The Influence of Conditioned Fear on Human Pain Thresholds: Does Preparedness Play a Role?

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Abstract: Emotionally charged facial expressions (happy, fear) served as conditioned stimuli in a differential fear conditioning procedure. Expressions were presented in pseudo-random order on a computer monitor. For half of the participants, the fear expression was paired with an aversive electric stimulation (UCS), whereas the happy expression was unpaired. The other participants had the opposite pairing. To assess the influence of conditioned fear on pain, expressions were shown again in the absence of the UCS and pain threshold was assessed during each expression. The latency of finger withdrawal from a radiant heat device was used to index pain threshold. Skin conductance response (SCR) and self-reported emotion were measured to assess fear conditioning. Consistent with preparedness theory, differential fear conditioning was only present when the fear expression was paired with the UCS. Moreover, pain threshold was only influenced by fear conditioning in persons for whom the fear expression was paired with the UCS. Specifically, finger withdrawal latencies were lower (suggesting hyperalgesia) during the fear expression than during the happy expression; an effect that was not present before CS/UCS pairing. This work suggests that some stimuli are more readily associated with an aversive event and can lead to pain enhancement.

Perspective: Although preliminary, these results suggest that fear-relevant environmental stimuli (including facial expressions) may provide important environmental cues during aversive events that influence the level of pain experienced.

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Key words: Pavlovian conditioning, pain perception, pain modulation, pain threshold, emotion, fear.

Generally, research suggests that positive emotions inhibit and negative emotions enhance pain. However, recent investigations suggest that a valence (pleasant – unpleasant) by arousal (calm – excited) interaction characterizes the direction of influence. Positively valenced emotions inhibit pain (regardless of arousal level), whereas negatively valenced emotions with low-to-moderate arousals enhance pain, but negative emotions with high arousal inhibit pain.

Some emotional responses are unconditioned/un-learned (fear of a predator). In contrast, most emotional responses are learned through associative processes, such as classical (Pavlovian) conditioning. In classical conditioning, a stimulus (conditioned stimulus, CS) that is repeatedly paired with an unlearned emotional stimulus (unconditioned stimulus, UCS) will develop the capacity to evoke an emotional response similar to the UCS (conditioned response, CR). Through this process, previously neutral stimuli can acquire emotional tone.

Interestingly, the stimulus that serves as the CS can influence the acquired CR. According to preparedness theory, certain stimuli are more readily associated with the UCS leading to more rapid CR development. Thus, the organism is “prepared” for conditioning. For example, research indicates that fear-relevant stimuli (snakes, angry/fear faces), when paired with an aversive UCS (prepared learning), result in faster CR acquisition, stronger CRs, and greater resistance to CR extinction than non-fear-relevant stimuli (flowers, happy faces). Pre- paredness is believed to be learned through evolution and reflects noncognitive learning. Unprepared learning
(pairing non–fear-relevant stimulus with aversive UCS), however, relies on cognitive associations and expectan-
ties.18,19

Importantly, classically conditioned CRs can influence pain. After repeated pairings with an aversive UCS, a previ-
ously neutral stimulus can elicit fear-like responses and changes in pain.9,10,22 In clinical settings, patients who receive repeated painful medical procedures (UCS) may develop an association between the practitioner and the painful procedure UCS. Future trips to the prac-
titioner can elicit conditioned fear (CR) and alter pain. Moreover, classical conditioning may play a role in the de-
development of chronic pain.5,11 Fear of pain (CR) can develop from repeated pairings of a painful UCS with a neutral environmental CS causing increased physiologi-
cal arousal and muscle tension that subsequently exacerbate pain and promote chronicization.5,11 Indeed, research has indicated that chronic pain patients, com-
pared with healthy control subjects, have greater muscle tension when exposed to pain-related images.11 As these examples illustrate, classical conditioning is important for the development of emotional responses that can influence pain. Thus, research employing classical condi-
tioning paradigms are useful for studying the develop-
ment of conditioned emotional responses and factors that influence their development, as well as the influ-
ence of the conditioned responses on pain.

