Hide your Pain: Social Threat Increases Pain Reports and Aggression, but Reduces Facial Pain Expression and Empathy

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Abstract

Earlier research studying the effects of social threat on the experience and expression of pain led to mixed results. In this study, female participants (N = 32) came to the lab with two confederates. Both confederates administered a total of 10 painful electrocutaneous stimuli to the participant. The framing of the administration was manipulated in a within-subjects design: In the low social threat condition the participant was told that the confederate could choose between 10 to 20 pain stimuli, thus they believed that this confederate chose to administer the minimum allowed number of pain stimuli. In the high social threat condition the confederate had a choice between 1 and 10 stimuli, thus they believed that this confederate chose to administer the maximum allowed number of stimuli. Participants reported on the intensity, unpleasantness, and threat value of the painful stimuli, and their facial expression was recorded. Moreover, aggression and empathy towards the confederates were assessed. As hypothesized, participants reported increased pain intensity, unpleasantness, and threat in the high social threat condition compared to the low social threat condition, but showed less facial pain expression. Finally, participants exhibited increased aggression and reduced empathy towards the confederate in the high social threat condition.

Key words: Social threat; pain; pain expression; injustice; aggression; communication; retribution; empathy

Perspective: Social threat reduces painful facial expression, but simultaneously increases pain reports, leading to a double burden of the person in pain. Additionally, social threat affected social relationships by increasing aggression and reducing empathy for the other.

1. Introduction

Social context can profoundly alter the experience and communication of pain [9,18,29] and it has been proposed to explicitly acknowledge the social dimension in the very definition of pain [64]. Social context can be harnessed to alleviate pain and facilitate coping with pain, for instance via social support [5,24] but much less is known about the effects of social contexts that are perceived as threatening [25], even though people with chronic pain frequently feel excluded [44], stigmatized [45,65], treated unfairly [35,47,51], and invalidated [27,28,62]. Experimental research investigating the effects of such experiences on the experience and communication of pain is lacking.

Pain is commonly communicated to others through facial expressions [39], which in turn are modulated by social context [9,58,60]. According to evolutionary theory, emotions in general and pain in particular are expressed when it is advantageous for survival to do so [63]. However, in a threatening (social) context expressing pain might not be so advantageous as it signals vulnerability, which could be exploited by adversaries. Consequently, pain expression might be suppressed in the presence of a threatening other [65]. While adaptive in a threatening situation, suppression of pain expression might also have side effects such as underestimation of pain by others, a bias that is common in both lay observers [17,42] and health-care professionals [22,46]. Moreover, a threatening social context may worsen the experience of pain itself. Pain that is inflicted intentionally leads to higher pain reports than pain that is inflicted non-intentionally [16], possibly because intentional pain is perceived as more threatening [29] or as unjust [54]. In sum, a threatening social context may suppress facial pain expression but simultaneously increase the experienced intensity of pain. Additionally, social threat might also have interpersonal consequences. An individual in a threatening social interaction, might react with aggression and reduced empathy towards threatening others, which can negatively impact social relationships and increase the risk for further social isolation [14,61]. For instance, it has been shown that the experience of social exclusion can reduce empathy towards others' suffering [10], increase aggression [57] and decrease prosocial behavior [56].

Evidence for the above-mentioned effects of social threat is mixed. A study by Peeters and Vlaeyen [38] found that social threat in the form of intentionally administered painful electrocutaneous stimuli led to decreased facial pain expression, but simultaneous increases in reported pain intensity for participants high in pain catastrophizing. In contrast, a recent study by our group was not able to replicate these results but showed that social threat was

associated with increased aggression, reduced empathy and increased threat value of pain [23]. However, these studies had a couple of limitations that might account for the mixed results: The low social control condition was still rated as rather threatening and there was considerable variability between participants because a between-subject design was used.

Here we aimed to replicate and extend earlier studies in this area [23,38]. We compared a high social threat condition with a low social threat condition [38]. We adapted the paradigm by Peeters and Vlaeyen [38] to maximize the difference between the high and low social threat condition, thereby trying to correct one of the limitations of the earlier studies. We also employed a within-subject design to minimize inter-individual variation. We hypothesized that a high social threat context (1) increases self-reported pain intensity, unpleasantness, threat, (2) decreases facial expression of pain, (3) increases aggression, and (4) reduces self-reported sympathy and empathetic distress compared to a less threatening social context. Moreover, we also evaluated the possible moderating influence of pain catastrophizing on self-reported pain and facial expression of pain.

