11]. However, literature on the effect of observational learning on *fear* of pain is scarce. Olsson et al. [34] systematically investigated different pathways leading to pain-related fear. Comparisons between these learning types (operationalized by changes in skin conductance) revealed that

observational and verbal fear learning can be as effective as aversive learning through firsthand experience.

Whereas the previous studies have mainly focused on autonomic responses and neural activity [33-35], the purpose of the current study is to examine whether observational learning of pain-related fear can lead to changes in fear beliefs and avoidance behavior, and whether this fear of pain extinguishes after actual exposure. Additionally, observational learning effects on pain unpleasantness and pain intensity are investigated. Furthermore, putative moderating effects of the observer's characteristics are explored. To address these questions, a differential fear conditioning procedure was used in healthy young adults. Participants watched a video showing human models performing two colored cold pressor tasks (CPTs). In a counterbalanced set-up, one color (CS+) was paired with painful facial expressions; the other color (CS-) with neutral faces. We expected participants to report more fear, and to expect higher pain unpleasantness and higher pain intensity regarding the CPT associated with the painful faces after watching the video models (observation phase). The differences in reported fear and expectancies between the two tasks were hypothesized to extinguish after direct contact with the stimuli (exposure phase). Moreover, we examined the putative influence of pain catastrophizing, trait fear of pain, and negative affectivity on these observational learning effects.

2 Materials and Methods

2.1 Participants

Sixty-two healthy female undergraduate (psychology) students of the University of Leuven (Belgium) participated in this experiment, for which they received either a course credit or five Euros. Exclusion criteria were color-blindness, diabetes, epilepsy, Reynaud's disease, recent arm fracture or wrist sprain prior to participating, earlier frostbite,

hypertension, and chronic pain. Participants were asked not to consume any caffeine-containing or alcoholic drinks at least two hours before testing. None of the participants had ingested analgesic pain medication on the day of testing. The mean age of participants was 19.8 (SD = 1.8, range 18-24). All (but one Chinese) participants were Caucasian. They all signed the informed consent document, stating that they would be asked to immerse their hands in different colored liquids at different temperatures for one minute each time, which was a harmless duration for the chosen temperatures. Nevertheless, participants were told that they could end participation at any time for any reason. Participants were randomly assigned to one of four conditions, depending on the color of the CS+, and the order of the CPTs. Eight participants (13%) were left-handed. Ethical approval was obtained through the Ethics Committee of the Faculty of Psychology and Educational Sciences of the University of Leuven (Belgium).

2.2 Apparatus and materials

Two identical Plexiglas boxes (Julabo®) were used as cold pressor task (CPT) apparatus, containing an electric immersion cooler, type FT200, and a bath circulator, type ED-19A. Each immersion bath measured 18cm high, 27cm wide, and 39cm long. In contrast to previous CPT studies, in which water temperatures of 2 to 4°C are generally used to induce painful sensations, temperature in the current experiment was held constant at 10°C (± 0.03°C). This temperature was considered to produce a more ambiguous sensation, leaving room for cognitive reappraisal of the experience. In situations of uncertainty, individuals tend to extract information from the environment to disambiguate the situation. Consequently, we expect participants to use the information of the facial expressions seen in the video to affect the meaning of their own immersion experiences [1]. The cold pressor apparatus was placed upon a trolley adjustable in height to provide comfortable access to the Plexiglas box. A registration button was placed on the bottom of each box to determine immersion latency and

early withdrawal. A third box, type TW20 Julabo, was used for water at room temperature (20.5°C ± 0.5°C). Before each CPT, participants were requested to hold their hand in this box for 60 seconds to ensure they all started with a similar skin temperature.

Painful facial expressions were used as aversive unconditioned stimuli; neutral faces as neutral stimuli. Video material with human facial expressions from a previous CPT study at the Maastricht University (Netherlands) was used with participants' consent [48]. Facial expressions in that study were assessed by means of the Child Facial Coding System (CFCS) [6], a coding system derived from the Facial Action Coding System [12], which can also be used in adults. Sixteen female participants – eight with the highest and eight with the lowest facial pain expression scores – were selected to create a video extract with a duration of 682 seconds. Models in this video were presented randomly with the restriction that a CS+ fragment always followed a CS- fragment. All video models were healthy females, both students and staff of the Maastricht University, performing a cold pressor task at 2°C. This temperature was cold enough to induce pain expressions. Mean age of the models was 31 years old for the CS+ condition fragments (median = 25.5, range 17-59), and 32 for the CS- fragments (median = 25.5, range 21-56). In each condition, there was one video model wearing glasses.

Ecoline, which is a safe and harmless colorant, was used to create two different CPTs (Creall®; orange, 1371003; pink, 1371017). One color (CS+) was associated with the painful facial expressions, while the other color (CS-) was paired with the neutral facial expressions (counterbalanced).

Each trial began with a video fragment of a hand immersing a CPT with colored water (orange vs. pink) appearing alone on the left side of the screen. After two seconds, a video extract of a model showing either a painful or a neutral facial expression, appeared on the right side of the screen and the colored CPT started to fade away. Two versions were made of

this video: one with the pink CPT and the other with the orange CPT associated with the painful facial expressions.