The purpose of this study was to examine the influence of socially relevant CSs on the development of condi-
tioned fear and the subsequent impact of conditioned fear on pain threshold. To do so, a differential fear-con-
tioning paradigm was used in which 2 facial expression CSs (happy, fear) were presented, and 1 (CS+) was paired with a moderately aversive 5-mA shock UCS. This UCS was chosen to promote moderately arousing CRs (mod-
errately arousing negative affect) and hyperalge-
sia.21,23,24 By contrast, other studies have used highly aversive UCSs that resulted in highly arousing CRs and hypoalgesia.5,10,22,33 Noxious radiant heat was later de-
lected during each CS to determine the influence of the CR on pain threshold. Thus, the impact of preparedness (previous noncognitive learning) on fear-conditioning was assessed. Based on preparedness theory, we pre-
dicted that moderately arousing conditioned fear would only develop in those participants for whom the fear expression served as the CS+,20,29,30 and only this group would demonstrate conditioned fear-induced hyperalge-
sia.

Materials and Methods

Participants

Fifty-seven undergraduate students provided in-
formed consent and received course credit for their par-
ticipation. Most were female (n = 36), white non-His-
panic (73.7%, n = 42), single (96.5%), and employed (68.4%), with an average age of 20.46 (SD = 1.74). Par-
ticipants were excluded for age <18 years, cardiovas-
cular, neurological, and/or circulatory problems, recent use of analgesic, anxiolytic, or antidepressant medication, recent psychological trauma, problems healing, Raynaud’s disease, or any medical problem exacerbated by stress. Nine were excluded because they did not experience the UCS as aversive (see Unconditioned Stimulus section below), 1 participant chose to discontinue the experiment before it was completed because the electric stimulations were too aversive, 3 were excluded due to equip-
ment problems, and 2 participants were excluded due to failure to correctly perform the heat tests. Thus, 42 par-
ticipants (31 female) were included in analyses. All pro-
cedures were approved by The University of Tulsa ethics review board.

Apparatus

Stimulus and questionnaire presentation and data acqui-
sition were computer-controlled, using a PC equipped with dual monitors and A/D board (PCI-6036E; National Instruments, Austin, TX). LabVIEW software (National Instruments) was used to control timing of the experimen-
tal protocol and all off-line data reduction. One 17-inch flat panel monitor was used by the experimenter to monitor experimental timing. The other 17-inch flat panel monitor positioned 0.5 meter from the participant pre-
tended visual stimuli and questionnaires. Skin conduc-
tance response (SCR) was sampled at 50 Hz and collected/ filtered using a Grass Instruments Model 15LT Bipolar Amplifier with a Dual DC (15A12) module and adaptor (Model SCA1; Grass Instruments, West Warwick, RI). Electric stimulation used as the UCS was delivered using a Grass Instruments stimulator (Model S88; Grass Instru-
ments), stimulus isolation unit (Model SIU8T; Grass Instru-
ments) was used to control timing of the experimen-
talstimulation used as the UCS was delivered using a Grass Instruments stimulator (Model S88; Grass Instru-
ments), stimulus isolation unit (Model SIU8T; Grass Instru-
iments), constant current unit (Model CCU1; Grass instru-
tments), and bipolar stimulating electrode (019-401400; Nicolet, Madison, WI). Sound-attenuating head-
phones and a video camera allowed the experimenter to communicate with and monitor the participant from an adjacent room.