2. Materials and Methods

Participants

Thirty-two female participants between the age of 18 and 38 (M_{age} = 21.97 years, SD_{age} = 3.50) were recruited by spreading flyers at the Faculty of Psychology and Educational Sciences of the KU Leuven as well as through the departmental Experiment Management System (EMS, Sona Systems) for a study investigating the effect of personality traits on the administration and the receiving of painful stimuli. In line with our earlier study [23], we decided to only recruit female participants in order to reduce inter-individual variability, since males and females differ in the encoding and decoding of pain [26]. Of the 32 participants, 29 (90.63%) were students. The exclusion criteria for this study were presence/diagnosis of (acute or chronic) pain, the use of anxiolytics or antidepressants, medical advice to avoid stressful situations, a neurological or psychiatric disorder, electronic implants (e.g., pacemakers), pregnancy, impaired, uncorrected vision, heart disease or other severe medical conditions and non-fluency in Dutch. Participants were recruited and compensated in two ways: First-year psychology students participated in return for course credit (n = 7; 21.9%); volunteers recruited by means of flyers were paid €8 for their participation (n = 25; 78.1%).

Ethical Approval

The experimental protocol was approved by the Social and Societal Ethics Committee (SMEC) of the KU Leuven (Belgium) (registration number: G- 2016 04 553). All participants provided written informed consent prior to participation. It was emphasized that participation was completely voluntary and that participants were allowed to stop the experiment at any time without any negative consequences.

Experimental design and social threat manipulation

In contrast to earlier studies [23,38], a within-subject design was employed with all participants running through both the high social threat and the low social threat condition. The advantage of this design is the reduction of inter-individual variability, which is especially important with regard to large variations in facial expression between individuals and was one of the limitations of earlier studies [23,38]. The presentation order of the conditions was randomized across participants (14 participants first received the low social threat and then the high social threat condition, the remaining 18 participants received them in reverse order) The manipulation of social threat was similar to earlier studies in this area [23,38]: Participants came to the lab with two female confederates (two Caucasian females, aged 23) whom they believed to be two other participants. Based on a bogus randomization procedure, the participant was allocated to receive painful electrocutaneous stimuli, whereas the confederates were allocated to administer them to the participant. The confederates were then asked to choose how many electrocutaneous stimuli she wanted to administer to the participant. In the *high social threat condition*, the confederate could choose between 1 to 10 stimuli and chose to administer the maximum of 10 painful stimuli. In the *low social threat condition*, the confederate could choose between 10 and 20 painful stimuli and chose to administer the minimum of 10 painful stimuli. This is in contrast to the earlier study by Karos et al. [23], where the confederate did not have a choice in the low social threat condition and administered 10 stimuli. We thought that this control condition would increase perceptions of safety and trust, because the confederate seemingly actively chooses the minimum amount of stimuli, rather than being told to do so by the experimenter. We aimed to further maximize the difference between the low social threat condition and the high social threat condition, thereby correcting for one of the limitations of our earlier study [23]. So while the number of painful stimuli in both conditions was identical (10 stimuli), the participant was led to believe that the confederates intentionally chose to deliver the maximum of painful stimuli in the *high social threat condition*. In addition, while the confederate in the *low social threat condition* expressed some concern for the wellbeing of the participant, the confederate in the *high social*

threat condition acted distant and uninterested towards the participant to further increase the difference in perceived social threat between the two conditions. Note that one confederate consistently took on the role of the high social threat confederate and the other the role of the low social threat confederate throughout the experiment and they were both trained using a relatively standardized protocol on how to act during the interaction.

Apparatus and experimental stimuli

Pain stimuli and calibration. Electrocutaneous squarewave stimuli of 3 seconds were administered by a commercial stimulator (DS5, Digitimer, Welwyn Garden City, England) through two electrodes (1cm diameter) filled with K-Y gel (Johnson & Johnson, New Brunswick, NJ, USA) and attached approximately 2cm from each other to the right ankle of the participants. At the beginning of the experiment the intensity of the electrocutaneous stimulus was individually calibrated. During this calibration procedure, the intensity of the stimulus was gradually increased while participants were asked to verbally rate the pain intensity of each stimulus on an 11-point Likert scale. This Likert scale ranged from 0 (feeling nothing) to 10 (worst pain imaginable). The participants were instructed to select a stimulus which was ‘‘moderately painful and demanding some effort to tolerate’’ (mean self-reported stimulus intensity was 8.15, *SD* = 0.87, range = 5-10). After selecting the painful stimulus, the participant was informed that she would receive a stimulus of maximally this amplitude during the remainder of the experiment. In fact, all stimuli administered during the remainder of the experiment were of the intensity selected during the calibration procedure. Participants were also given the possibility to increase or decrease the selected stimulus intensity at this point (mean physical stimulus intensity was 7.26 mA, SD = 4.59, range = 1.5 – 20.25 mA).