2.3 Measures

2.3.1 Self-reports regarding the CPTs

After watching the video, as well as after each immersion, a list of single item numerical rating scales (NRS) was presented [41, 47, 48]. Participants indicated the level of fear (0 = *not fearful at all*; 10 = *very fearful*), pain unpleasantness (-5 = *very unpleasant*; 5 = *very pleasant*), and pain intensity (0 = *not painful at all*; 10 = *very painful*) they expected to experience (observation phase) or actually experienced (exposure phase) with regard to both CPTs. Pain unpleasantness scores were recoded afterwards (0 = *very pleasant;* 10 = *very unpleasant*). Experienced pain intensity during exposure was assessed using verbal pain ratings instead of NRS [48]. Participants reported their experienced pain intensity out loud every time a tone was presented (5s, 10s, 20s, 40s, and 60s during immersion; 20s, 40s, and 60s after immersion). A pain rating scale, ranging from 0 (*not painful at all*) to 10 (*extremely painful*), accompanied the tone on a computer screen as a guideline for participants. At the end of the experiment, self-reported hesitation to immerse their hand in both CPTs was assessed using a NRS (0 = *not at all*; 10 = *very much*).

2.3.2 Avoidance behavior

Time that elapsed between the appearance of the instruction on the computer screen ('you may now immerse your hand into the liquid') and pressing the registration button on the bottom of each colored CPT was registered (with Affect 4.0, a Windows-based software package) [43]. This latency time was considered a behavioral measure of avoidance tendency. At the end of the experiment, participants were asked which of the two colored immersions they wanted to repeat if they had to choose one more immersion task and for which reason.

Avoidance of the task that was associated with the painful facial expressions was considered an indicator for pain-related fear.

2.3.3 Pain Catastrophizing

The 13-item Pain Catastrophizing Scale (PCS) measures the frequency of catastrophizing thoughts and feelings people generally experience during painful situations [45, 46]. Such experiences include headaches, tooth pain, joint, or muscle pain, and may be caused, for instance, by illness, injury, dental procedures, or surgery. Ratings were given on a 5-point Likert scale ranging from 0 *(not at all)* to 4 *(always)*. Examples of items include 'When I'm in pain, I feel I can't stand it anymore', 'When I'm in pain, I can't seem to keep it out of my mind', and 'When I'm in pain, I become afraid that the pain may get worse'. Although a three factor structure - with the subscales Rumination, Magnification, and Helplessness – has been reported, only the total PCS score was used in this experiment, with high scores representing high levels of pain catastrophizing. Psychometric analyses revealed good internal consistency (Cronbach's alpha = 0.90) and construct validity [8, 46].

2.3.4 Trait Fear of Pain

The Fear of Pain Questionnaire (FPQ) consists of 31 items describing painful experiences [29, 40]. Participants report the degree of fear they experienced when going through those kinds of pain. Answers were rated on a 5-point Likert scale (A = *no fear at all*; E = *extremely fearful*). The three-factor model of the FPQ consists of the subscales Severe pain, Minor pain, and Medical pain, but only the total score was used in our study. Internal consistency and test–retest stability of this questionnaire are good (Cronbach's alpha = 0.91), and validity has been supported in clinical as well as non-clinical samples [36, 40, 42].

2.3.5 Trait Negative Affectivity

Negative affectivity was measured by means of the Trait version of the Positive And Negative Affect Schedule (PANAS) [37, 50]. This questionnaire consists of 20 adjectives

describing positive and negative emotions. Participants were requested to rate the frequency by which they experienced those feelings in daily life (*very little*; *very often*). The PANAS consists of two subscales, namely Positive affectivity and Negative affectivity, but only the latter one was of interest in this study. The sum of the ten negative adjective scores yielded the total score for Negative affectivity (PANAS-NA). Internal consistency of this subscale indicated good reliability (Cronbach's alpha = 0.88).

2.3.6 Contingency awareness

At the end of the experiment, participants were shown a picture of each of the two colored CPTs together with 16 pictures of the video models of the observation phase. Painful or neutral facial expressions of the models were clearly visible. Participants were asked to sort out these pictures into two piles, combining the models with the CPTs used in the video.

2.4 Procedure

Participants were informed about the course of the experiment before signing informed consent. They were told that the study investigated responses to cold stimuli. Before the start of the experiment, participants completed the Pain Catastrophizing Scale [46], the Fear of Pain Questionnaire [40], and the Trait version of the Positive And Negative Affect Schedule [37].

The experiment consisted of three phases (see Fig.1). During the *observation phase*, the video of the 16 facial expressions of human models performing a CPT was shown on a computer screen. Afterwards, participants were asked to report pain-related fear, expected pain unpleasantness, and expected pain intensity related to their own performance on the upcoming CPTs, without being aware of the total duration of the tasks. During the *exposure phase*, participants consecutively immersed one hand in the first CPT (e.g. CS+) and the other hand in the second CPT (e.g. CS-), for one minute each time, without watching the neutral and painful facial expressions. The order of the CPTs was counterbalanced to control for

carry-over effects. Both immersions were preceded by a one-minute room temperature immersion and followed by a recovery period, also lasting one minute. Temperature of the water was held constant at 10°C. During immersion, a tone was presented at five points in time. At those moments, participants verbally indicated the level of pain they experienced on an 11-point rating scale. After 60 seconds, the instruction to remove the hand from the colored liquid appeared on the computer screen. During the *recovery phase* (one minute after each immersion), the same tone was presented and pain ratings were registered in order to examine the decline of participants' pain experience. After each CPT, participants were instructed to report pain-related fear and pain unpleasantness, based on their current experience with both CPTs. Once the two tasks were completed, self-reported hesitation was assessed and participants were asked which of the CPTs they wanted to repeat if they had to choose one more immersion task and for which reason. Subsequently, contingency awareness was checked by means of pictures of the models from the video extracts. At the end of the study, all participants were invited for a debriefing where they were informed about the objectives and broader context of the experiment.