Conditioned Stimuli: Facial Expression Pictures

Pictures of facial expressions were chosen from the Montreal Set of Facial Displays of Emotion.1 The pictures consisted of displays of fear, happy, and neutral expres-
sions. A female and male model (both white) displaying each of these expressions were chosen. Model gender was controlled by counterbalancing across participants. Facial expressions were displayed on the computer screen for 10 seconds with a random inter-trial interval (ITI) of 35 to 75 seconds during habituation and extinction and 35 to 50 seconds during acquisition. Interval lengths were set to ensure adequate recovery time be-
tween radiant heat tests (ie, to reduce sensitization). Fa-
cial expressions were presented in a pseudorandom or-
der with the same expression appearing no more than 2 times consecutively. Each of the expressions was shown 3 times during the habituation phase. The neutral expres-
sion was only presented during habituation to examine hypotheses not addressed in the present study; thus, neutral expression data will not be discussed here. Dur-
therefore decided some participants would not find the UCS aversive. It was same stimulus intensity was used, there was a risk that tions of moderate discomfort to mild pain. Because the chosen because pilot testing suggested it led to sensa-

pants to the UCS before testing. A 5-mA intensity was

threshold) to eliminate the need to pre-expose partici-

ations were displayed 4 times each. Prior to the experi-

ment, half of the participants were assigned to have the fear expression as a CS+ (Fear CS+ group) and the other half to have the happy expression as the CS+ (Happy CS+ group).

**Unconditioned Stimulus (UCS – Electric Stimulation)**

The stimulating electrode was applied over the retro-
malleolar pathway of the left sural nerve. The site was first degreased with alcohol, slightly abraded with Nu-

Prep gel to achieve impedances below 10 KΩ, and then conductive gel (EC60; Grass Instruments) was applied. The computer controlled the onset/offset of electric stim-

ulation. Previous research suggests that shock exposure itself can influence pain perception.21,25 Therefore, it was decided to use the same stimulus intensity (ie, 5 mA) rather than the same perceived intensity (eg, pain threshold) to eliminate the need to pre-expose partici-

tants to the UCS before testing. A 5-mA intensity was chosen because pilot testing suggested it led to sensa-
tions of moderate discomfort to mild pain. Because the same stimulus intensity was used, there was a risk that some participants would not find the UCS aversive. It was therefore decided a priori to exclude participants that did not rate the UCS as at least mildly uncomfortable (≥10 on the 0 to 100 scale, see UCS Pain Rating Scale section below). As a result, 9 participants were excluded (4 rated it 0, 5 rated it as ≤5). Each stimulation consisted of a 150-msec train of rectangular wave pulses of 1 msec duration and 3 msec interstimulus intervals (250 Hz). Electric stimulations were delivered simultaneous with CS+ offset during the acquisition phase only. Therefore, a total of 4 electric stimulations were presented.

**UCS pain rating scale.** This computer-presented scale was oriented vertically with labels of 0 (no sensa-
tion), 1 (just noticeable), 25 (uncomfortable), 50 (pain-
ful), 75 (very painful), and 100 (maximum tolerable). Parti-
cipants dragged an indicator to the desired point along the scale and pressed a button to submit their answer.28 At the end of the experiment, participants were asked to rate their sensation of the UCS to verify its aversiveness. Participants were only included in analyses if they rated the UCS ≥10.

**Pain Threshold: Finger Withdrawal Latencies**

A bottom-illuminated radiant heat device was used to deliver noxious heat.21 Light from a slide projector bulb was focused onto the distal digit of the participants' blackened fingertips using a condenser lens. The index, middle, and ring fingers of the nondominant hand were alternated to minimize sensitization and finger order was counterbalanced across participants.26 Participants were instructed to remove their finger as soon as the heat became painful. The time from light onset to finger withdrawal (in seconds) was used as a measure of pain threshold.21–23,25 Light onset was controlled by the com-

puter and finger withdrawal was detected by photore-
sistors in the platform of the device. The computer timed and recorded finger withdrawal latencies to the nearest hundredth of a second. Heat onset occurred 5 seconds after facial expression onset during habituation and extin-
tection phases to test pain threshold. An 8-second cutoff was used to avoid tissue damage. Latencies less than 0.5 second were treated as missing data.