Software and computer. The experiment was run on a Windows XP computer (Dell Optiplex 755) with 2GB RAM and an IntelCore 2 Duo processor at 2.33 GHz and an ATI Radeon 2400 graphics card with 256 MB of video RAM. Programming of the experiment was done in Affect (version 4.0) [49]. As mentioned previously, the experiment started with a bogus randomization procedure in which the participant and the two confederates were allegedly allocated one of two roles: administrator or receiver of electrocutaneous stimuli (see Procedure). For this allocation we used the same computer program reported by Peeters and Vlaeyen [38]. This program depicted a coin toss after the participant chose a side (head or tails) by clicking on a button. Note that the participant was always selected as the receiver of the electrocutaneous stimuli and the two confederates as the two administrators.

Apparatus. A webcam (HD Webcam C525, Logitech, Newark, CA) was installed on top of the computer screen and was used to record participants' facial expressions and the self-report ratings throughout the experiment. The instructions throughout the experiment were delivered by an audiotape, which was prerecorded. The instructions were spoken by a male native Belgian Dutch speaker and indicated when the electrocutaneous stimuli were to be administered and prompted for the self-report ratings of the participant (see Outcome Measures). Lastly, the confederates used a two-button response box to administer the electrocutaneous stimuli following the audiotape instructions, which was placed on the table.
Experimental setting. The experiment took place in a sound-attenuated experimental room, equipped with a table, a computer screen and two chairs facing each other. Communication between the experimental and the experimenter's room was possible through an intercom system and the experimenter could observe the participant throughout the entire experiment.

Outcome measures

Pain expression. Painful facial expressions of each participant were rated using the Childhood Facial Action Coding System (CFCS) [4]. This system is based on the Facial Action Coding System (FACS) [12], a fine-grained anatomically based system that is considered the gold standard when decoding the facial expression of pain [39,43]. Six facial action units which have been demonstrated to be the most reliable indicators of pain are brow lowerer, eye squeeze, eye squint, nose wrinkle, check raiser and upper lip raise [31,32,38,39,41]. Even though the CFCS was originally developed for children, it has been successfully used in previous studies investigating the effects of social threat on pain in (young) adults, so in the interest of comparability between studies we used the same action codes here [23,38].

Each video fragment consisted of twenty four-second segments capturing one second prior and three seconds after administration of the electrocutaneous stimulus. Each second of the four-second interval was coded using a software program enabling the rater to view and review each second at normal rate and at a rate of one-tenth of a second. For each time interval, a mean score per second for each of the six facial actions was calculated. A total score was calculated by summing these mean scores per participant and per condition [6]. All action codes were coded by one of the confederates (L.D.) who was trained by the first author, who is a certified CFCS coder. These ratings were used for all the analyses of pain expression. The first author independently also rated a random subset of 20% of all video

fragments. Inter-rater reliability between the two coders was satisfactory for overall frequency (> .79) and intensity (> .73).

Verbal ratings. Participants were asked to verbally rate the intensity, unpleasantness and threat value of the painful stimulus after each electrocutaneous stimulus. They were asked how painful they found the painful stimulus (*pain intensity*) on a scale from 0 (feeling nothing) to 10 (worst pain imaginable), how unpleasant they perceived the painful stimulus (*pain unpleasantness*) on a scale from 0 (not unpleasant at all) to 10 (extremely unpleasant) and how threatening they found the painful stimulus (*threat value of pain*) on a scale from 0 (not threatening at all) to 10 (extremely threatening).

Aggression. Aggression has been defined as any behavior that is directed at another individual with the intent to cause harm, frequently in response to provocation or threat [1]. In line with the earlier study by Karos et al. (2018), aggression was operationalized by asking the participant to choose the number of painful electrocutaneous stimuli that would be administered back to the confederates. They could choose between 1 to 20 stimuli for each confederate. At this moment the participants were unaware that these electrocutaneous stimuli were never actually administered to the confederates.