- Insert Fig. 1 about here –

2.5 Statistical analyses

Repeated measures ANOVA, with stimulus type (CS+ versus CS-) as the within subject variable, was used to analyse indices of *pain-related fear*, both after observation and exposure. Similar analyses were conducted for *pain unpleasantness, expected pain intensity,* immersion latency, and self-reported hesitation*. Experienced pain intensity* was investigated separately for exposure and recovery by means of repeated measures ANOVA with stimulus type and time as within subject variables. In order to investigate the influence of putative

moderators, centered PCS, FPQ, and PANAS-NA scores were entered as covariates. Moderation was present if a significant statistical interaction was found between scores on the questionnaire and stimulus type. Regression analyses were conducted separately for both stimulus types to explore moderation effects. Subsequently, regression slopes were plotted. All analyses were conducted with an alpha ≤ 0.05, using SPSS 17.0. Where relevant, Greenhouse-Geisser estimates of sphericity were used to correct degrees of freedom whenever this sphericity assumption was violated (Mauchly's Test of Sphericity), resulting in the report of partial degrees of freedom.

3 Results

3.1 Sample characteristics

Participants' scores on the questionnaires are presented in Table 1. Mean scores were comparable to what has been reported in previous research [37, 40, 46]. Scores on the FPQ were positively correlated with those on the PCS and scores on the PANAS-NA. An overview of participants' mean scores, standard deviations, and ranges for all dependent variables in the three phases are presented in Table 2.

- Insert Table 1 about here –
- Insert Table 2 about here -

3.2 Self-reports concerning the CPTs

3.2.1 Observation phase

A main effect of stimulus type was found on *fear of pain*, $F(1,60) = 69.14$, $p < 0.001$ (Fig. 2). Participants reported more fear (mean = 5.75, 95% CI = 5.04-6.47) with regard to the CS+ task compared to the CS- task (mean = 1.90, 95% CI = 1.30-2.50). In addition, pain

catastrophizing, fear of pain, and negative affectivity scores were associated with fear reports, $F(1,59) = 19.65$, $p < 0.001$; $F(1,59) = 20.36$, $p < 0.001$; $F(1,59)$ 5.84, $p = 0.02$, respectively. Participants with a higher score on the measures of these constructs reported more fear regarding both CPTs. A significant PANAS-NA x Stimulus type interaction was found on pain-related fear, $F(1,59) = 4.20$, $p = 0.04$, indicating that negative affectivity moderated the observational fear learning effect. Concerning the CS+ task, participants scoring higher on negative affectivity reported more pain-related fear compared to lower scorers, $\beta = 0.36$, $p = 0.004$. Concerning the CS- task, no difference on pain-related fear was found between lower and higher levels of negative affectivity ($\beta = 0.04$, ns) (Fig. 3). In contrast to our expectations, pain catastrophizing (PCS) and trait fear of pain (FPQ) did not moderate this observationally learned fear of pain, $F(1,59) = 0.57$, ns; $F(1,59) = 3.85$, ns, respectively.

Concerning *expected pain unpleasantness*, a main effect of stimulus type was found, $F(1,60) = 117.47$, $p < 0.001$ (Fig. 2). Participants expected pain to be more unpleasant (mean = 8.16, 95% CI = 7.70-8.63) when being exposed to the CS+ task compared to the CS- task (mean = 4.12, 95% CI = 3.56-4.67). No main effects of pain catastrophizing, $F(1,59) = 3.31$, $p = 0.07$, fear of pain, $F(1,59) = 1.03$, ns, or negative affectivity, $F(1,59) = 0.30$, ns, were found. Furthermore, scores on these measures did not moderate the relationship between stimulus type and expected pain unpleasantness, $F(1,59) = 0.76$, ns; $F(1,59) = 0.70$, ns; $F(1,59) = 2.27$, ns, respectively.

With regard to *expected pain intensity*, a main effect of stimulus type was found $F(1,60) = 59.37$, $p < 0.001$ (Fig. 2). Participants expected more intense pain with respect to the CS+ task (mean = 6.62, 95% CI = 5.91-7.33) compared to the CS- task (mean = 2.39, 95% CI = 1.67-3.12). No main effects of PCS, $F(1,59) = 1.73$, ns, FPQ, $F(1,59) = 3.47$, $p = 0.07$ or PANAS-NA, $F(1,59) = 0.45$, ns, were found. Pain catastrophizing, fear of pain and negative affectivity did not moderate the relationship between stimulus type and expected pain, $F(1,59) = 0.78$, ns; $F(1,59) = 0.80$, ns; $F(1,59) = 1.91$, ns, respectively.

- Insert Fig. 2 about here –
- Insert Fig. 3 about here –

3.2.2 Exposure phase

Results of the exposure phase are shown in Fig. 2. After firsthand experience with the CPTs, main effects on *pain-related fear* were found for stimulus type, $F(1,60) = 5.34$, $p = 0.02$, pain catastrophizing, $F(1,59) = 14.98$, $p < 0.001$, and trait fear of pain, $F(1,59) = 18.68$, $p < 0.001$, despite equal temperature of both CPTs. More fear was reported with regard to the CS+ task (mean = 3.87, 95% CI = 3.14-4.60), compared to the CS- CPT (3.18, 2.52-3.84). Participants who scored high on PCS and/ or FPQ reported more fear during both CPTs, compared to low scorers. No main effect of negative affectivity was found, $F(1,59) = 3.35$, $p = 0.07$. Pain catastrophizing, trait fear of pain, and negative affectivity did not moderate this observational fear learning effect, $F(1,59) = 0.27$, ns; $F(1,59) = 0.26$, ns; $F(1,59) = 2.49$, ns, respectively.