**Manipulation Checks**

Physiological arousal and self-report emotion mea-

sures were used to assess the effectiveness of differential fear-conditioning procedures.

**Skin conductance response (SCR).** SCR was used to measure sympathetic arousal resulting from the onset of each facial expression CS. SCR was measured by plac-

ing Ag-AgCl electrodes filled with isotonic paste (EC33; Grass Instruments) on the volar surface of the middle and ring fingers of the right hand. The signal was recorded 2 seconds before and 10 seconds during the presentation of facial expressions. To calculate SCR resulting from pic-
ture onset, mean skin conductance in the 1 second be-

fore the onset of the facial expression was subtracted from each half-second epoch during the expression. SCR was defined as the maximum increase 1 to 4 seconds after expression onset.3,32 Therefore, SCR corresponds to the peak arousal resulting from the picture stimulus alone (ie, no UCS or heat-related artifacts contaminate the response).

**Subjective ratings: Valence and arousal ratings.** The Self-Assessment Manikin (SAM)2 consists of 2 sets of 5 pictographs depicting affective valence/pleasure (un-

pleasant-pleasant) and arousal (calm-excited). A com-

puterized version of the SAM was constructed using Lab-

VIEW, and participants dragged an indicator for each scale on or between any of the pictographs and submit-
ted their answer by computer mouse. This yielded ratings between 1 and 9 for each dimension, with higher scores being associated with greater subjective arousal and pleasure (lower pleasure scores = greater displeasure). Participants rated their affective reactions immediately after each expression during the habituation phase. At the end of the experiment, fear and happy expressions were presented again and participants were asked to again rate their affective reaction to the expressions. These post-conditioning ratings were compared with ratings from the last habituation trial (preconditioning) to determine if conditioning influenced affective judgments of the stimuli.14,15

**Background Questionnaires**

Several questionnaires were used to examine group differences on variables that could influence responses to the experiment. The catastrophizing subscale of the Coping Strategies Questionnaire (CSQ) was used to de-
termine if groups differed in their catastrophic thoughts associated with pain.12 Higher scores on this subscale are associated with greater catastrophizing and pre-
dict enhanced subjective pain and poorer clinical pain
outcomes. The Self-Efficacy for Pain Reduction scale (SE-PR) is a 5-item scale that measures participants’ beliefs that they can reduce their pain without medication. Scores range from 0 to 50 with higher scores being associated with greater self-efficacy. The Behavioral Activation and Behavioral Inhibition Scales (BIS-BAS) were measured to examine propensities to respond to reward or punishment that could influence responses to fear conditioning. Behavioral activation (BAS) is the propensity to move toward desired outcomes and behavioral inhibition (BIS) is associated with avoiding unpleasant stimuli.

**Procedure**

After obtaining informed consent, stimulating and recording electrodes were applied and participants were seated in a recliner approximately 0.5 m from the computer monitor. Participants were then instructed on how to use the computer-presented questionnaires and radiant heat device. Fig 1 presents the 3 phases of fear conditioning: Habituation, acquisition, and extinction. Before the habituation phase, instructions were provided by the computer indicating that pictures of facial expressions would be presented and that heat tests would be presented randomly during and between pictures, but that electric stimulations would not be delivered during that phase. Also prior to habituation, 3 practice radiant heat tests were delivered to familiarize the participant with the process. Fear, happy, and neutral expressions were presented in pseudorandom order 3 times each during habituation and pain threshold was assessed during 2 of each expression type. After habituation, computer-presented instructions informed participants that only 2 of the previously seen expressions (happy, fear) would be presented and that electric stimulations (UCS) would be presented during 1 of the expressions. Fear and happy expressions were then presented 4 times each in pseudorandom order during acquisition. Those participants assigned to the Fear CS+ group received stimulations contiguous with the offset of fear expressions, but not during the happy expression. The reverse was true for participants assigned to the Happy CS+ group. Pain threshold was not tested during CSs in the acquisition phase. During extinction, happy and fear expressions were presented 4 times each in pseudorandom order and pain threshold was tested during 2 presentations of each expression. The UCS was not presented during the extinction phase. Heat onset occurred 5 s following the onset of a facial expression. To minimize the association between heat pain and pictures of facial expressions, heat tests were delivered during 7 intertrial intervals (2 habituation, 3 acquisition, 2 extinction). At the end of the experiment, participants rated the UCS using the pain rating scale and their affective reactions to the facial expressions using the SAM. Then, sensors were removed and participants were debriefed.