Empathy. The assessment of empathy towards the confederate was based on the work of Batson et al. [2]. Participants were asked to rate a total of four self-oriented (worried, upset, anxious, sad) adjectives assessing *empathic distress* and three other-oriented (understanding, compassionate, sympathizing) adjectives assessing *compassion/sympathy* when imagining the confederate receiving painful electrocutaneous stimuli. Each adjective was rated on an 11-point Likert scale (ranging from 0 = 'not at all' to 10 = 'very much'). Scores could range from 0 to 40 for empathic distress, and 0 to 30 for compassion/sympathy with higher scores indicating higher levels empathic distress and compassion/sympathy, respectively.

Social threat. The Social Threat Questionnaire (STQ) [38] consists of 14 statements concerning the relation between the confederate and the participant. Participants were asked to rate the degree to which they agreed with each of the statements, using an 11-point Likert-scale ranging from 0 = 'completely disagree' to 10 = 'completely agree'). Social threat was conceptualized through three dimensions, namely: specific social threat (e.g., "*I had the feeling the other participant enjoyed hurting me*"), social proximity (e.g., "*I feel close to the other participant*"), and social likeability (e.g., "*the other participant is honest*"). The score ranges from 0 to 140, with higher scores reflecting increased perceptions of social threat.

Internal consistency was good, both in the high (α = .89) and low social threat condition (α = .88).

Pain catastrophizing. The Pain Catastrophizing Scale (PCS) (Sullivan, Bishop, & Pivik, 1995) was used as a measure of catastrophic thinking associated with pain. Participants were asked to reflect on past painful experiences and indicate on a 5-point scale (0 = 'not at all' to 4= 'all the time') to which degree they experienced each of 13 thoughts or feelings. The PCS yields a total score and three subscales assessing rumination, magnification, and helplessness with a total score ranging from 0 to 52, with higher scores reflecting higher levels of pain catastrophizing.

Procedure

The participant arrived at the laboratory together with the two confederates and were seated at a table, facing each other (see Figure 1). Subsequently, they provided informed consent and the two different roles (*administrator* / *receiver*) were explained. Then the bogus randomization program was run, always allocating the role of receiver to the participant. The confederates were led to an adjacent room and the calibration procedure was performed with the participant (see Electrocutaneous pain stimuli and calibration). Afterwards, depending on the order of conditions, one of the two confederates was called back into the room. The experimenter placed a button box on the table and instructed the confederate to administer electrocutaneous stimuli by pressing the left button when prompted. Depending on the condition, the confederate could choose to administer between 1 to 10 stimuli (*high social threat condition*) or between 10 to 20 stimuli (*low social threat condition*). Both confederates always chose to administer 10 stimuli. The confederate was asked to verbally express her choice when prompted by the audio instructions. The participant was then instructed to orally respond to the questions posed by the audio instructions. Subsequently, the experimenter would leave the room and start the audio instructions. The instructions prompted the confederate to administer the electrocutaneous stimuli following a 3 second countdown. Nine seconds after each electrocutaneous stimulus, the participant was cued to provide the verbal ratings in the presence of the confederate (see Outcome Measures). During this procedure, the participant's facial expression was recorded.

After completion of the final verbal rating by the participant, the experimenter returned to the experimental room and asked the confederate to leave the experimental room and the participant to fill in online questionnaires. Then the same procedure was repeated with

the other confederate. Afterwards the experimenter explained that the roles of administrators and receiver would be reversed for the final phase of the experiment, and the aggression and empathy measures were taken. Afterwards, the participant was asked to fill in the questionnaires on the computer while the experimenter was allegedly performing the calibration procedure and administration of the electrocutaneous stimuli with the participant in another experimental room. After the participant filled in all questionnaires, both the confederates and the experimenter reentered the room and fully debriefed the participant.