For *pain unpleasantness* ratings, no main effects of stimulus type $F(1,60) = 0.17$, ns, pain catastrophizing, $F(1,59) = 0.29$, ns, fear of pain, $F(1,59) = 0.84$, ns, or negative affectivity, $F(1,59) = 0.29$, ns, were found. However, a Stimulus type x PCS interaction was found, $F(1,59) = 4.70$, $p = 0.03$, indicating that pain catastrophizing moderated the observational learning effect on pain unpleasantness. However, regression analyses for both stimulus types separately did not reveal any significant relation with pain unpleasantness (CS+: $\beta = 0.20$, ns; CS-: $\beta = 0.08$, ns) (Fig. 4). Trait fear of pain, $F(1,59) = 0.93$, ns, and negative affectivity, $F(1,59) = 0.37$, ns, did not show a moderating effect.

The course of *pain intensity* during exposure was investigated by means of repeated measures ANOVA with stimulus type and time as within subject variables (Fig. 5). A main

effect of time was found for pain intensity during immersion, $F(1.91,89.59) = 156.45$, $p < 0.001$, with pain experience increasing over time. No main effect of stimulus type was found, $F(1,47) = 0.69$, ns, indicating that the observational fear learning effect did not generalize toward experienced pain. In addition, no interaction was found between stimulus type and time, $F(2.96,139.22) = 1.41$, ns, indicating that pain intensity across time was similar for the CS+ and the CS- task. High pain catastrophizers and participants with high fear of pain scores reported more pain during immersion compared to low scorers, $F(1,46) = 5.12$, $p = 0.03$; $F(1,46) = 4.06$, $p = 0.05$, respectively. No main effect of negative affectivity was found during immersion, $F(1,46) = 0.002$, ns. Pain catastrophizing, trait fear of pain, and negative affectivity did not moderate the relationship between stimulus type and pain intensity ratings, $F(1,46) = 0.02$, ns; $F(1,46) = 0.006$, ns; $F(1,46) = 0.11$, ns, respectively.

- Insert Fig. 4 about here –

3.2.3 Recovery phase

Analyses of *pain intensity ratings* one minute *after immersion* revealed a main effect of time, $F(1.31,77.38) = 116.08$, $p < 0.001$, with pain intensity diminishing over time. No main effect of stimulus type was found, $F(1.59) = 2.37$, ns, indicating that pain ratings were similar for both CPTs. Additionally, pain ratings across time were similar for both CPTs, as no interaction was found between stimulus type and time $F(1.43,84.29) = 0.81$, ns. Main effects were found for pain catastrophizing, $F(1,58) = 4.08$, $p = 0.05$, and trait fear of pain, $F(1,58) = 14.06$, $p < 0.001$. Participants with high PCS and/ or FPQ scores reported more pain compared to low scorers. No main effect of negative affectivity was found after immersion, $F(1,58) = 1.17$, ns. Pain catastrophizing, trait fear of pain, and negative affectivity did not

moderate the relationship between stimulus type and pain intensity ratings during recovery, $F(1,58) = 0.23$, ns; $F(1,58) = 0.49$, ns; $F(1,58) = 0.11$, ns, respectively.

- Insert Fig. 5 about here –

3.3 Avoidance behavior

Latency time was available only for 50 participants (81%), due to technical difficulties occurring in the course of the experiment. No difference between the CS+ and CS- task was found with regard to immersion latency (suppression of the button), $F(1,49) = 0.36$, ns, although participants had the impression to be more indecisive before starting the CS+ task, $F(1,61) = 18.62$, $p < 0.001$ (self-reports, CS-: mean = 2.02, SD = 2.25; CS+: mean = 3.40, SD = 2.96). There were no early withdrawals in either task. When being asked which of the two CPTs they would choose when requested to perform one additional CPT, only 50% of the participants preferred to repeat the CS- task. Hence, no avoidance behavior was observed regarding the CS+ task, suggesting that both CPTs were perceived equally aversive.

3.4 Contingency awareness

The picture sorting task to assess contingency awareness revealed that 95% of the participants were aware of the contingency between color and facial expression. Awareness data of two participants were missing. However, data of all participants were included in statistical analyses as contingency awareness is not a necessary feature for differential fear conditioning in pain [52].

4 Discussion

Although there is accumulating research evidence supporting the fear-avoidance model in explaining pain-related interference with daily life activities, literature on the

acquisition of pain-related fear is scarce [24]. The primary aim of this study was to investigate whether pain-related fear develops by observing others displaying pain behavior. Using a differential fear conditioning procedure, participants watched a video showing human models performing colored cold pressor tasks (CPTs). Participants were informed that they would perform the same tasks afterwards. One color (CS+) was associated with painful facial expressions of the video models; the other (CS-) with neutral faces (counterbalanced). The results showed that participants reported more *pain-related fear* when anticipating the CPT associated with the painful expressions (CS+). They also expected this task to be more *unpleasant* and *painful* than the CS- task. After firsthand exposure to the CPTs, no difference was found with regard to *pain intensity* or *pain unpleasantness*, although participants still reported more *pain-related fear* regarding the CS+. During recovery, pain intensity ratings regarding both CS+ and CS- tasks rapidly diminished. Furthermore, the acquisition of pain-related fear was more pronounced in participants higher in negative affectivity.