**Data Analysis**

Repeated-measures ANOVAs were used for most analyses. Independent variables included Expression Type (Happy vs Fear), CS+ Expression (Fear CS+ group vs Happy CS+ group), CS Type (CS+ vs CS–), and Trial. Therefore, Expression Type refers to the content of the picture (happy face or fear face) being shown (before fear conditioning), regardless of which picture is the CS+. CS+ Expression refers to the group assignment of participants to receive electric stimulations during the fear face (Fear CS+ group) or the happy face (Happy CS+ group), and CS Type indicates the stimulus (during acquisition or extinction) reinforced with shock (CS+) or not (CS–). Participant sex was not included in analyses because of the underrepresentation of males in the sample. Follow-up comparisons were conducted using Bonferroni corrected tests. Greenhouse-Geisser correction was used when needed to correct for sphericity and the corresponding epsilon (ε) was reported. Partial eta-squared ($\eta^2$) was used as the effect size for $F$ tests. Cohen provides guidelines for interpreting $\eta^2$ (small = 0.01, medium = 0.06, large = 0.14).

Individual differences in the experienced aversiveness of the UCS could have an effect on the CRs (eg, greater aversiveness could lead to more negative and arousing

![Figure 1. Differential fear-conditioning procedure.](image-url)
CR and hypoalgesia). To examine this hypothesis, analyses on SCR, subjective ratings, and pain outcomes were conducted again controlling for UCS pain rating by entering it as a covariate. This did not influence results or interpretations reported below.

Hypotheses

Physiological arousal (SCR) was expected to decrease with repeated presentations of facial expressions during habituation. During acquisition, reactions indicative of fear (increased skin conductance, subjective displeasure and arousal) were expected to be greater during the CS+ than during the CS−, but only when the fear expression served as the CS+. Pain threshold was not expected to differ by facial expression during habituation (before fear conditioning). However, when tested during extinction (after fear conditioning), pain threshold was predicted to be lower (hyperalgesia) when tested during the CS+ relative to the CS−, but only when the fear expression served as the CS+.

Results

Preliminary Analysis

Analyses were conducted on background variables to ensure that there were no differences between persons included or excluded from analyses. No group differences for age, gender, CSQ catastrophizing, self-efficacy, or Behavioral Activation-Behavioral Inhibition scales emerged ($P > .05$).

For persons completing the experiment, analyses also compared CS+ expression groups (Fear CS+ vs Happy CS+) on background variables. No differences were found ($P > .05$). Importantly, the 2 groups did not differ in their pain ratings of the shock UCS, $t = .42$, $P = .68$ (Fear CS+ group mean = 52.85, Happy CS+ group mean = 49.59).