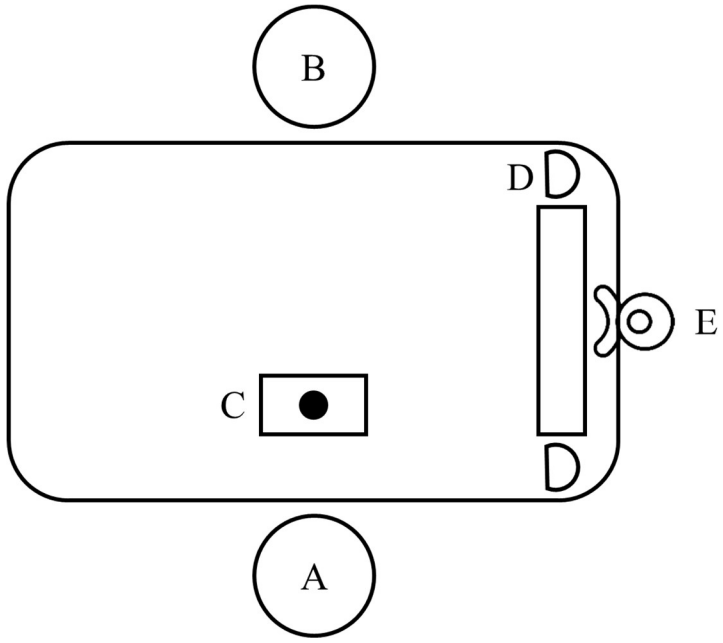

Figure 1 Schematic representation of the experimental setting with the confederate (A) and the participant (B) sitting at a table across from each other, a button box used to administer the electrocutaneous stimuli (C), speakers to present the audio instructions (D), and a webcam to record the facial expressions of the participant (E).

Statistical Analyses

First, a one-way ANOVA was run as a manipulation check to compare the scores on the STQ between the high and low social threat condition. Second, to test whether social threat affects self-reported pain intensity, unpleasantness or threat value of pain (*hypothesis 1*), three separate 2 [Condition (high / low social threat)] x 10 [Trial (1-10)] repeated measures analyses of variance (RM ANOVAs) were carried out to examine differences for self-reported pain intensity, unpleasantness and threat value of pain between the conditions. Pain catastrophizing (PCS) was included as a covariate, similar to Peeters and Vlaeyen

(2011). Planned comparisons were carried out to test our a priori hypotheses. Third, to investigate whether social threat reduces pain expression (*hypothesis 2*), a RM ANOVA with condition (high / low social threat) as independent variable, non-verbal pain expression as dependent variable, and pain catastrophizing as covariate was run. Fourth, to investigate whether social threat increases aggression (*hypothesis 3*) and reduces empathy (*hypothesis 4*), separate paired samples t-tests were run to compare the high with the low social threat condition. To account for possible order effects, order 2 [Order (high – low / low – high) was included as a between-subject factor in all analyses. An alpha level of .05 was used for all statistical tests. Greenhouse-Geisser corrections are reported when appropriate. Uncorrected degrees of freedom and corrected *p*-values are reported together with ε and the effect size indication η_p^2. Planned comparisons were carried out to test our a priori hypotheses and are reported with effect size indication for Cohen's d. Holm-Bonferroni correction was used to correct for multiple testing per hypothesis and to keep the experimentwise α at .05 [19]. All statistical analyses were run using SPSS 20 (Armonk, NY: IBM Corp.).

3. Results

Manipulation check

As intended, perceived social threat was significantly greater in the high social threat condition, $M = 87.19$, $SE = 3.83$, compared to the low social threat condition, $M = 31.75$, $SD = 3.37$, $F(1, 30) = 11.04$, $p = .002$, $\eta_p^2 = .27$, indicating that the manipulation of social threat was successful. There was no main or interaction effect with order ($F < .62$). Pain catastrophizing was not a significant covariate in any of the following analyses and was therefore excluded from all the analyses reported here.

Hypothesis 1: Does social threat increase pain intensity, unpleasantness and threat value of pain?

There was randomly missing data due to technical difficulties, which was imputed using expectation maximization (0.94% for pain intensity, pain unpleasantness, and threat value of pain).

Pain intensity. As expected, pain intensity ratings were higher in the high social threat condition, $M = 6.18$, $SE = .30$, compared to the low social threat condition, $M = 5.71$, $SE = .28$, $F(1, 270) = 5.87$, $p = .02$, $\eta_p^2 = .16$ (see Figure 2). There was no main effect of trial, $F(9,$

270) = 2.72, p = .09, ε = .18, η_p^2 = .08, and no interaction between condition and trial, F(9, 270) = .97, p = .46, ε = .64, η_p^2 = .03. There were no main or interaction effects with order on pain intensity ratings (all F < .83).