The present study is one of the first to provide evidence for observational learning of pain-related fear beliefs in humans. In general, three pathways have been considered in the etiology of fear: experiential learning (i.e., fear develops after direct experience with the aversive stimulus) [38], instructional learning (i.e., transmission of verbal information about the aversive stimulus) [15, 32], and observational learning (i.e., learning as a consequence of observing others' behaviors encountering an aversive stimulus). Common to these pathways is that a neutral stimulus acquires motivational qualities after being functionally associated with an aversive stimulus. Although it is widely accepted that knowledge about fear-related objects or situations can be acquired by social observation [38], the evidence is meager, and related studies in the area of pain-related fear almost non-existent. In addition, much of the available evidence on observational fear learning has been obtained using retrospective self-reports [21]. During the last decade, however, experimental evidence has been generated for observational learning as a pathway to fear in children. Toddlers displayed greater fear

expressions and avoidance behavior towards a novel fear-relevant toy (plastic snake or spider) after witnessing their mothers with fear and disgust expressions towards that toy [17]. Similarly, children exposed to pictures of novel animals paired with pictures of either scared, happy or no facial expressions displayed more avoidance behavior to the animals that they had previously seen paired with scared faces [2]. In the context of *pain*, most research has focused on the influence of modeling on pain intensity, threshold and tolerance. For example, Craig and Weiss [7] examined the impact of pain tolerant and intolerant social models on students' verbal pain reports induced by electrical stimulation. There was a significant impact on both pain expressions and willingness to accept pain stimuli of increased intensity. More recently, Olsson et al. (2004) demonstrated that observational fear learning occurred through observation of the emotional expression of a confederate receiving shocks paired with a CS+ (angry male faces).

The results of the current study show that pain-related fear can be acquired by healthy subjects observing another person displaying pain behaviors when being in contact with an ambiguous stimulus. Not only are subjects aware of the contingencies between the facial expressions and the color of the CPT's, they indeed report more fear for the CS+, and expect the CS+ to be more painful. Despite the ambiguous but equal temperature of both CPTs, fear of pain did not totally extinguish after the actual exposure to the water although the difference in fear ratings is much lower than after the observation phase. Possibly, repeated exposures are needed for fear to extinguish totally [27]. Despite the difference in fear levels after immersion, no differences in pain intensity and unpleasantness were reported. This is in contrast with the study of Arntz and Claassen [1], in which fear beliefs were found to increase pain intensity ratings during exposure. One possible explanation for the absence of a differential effect on pain intensity may relate to the temperature of the CPTs. Pain intensity ratings rapidly increased throughout both immersions. Consequently, participants might have perceived both tasks as aversive/painful, rather than ambiguous. The results of the behavioral

measures used in the current experiment revealed no difference between the two tasks regarding immersion latency. One possible explanation for the absence of this differential effect might be related to the peremptory nature of the instruction (participants were asked to immerse their hand into the liquid as soon as the instruction appeared on the computer screen). Perhaps a better instruction would have been to ask participants to immerse their hand into the water whenever they felt ready to do so. Furthermore, participants did not show a preference for the CS- task when they were asked which task they would prefer to repeat. These findings raise the question under which conditions observationally learned fear translates into avoidance behavior. Personal relevance or needs of the observer might play an important role in this process [19]. Potentially painful situations may be more salient and relevant to pain patients compared to healthy controls, thereby facilitating the translation of fear beliefs into overt avoidance. The current findings may have implications in the context of clinical pain, although we have to be cautious in generalizing these results to a clinical population. Regarding the acquisition of pain-related fear, it is possible that relatives or friends of pain patients who witness these individuals avoiding particular situations or movements because of their pain-related fear, learn a contingency between avoiding and (relief of) pain. Later in life, when experiencing pain themselves, this latent knowledge may become activated, and may potentiate avoidance behavior, a process by which an individual may enter a downward spiral of increasing disability and pain [49]. Furthermore, the results suggest that individuals with higher negative affectivity may be more prone to develop pain-related fear. Negative affectivity is a general dimension of subjective distress that subsumes a variety of aversive mood states, including fear [50]. This finding extends prior research indicating that individuals reporting higher negative affectivity show hypervigilance to different forms of threat, and therefore are assumed to be more vulnerable to develop specific fears [13].

It is likely that the strength of observational learning also depends upon the nature of the relationship between model and observer, with models perceived as in closer proximity having more impact than those perceived as belonging to an 'outgroup' [18, 51]. In the current study, pain sufferers and observers were strangers to each other. Accordingly, observational learning effects may be larger when the pain sufferer is a spouse or an acquaintance. In addition, the observer's capacity to empathize with the model might influence the experienced distress [18].

Knowledge about pain-related fear acquisition may help developing novel pain management programs, since this fear can be more disabling than the pain itself, and is one of the risk factors leading to chronic disability [8]. Results of the current study suggest that observing others expressing pain may lead to an increase in pain-related fear beliefs and enhanced pain intensity expectancy. Extinction of pain-related fear for the CPT was tested through actual experience of the CPT. It would be interesting to test whether extinction can also be established by observing another person being exposed to the CPT without the painful expression as the US. Such a technique might also be useful in pain treatments. Witnessing a model acting fearless with respect to a painful stimulus or situation may be a protective factor in fear learning, resulting in decreased pain intensity expectancy, which in turn might lead to reduced subjective pain experience and pain-related brain activation [22].

There are several limitations to this study, yielding implications for future research. First, an important limitation is the lack of a baseline measure for pain-related fear for the CPTs, precluding statistical control for differences on this measure in testing fear acquisition through observation. Second, Lang [23] conceptualized fear as three relatively independent response systems: language behavior (self-reports), physiological responses, and avoidance behavior. In the current study only self-reports and behavioral measures were included. Future studies should comprise sensitive, reliable measures for all three fear components. Third, only facial pain expressions of the models were used. We expect the observational learning effect

to be stronger if the faces are accompanied by vocal expressions and total body movements. This would also increase the ecological validity of the unconditioned stimuli [9]. Nonetheless, differential effects after observation of the video models were quite pronounced. Finally, participants were all healthy young females, which restricts external validity and further studies are needed to test whether our findings generalize to male samples and individuals suffering acute or chronic pain.