Manipulation Checks for Differential Fear Conditioning

Skin conductance response (SCR). Fig 2 presents SCR data during habituation, acquisition, and extinction phases. A 2 (Expression Type: Happy, Fear) × 3 (Trial) repeated-measures ANOVA was conducted on habituation phase SCR. No effects were significant ($P > .05$) suggesting fear and happy facial expressions did not differ in the arousal they elicited prior to conditioning. A 2 (CS+ Expression) × 2 (CS Type) × 4 (Trial) repeated-measures ANOVA was conducted on acquisition phase SCR. There was a significant main effect of trial ($F(3,120) = 4.46$, $P = .005$, $\eta^2 = .10$) that was qualified by an interaction of CS Type × Trial ($F(3,120) = 3.91$, $P = .017$, $\eta^2 = .09$, $\epsilon = .81$), but more importantly by the interaction of CS Type × CS+ Expression ($F(1,40) = 5.17$, $P = .028$, $\eta^2 = .12$). Consistent with preparedness theory, follow-up comparisons for the CS Type × CS+ Expression interaction indicated SCR activity was greater during the CS+ than CS− in the Fear CS+ group ($P < .01$), but not the Happy CS+ group ($P = .78$). A 2 (CS+ Expression) × 2 (CS Type) × 4 (Trial) mixed ANOVA was conducted on extinction phase SCR. No effects were significant ($P < .246$, $P > .12$) suggesting conditioned physiological arousal extinguished in the absence of UCS reinforcement. Together, these data suggest that physiological arousal was conditioned and influenced by preparedness.

Subjective ratings. For these analyses, 2 (Expression Type: Happy vs Fear) × 2 (CS+ Expression) repeated-measures ANOVAs were conducted separately for

![Figure 2](image-url). Skin conductance responses (SCR) by study phase (habituation, acquisition, extinction), CS Type (CS+ vs CS−), and CS+ Expression (Happy CS+ Group vs Fear CS+ Group). No group or CS Type differences were found for habituation. However, during acquisition, participants who were shocked during the fear expression (Fear CS+ Group) had greater SCR during the CS+ compared with the CS−, an effect that was not present for participants shocked during the happy expression (Happy CS+ Group). No group or CS Type effects were present during extinction.
pre- and postconditioning (habitation vs extinction) ratings. Fig 3 presents subjective arousal ratings. There were no significant effects in the analysis of preconditioning arousal ratings (Ps > .05), but there was a significant Expression Type × CS+ Expression interaction for postconditioning ratings, \( F(1,40) = 15.03, P < .001, \eta^2 = .27 \). After conditioning, the Fear CS+ group rated the fear expression (CS+) higher than the happy expression (CS−) \( (P < .001) \), but there was no difference in arousal ratings of expressions in the Happy CS+ group \( (P > .05) \).

**Pain Threshold: Finger Withdrawal Latencies**

Fig 5 depicts finger withdrawal latencies for habituation and extinction phases. For these analyses, latencies were averaged by facial expression type (happy vs fear) separately for each phase (habituation vs extinction). For habituation trials, a 2 (Expression Type: Happy vs Fear) × 2 (CS+ Expression) repeated-measures ANOVA was conducted. No significant effects were obtained \( (Ps > .05) \), suggesting that facial expressions did not influence pain threshold prior to conditioning. In contrast, a 2 (CS Type: CS+ vs CS−) × 2 (CS+ Expression) repeated-measures ANOVA on extinction trials found a significant CS Type × CS+ Expression interaction, \( F(1,40) = 7.18, P = .01, \eta^2 = .15 \). Follow-up comparisons indicated that pain thresholds were significantly lower (hyperalgesia) during the
CS+ than the CS− in the Fear CS+ group (P = .04), whereas there was no difference between CS+ and CS− in the Happy CS+ group (P = .10). Therefore, these data suggest preparedness moderates the influence of conditioned fear on pain.

**Exploratory Analyses**

Prior research suggests that shock exposure causes hypoalgesia (pain reduction) in humans. Indeed, examination of Fig 5 suggests pain thresholds generally increased in both groups after shock exposure. To determine whether this effect was significant, pain thresholds were averaged by phase (habituation vs extinction), collapsing across expression type. These latencies were analyzed using a 2 (Phase) × 2 (CS+ Expression) repeated-measures ANOVA. Only the main effect of phase was significant \( F(1,40) = 30.96, P < .001, \eta^2 = .44 \), suggesting pain threshold did increase after conditioning. This effect remained even if UCS pain rating was added as a covariate to control for individual differences in experienced aversiveness of the shock.