Pain unpleasantness. In line with the pain intensity ratings, pain unpleasantness ratings were higher in the high social threat condition, M = 5.46, SE = .29, compared to the low social threat condition, M = 4.81, SE = .31, F(1, 270) = 16.85, p < .001, η_p^2 = .36 (see Figure 2). Moreover, pain unpleasantness ratings increased across trials in both conditions, F(9, 270) = 4.68, p = .02, ε = .21, η_p^2 = .14. However, this sensitization did not differ between the two conditions, F(9, 270) = 1.01, p = .37, ε = .53, η_p^2 = .03. Again, there were no effects of order on pain unpleasantness (all F < 1.01).

Threat value of pain. The effect of condition and trial did depend on the order of conditions, Condition x Trial x Order, F(9, 270) = 3.22, p = .02, η_p^2 = .10. We then ran two separate analyses based on order including Trial and Condition as factors. We found that the threat value of pain was higher in the high social threat group, M = 3.94, SE = .49, compared to the low social threat group, M = 2.21, SE = .38, but only in participants who were first exposed to the high social threat condition, Condition, F(1, 153) = 16.09, p = .001, η_p^2 = .49. The interaction between Condition and Trial was not significant (F = 1.49) and neither was the main effect of Trial (F = 1.65). In contrast, the effect of condition was not significant in those participants who received the low social threat condition first, M = 2.16, SE = .39, followed by the high social threat condition, M = 2.85, SE = .45, was the second , Condition, F(1, 117) = 3.81, p = .07, η_p^2 = .23 (see Figure 2). Again, the interaction between Condition and Trial was not significant (F = 1.88) and neither was the main effect of Trial (F = 2.71).

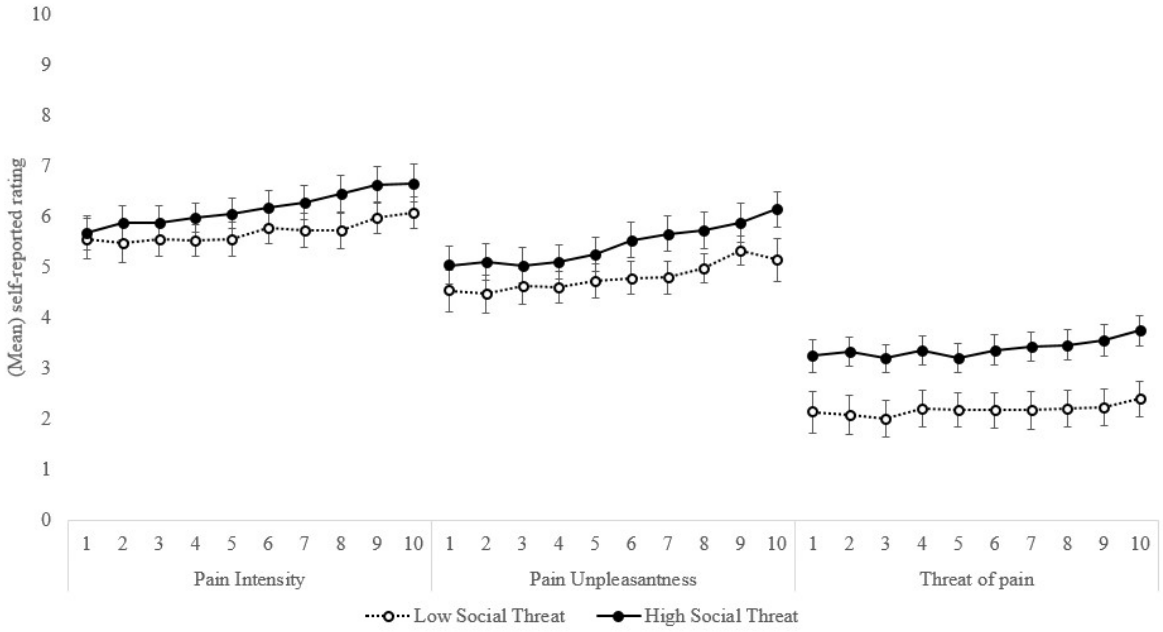

Figure 2 Self-reported mean (+SE) pain intensity, pain unpleasantness and threat of pain ratings in the low and high social threat condition for each of the 10 electrocutaneous stimuli. Note: SE, standard error term based on mixed analyses estimates.

Hypothesis 2: Does social threat reduce pain expression?