Despite these limitations, the findings of this study provide preliminary evidence for observational learning of pain-related fear beliefs in humans. Participants feared the CS+ CPT after witnessing models' pain expressions, indicating that direct experience is not a necessary feature for the acquisition of pain-related fear.

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6 Disclosure

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8 Figure legends

Figure 1. Graphical overview of the experimental procedure, with the measurements during the observation, exposure, and recovery phases. During the observation phase, one color is associated with painful facial expressions of the video (top), while the other color is paired with neutral expressions (bottom).

Figure 2. Self-reports concerning the CPTs after watching the video (observation phase) and after each immersion (exposure phase).

* $p < 0.05$, ** $p < 0.001$.

Figure 3. Observation phase. Negative affectivity (PANAS-NA) moderated the relationship between stimulus type and pain-related fear during the observation phase. Regression lines for both stimulus types are shown. Scores of the questionnaires were centered.

* $p < 0.05$, ** $p < 0.01$

Figure 4. Exposure phase. Pain catastrophizing moderated the association between stimulus type and pain unpleasantness during the exposure phase. Regression lines for both stimulus types are shown. Scores of the questionnaires were centered.

* $p < 0.05$, ** $p < 0.01$

Figure 5. Pain intensity ratings during exposure (left) and recovery (right).

Figure 1

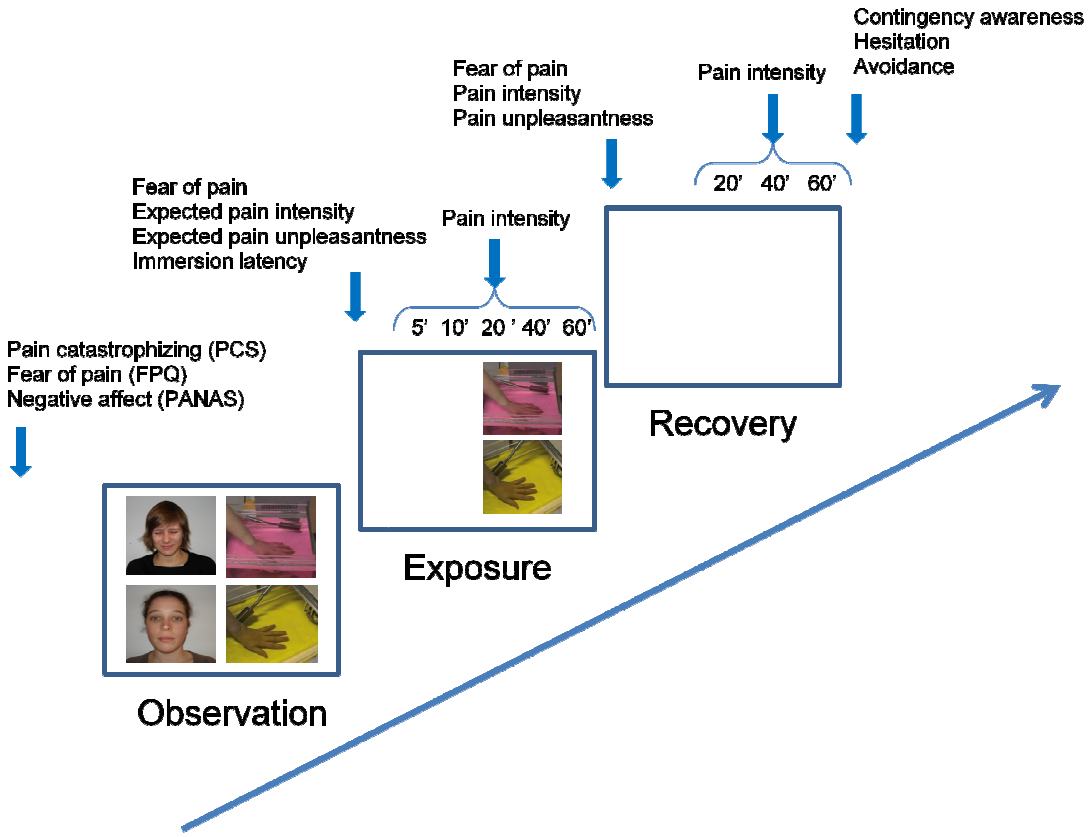
Contingency awareness
Hesitation
Avoidance
Fear of pain
Pain intensity
Pain unpleasantness
Pain intensity
20' 40' 60'
Fear of pain
Expected pain intensity
Expected pain unpleasantness
Immersion latency
Pain intensity
5' 10' 20 ' 40' 60'
Pain catastrophizing (PCS)
Fear of pain (FPQ)
Negative affect (PANAS)
Recovery
Exposure
Observation