It is possible that perceived UCS aversiveness influenced the degree of hyperalgesia that resulted from fear conditioning. To examine this issue, Pearson’s r was calculated to assess the relationship between UCS pain ratings and the effect of conditioning on finger withdrawal latencies in the fear CS+ group (mean extinction CS+ latency minus mean extinction CS− latency). To avoid restriction of range, this analysis included persons that rated the UCS <10 who were originally excluded from the study (results did not differ, however, if they were omitted). The correlation was not significant \( r = -.24, P = .27 \) suggesting UCS aversiveness was not related to the pain modulation observed.

**Discussion**

This study was conducted to examine the influence of preparedness on the acquisition of a learned emotional response (conditioned fear) and to determine whether preparedness moderated the influence of conditioned fear on pain threshold. Specifically, pictures depicting fear and happy facial expressions were used as conditioned stimuli (CS) in a differential fear conditioning paradigm in which 1 CS was paired with an aversive unconditioned stimulus (UCS; shock). After fear conditioning training, facial expressions were presented again during pain testing to examine the influence of conditioned fear on pain threshold. Consistent with preparedness theory, conditioned fear was only acquired when the fear expression served as the CS+ (was paired with an aversive UCS). When the fear expression was the CS+, it acquired the ability to evoke physiological (SCR) and subjective arousal, and its ability to evoke negative emotion was enhanced. Interestingly, the conditioned physiological reaction extinguished quickly, but the conditioned subjective arousal and negative emotion persisted until the end of the experiment (because these were measured after all extinction trials). Importantly, the fear expression CS+ led to hyperalgesia (lowered pain threshold) relative to the happy expression CS−. This relative hyperalgesia was not present prior to conditioning. In contrast, when the happy expression served as the CS+, conditioned fear was not acquired and no change in pain threshold was elicited by the happy expression CS+. Together, these data suggest the fear expression was more readily associated with the aversive shock UCS and therefore acquired the ability to elicit negative emotion with moderate arousal and hyperalgesia. Conversely, the happy expression was not readily associated with the shock and appeared resistant to developing the capacity to elicit conditioned fear. However, it remains possible that increasing the number of acquisition trials would allow a stronger association to be developed between the happy expression and the UCS and endow it with the ability to elicit negative affect and hyperalgesia. Alternatively, it is possible the aversive UCS imbues other salient negative stimuli in the environment with the capacity to evoke hyperalgesia, regardless of the CS− UCS contingencies. Indeed, pain thresholds were lower during the fear expression CS− than the happy expression CS+ (although this was not statistically significant; Fig 5). Thus, it is important that future studies with greater power examine these issues.

In contrast to prior studies that observed conditioned fear-induced hypoalgesia, we found that conditioned fear led to hyperalgesia. We believe these divergent findings can be explained by differences in the intensity of the UCS and the conditioned emotional response acquired. As previously noted, evidence suggests negative emotion can have opposite effects on pain depending on the intensity of the negative emotion (as assessed from arousal level). Negative emotions with low-to-moderate arousal enhance pain, whereas negative emotions with high arousal inhibit pain. The UCS used in the present study differed in its aversiveness from prior studies. The 5-mA shock UCS was chosen to be brief and aversive, but only mildly painful. The average rating of the shock was around 50, corresponding to the sensation of mild pain. By contrast, the UCS used by Rhudy and Meagher was a 12-mA shock, and Willer et al’s was a 70-mA shock. The UCS used by Flor and colleagues consisted of prolonged (15 to 25 minutes) mental arithmetic plus aversive noise and was paired with the CS+ on multiple days. Thus, it is likely the UCSs in these other studies were more aversive and promoted the acquisition of intense (highly arousing) negative emotion, whereas the current study elicited less intense (low-to-moderate arousal) negative emotion. Unfortunately, it is difficult to directly compare the intensity of the conditioned responses across studies, because manipulation checks were different. In 1 study, however, SCR was also measured. The level of physiological arousal elicited by the CS+ in that study was 3 to 6 times greater than the present study. Therefore, it would appear that the conditioned fear acquired in the present study was less intense—a difference that likely resulted in hyperalgesia rather than hypoalgesia. Therefore, the paradigm used in the current study could be used as an experimental model for understanding how...
patients develop conditioned negative emotions and enhanced pain to aversive medical procedures that are administered repeatedly (e.g., dental procedures, cancer treatment). Although preliminary, these results suggest that fear-relevant environmental stimuli (including facial expressions) are more likely to acquire the ability to evoke conditioned fear and hyperalgesia than non–fear-relevant stimuli. However, additional research is needed to extend these findings to a clinical setting.