Two participants had to be excluded from this analysis because of technical difficulties during the recording of the facial expression. As expected, facial expressions in the high social threat condition, $M = 3.01$, $SE = .91$, were lower than in the low social threat condition, $M = 6.97$, $SE = 1.19$, $F(1,28) = 16.52$, $p < .001$, $\eta_p^2 = .37$ (see Figure 3). There was no main or interaction effect with the order of conditions (all $F < 2.42$).

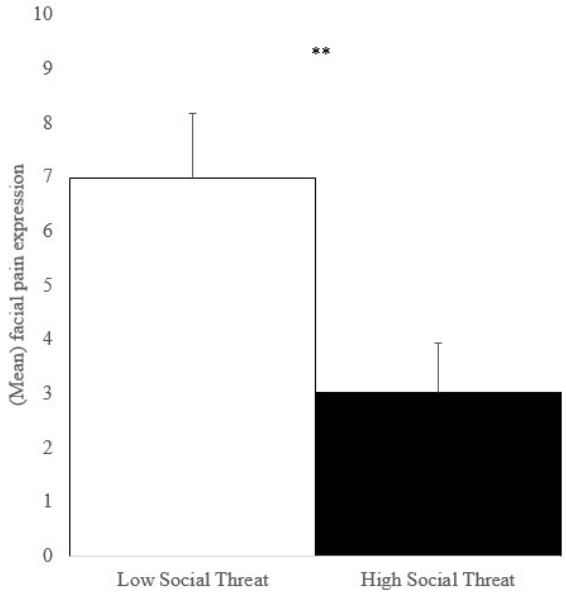

Figure 3 Mean (+ SE) facial pain expression in the low and high social threat condition, as well as in the baseline (during calibration) phase. Note: SE, standard error term based on mixed analyses estimates, $^{**}p < .001$.

Hypothesis 3: Does social threat increase aggression?

One participant's response was not recorded due to a technical error and was therefore excluded from the analysis. Participants were willing to administer more electrocutaneous stimuli to the confederate in the high threatening condition, $M = 8.45$, $SE = 1.06$, compared to the low social threat confederate, $M = 3.84$, $SE = .64$, $F(1,29) = 17.47$, $p < .001$, $\eta_p^2 = .38$ (see Figure 4, Panel A). Interestingly, only participants in the threatening condition were willing to exceed the 10 electrocutaneous stimuli that they were given ($n = 9$, 29.03%) (see Figure 4, Panel B). Again, this effect did not depend on the order of conditions (all $F < 2.14$).

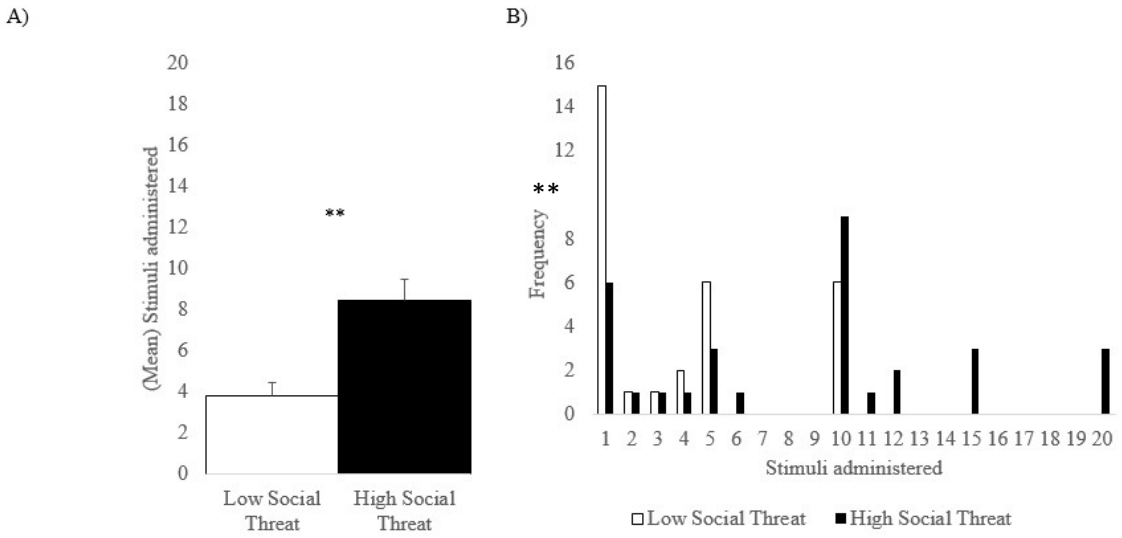

Figure 4 A) Mean (+ SE) electrocutaneous stimuli administered to the confederates in the low and high social threat condition. Note: SE, standard error term based on mixed analyses estimates, $^{**}p < .001$. B) Number of participants (n) who selected each amount of stimuli

Hypothesis 4: Does social threat reduce empathy?