Figure 2

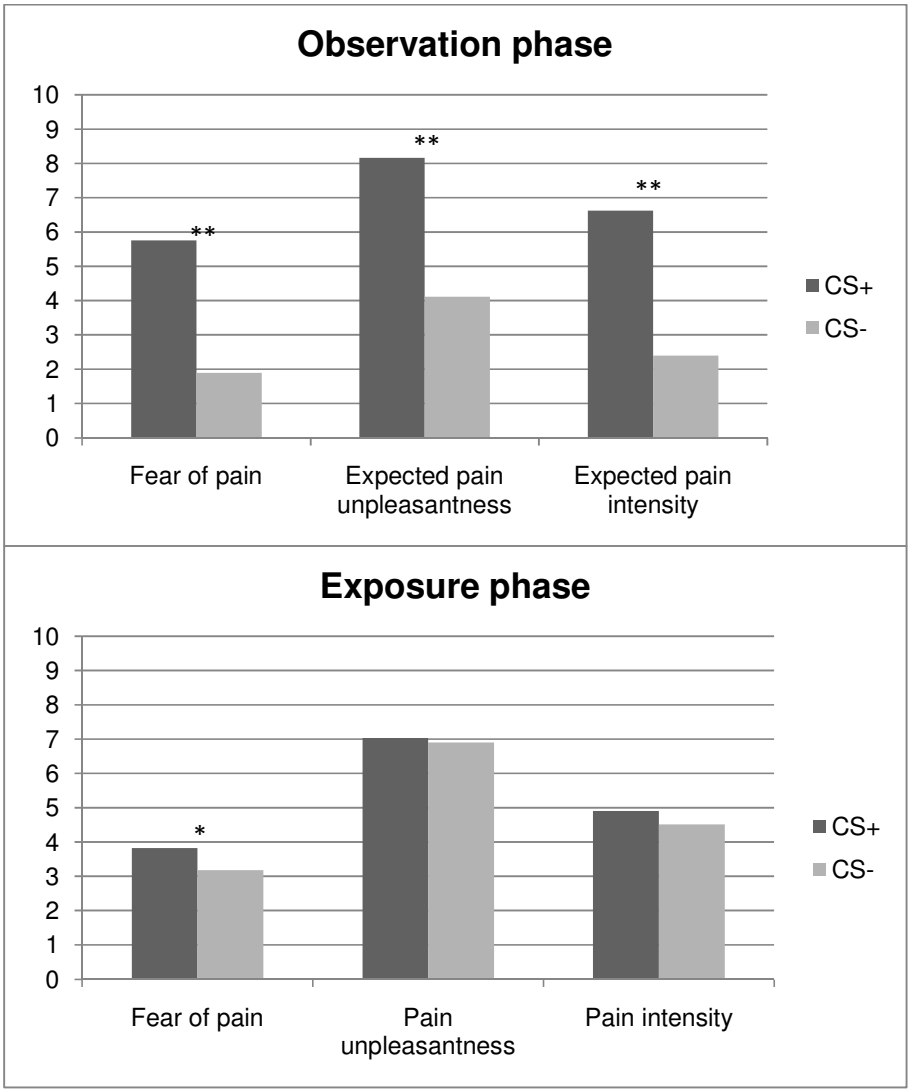
Observation phase
10
9
8
7
6
5
4
3
2
1
0
**
**
**
Fear of pain
Expected pain unpleasantness
Expected pain intensity
CS+
CS-
Exposure phase
10
9
8
7
6
5
4
3
2
1
0
*
Fear of pain
Pain unpleasantness
Pain intensity
CS+
CS-

Figure 3

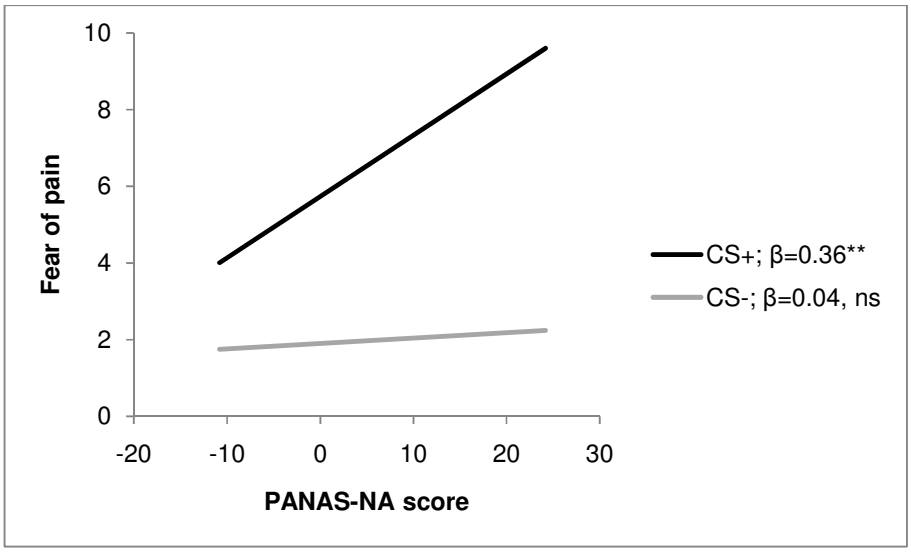
10
8
6
4
2
0
Fear of pain
-20
-10
0
10
20
30
PANAS-NA score
CS+; β=0.36**
CS-; β=0.04, ns

Figure 4

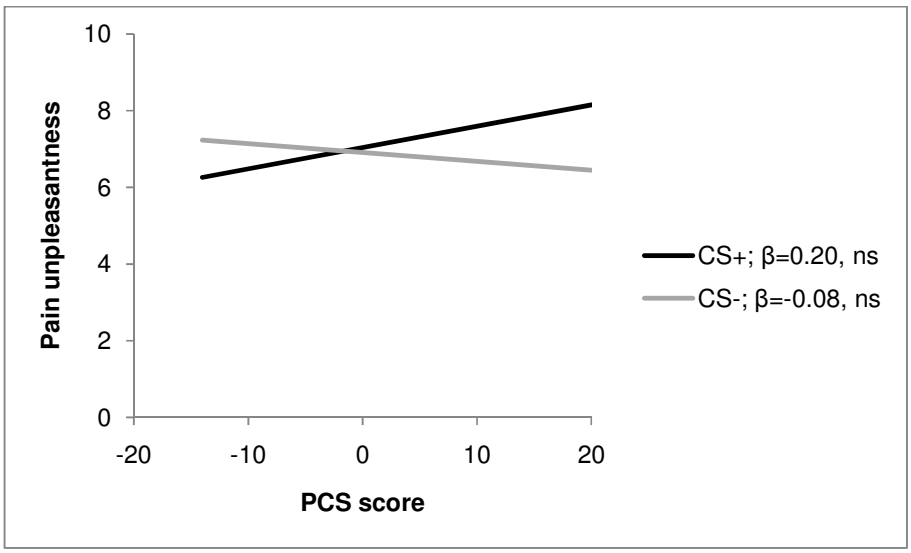
10
8
6
4
2
0
Pain unpleasantness
-20
-10
0
10
20
PCS score
CS+; β=0.20, ns
CS-; β=-0.08, ns