Exploratory analyses suggested that shock exposure led to hypoalgesia, because pain thresholds were increased in both groups during extinction relative to habituation. Admittedly, the present study did not use the proper controls necessary to make causal statements about shock exposure (i.e., a no-shock control group was not used). However, shock-evoked hypoalgesia is consistent with several other well-controlled studies using similar methods for delivering shock and testing pain.21,25 If the shock UCS does elicit hypoalgesia, this suggests that the hypoalgesia is not an unconditioned response to the shock, because unconditioned responses to the UCS should become associated with the CS+ during conditioning. Thus, 1 of the conditioned responses (CR) acquired by the CS+ should have been hypoalgesia. In the present experiment, however, the fear expression CS+ elicited hyperalgesia and the happy expression CS+ elicited no change in pain. At present, the processes that mediate shock-evoked hypoalgesia are unknown. However, emotion may play a role because individual differences in the emotional reaction to shock have been found to determine the effect of shock on pain. Indeed, research suggests that hypoalgesia is observed when fear is elicited, but no effect on pain results when shock elicits a mixture of fear and humor.25 In the present study, exploratory analyses that controlled for the painfulness of the shock (which could be argued to be a surrogate measure of fear) suggested that it did not affect the level of hypoalgesia observed. Whatever the mechanism, shock-evoked hypoalgesia likely attenuated some of the hyperalgesic effect resulting from the discrete fear expression CS+ and may have masked the hyperalgesia of the happy expression CS+. Further research is needed to test this hypothesis.

It is important to note a few study limitations. There were a number of participants that had to be excluded because they did not find the shock UCS aversive. Although we did not find that these participants differed on any of the study variables, it remains possible that they were different on other critical unmeasured variables. Other limitations relate to the generalizability of our findings. We limited pain testing to 1 modality (radiant heat), limited our outcome criterion to pain threshold, and limited our behavioral response to finger withdrawal. Although other studies have found that conditioned emotional responses influence other pain modalities (shock), other outcome criteria (pain tolerance, nociceptive reflex threshold), and other behavioral responses (subjective pain ratings),17,31,34 additional research is needed to extend the specifics of our findings. Further, we did not include a neutral expression comparison group which would have provided additional information regarding the specific effects of fear vs happy expressions.

In sum, these data suggest that facial expressions may provide important environmental cues during aversive events that influence the level of pain experienced. If fear-relevant stimuli are repeatedly paired with an aversive event, exposure to the fear-relevant stimulus may lead to negative emotions and enhanced pain. On the other hand, pleasant stimuli (such as happy facial expressions) appear resistant to fear conditioning and may not acquire the ability to evoke negative emotion and enhanced pain. This suggests clinical settings might benefit from minimizing fear-relevant stimuli and maximizing pleasant stimuli in the environment, including the facial expressions of practitioners. Doing so may reduce conditioned fear and hyperalgesia. However, these recommendations must be taken with caution until results are replicated in a clinical setting and their clinical relevance determined. Furthermore, it is important that future studies systematically vary the number of acquisition trials and measure other pain outcomes. It is also important to determine whether these results generalize to chronic pain populations given the possibility that CNS mechanisms associated with emotion and pain may become altered by persistent pain.17,31,34

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