Figure 5

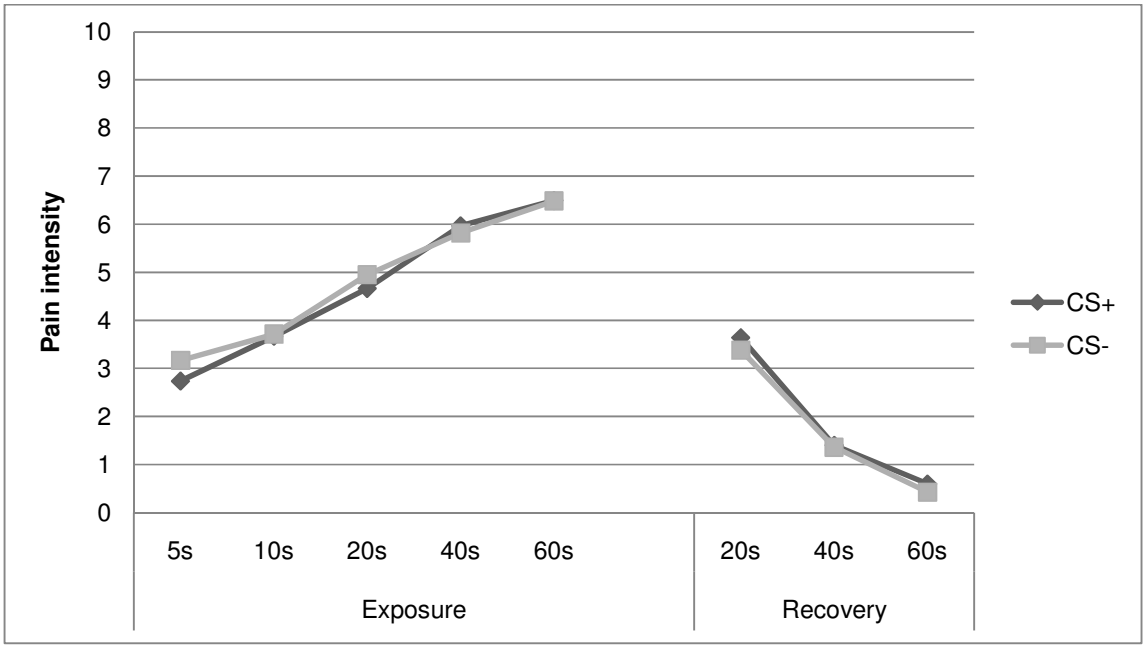
Pain intensity
10
9
8
7
6
5
4
3
2
1
0
5s
10s
20s
40s
60s
20s
40s
60s
Exposure
Recovery
CS+
CS-

Table 1

Means (M), Standard Deviations (SD), Cronbach's alpha, and Pearson intercorrelations of the Questionnaires.

Variable	Cronbach's alpha	M	SD	2	3
1 Pain catastrophizing (PCS)	0.90	17.02	8.42	0.47*	0.19
2 Trait fear of pain (FPQ)	0.91	75.29	14.79	-	0.35*
3 Negative affectivity (PANAS-NA)	0.88	20.81	6.48	-	-

Note. PCS = Pain Catastrophizing Scale, FPQ = Fear of Pain Questionnaire, and PANAS-NA = Positive And Negative Affect Schedule - Negative Affectivity subscale.

* $p < 0.05$.

Table 2

Means (M), Standard Deviations (SD), and response ranges for the different dependent variables throughout the three experimental phases.

Phase	Variable	Stimulus type	M	SD	range
Observation phase	Pain-related fear	CS+	5.75	2.81	0-10
		CS-	1.90	2.36	0-9
	Pain unpleasantness	CS+	8.16	1.81	0-10
		CS-	4.11	2.18	0-8
	Pain intensity	CS+	6.62	2.78	0-10
		CS-	2.39	2.83	0-9
Exposure phase	Pain-related fear	CS+	3.82	2.84	0-9
		CS-	3.18	2.57	0-8
	Pain unpleasantness	CS+	7.03	2.33	1-10
		CS-	6.90	2.37	0-10
	Latency time (ms)	CS+	3504	1061	1986-6047
		CS-	3394	1043	1837-7178
	Pain intensity 5s	CS+	2.74	2.27	0-8
		CS-	3.16	2.32	0-8
	Pain intensity 10s	CS+	3.67	2.43	0-9
		CS-	3.71	2.41	0-8
	Pain intensity 20s	CS+	4.66	2.47	0-10
		CS-	4.95	2.51	0-9
	Pain intensity 40s	CS+	5.97	2.40	0-10
		CS-	5.82	2.42	0-10
	Pain intensity 60s	CS+	6.49	2.27	0-10
		CS-	6.48	2.42	0-10
Recovery phase	Pain intensity 20s	CS+	3.64	2.65	0-8
		CS-	3.38	2.61	0-8
	Pain intensity 40s	CS+	1.40	1.80	0-6
		CS-	1.36	1.67	0-5
	Pain intensity 60s	CS+	1.06	1.81	0-4
		CS-	0.43	0.83	0-3

Note. CS+ = aversive conditioned stimulus; CS- = neutral conditioned stimulus