As hypothesized, participants had less empathic distress, $F(1,30) = 6.09$, $p = .02$, $\eta_p^2 = .17$, and less compassion/sympathy, $F(1,30) = 10.31$, $p = .003$, $\eta_p^2 = .26$, for the confederate in the high social threat condition ($M_{distress} = 14.99$, $SE_{distress} = 1.57$, $M_{compassion} = 19.84$, $SE_{compassion} = 1.27$) compared to the low social threat condition, ($M_{distress} = 18.16$, $SE_{distress} = 2.05$, $M_{compassion} = 25.40$, $SE_{compassion} = 1.27$) (see Figure 5). In both cases, this effect was independent of the order of conditions (all $F < 2.18$).

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4. Discussion

This study investigated the effects of a threatening social context on self-reported pain, facial pain expression, aggression and empathy. First, the manipulation of social threat was successful. The low social threat condition was experienced as less threatening compared to the high social threat condition. Moreover, the low social threat condition was also rated as less threatening compared to the earlier study by Karos et al. [23]. This was likely a result of the implemented methodological changes in the present study: The confederate in the low social threat condition behaved more compassionately and chose the minimum number of stimuli (10 out of 20), rather than being requested to simply administer 10 stimuli. Consequently, the low social threat condition in the present study was experienced as less threatening compared to the earlier studies [23,38].

We found support for all four hypotheses. Participants reported that the pain in the high social threat condition felt more intense, more unpleasant, and more threatening compared to the low social threat condition (hypothesis 1). These findings are in line with the original study by Peeters and Vlaeyen [38] and the study by Gray and Wegner [16]. In contrast, Karos et al. [23] found that perceived social threat was associated with the threat value of pain, but not pain intensity or pain unpleasantness. Here we found that social threat indeed increased the threat, unpleasantness, and the experienced intensity of painful electrocutaneous stimuli themselves. The effect of social threat on the threat value of pain was dependent on the order of the conditions, and was only present when the high social threat condition was the first condition. This could possibly be a novelty effect. The high social threat context did not increase the threat value of stimuli that were already rendered relatively safe beforehand (in the low social threat condition within the relative safety of a laboratory environment). In contrast, the low social threat context might have acted as a safety signal that could reduce increased threat of pain [29,60], possibly driven by a feeling of relief, when following the high social threat condition. In conclusion, a threatening social context might be especially detrimental in determining the threat value of painful stimuli that are novel and unknown.

The elevated pain reports but lower facial pain expressions in the high social threat condition compared to the low social threat condition indicate a remarkable dissociation between pain reports and facial pain expression (hypothesis 2). This finding is similar to the original study by Peeters & Vlaeyen [38] and in line with predictions from evolutionary theory [63,65], which proposes that it is disadvantageous to express vulnerability (i.e., pain) in a threatening social environment. It is also worth noting that we again did not find any effect of pain catastrophizing on pain reports or the facial expression of pain, contradicting predictions

of the communal coping model of pain that people high in pain catastrophizing express more pain in the presence of others in order to elicit help [52]. Interestingly, we did not find this result in an earlier study [23]. There are two likely reasons for this discrepancy: First, this study employed a within-subject design, and thereby eliminated inter-individual variability in pain expressiveness, leading to increased power when focusing on context effects within individuals. Second, the low social threat condition in the current study was perceived as less threatening compared to the study by Karos et al. [23]. This raises questions about the boundary conditions of this effect: Is painful facial expression only reduced in actively hostile and threatening environments, or does even an ambiguous social environment lead to reduced facial expression?

Earlier studies have shown that even social interactions that were intended as *neutral*, can lead to decreased facial pain expression [20,29]. Similarly, emotional contagion in rats and humans has been shown to be inhibited in the presence of an unfamiliar conspecific [34]. In other words, the suppression of facial expression might be much more widespread than originally thought, and this suppression might only be released in a context where another is perceived to be actively helpful / cooperative, rather than in the presence of a stranger who is somewhat ambiguous as was the case in the earlier study by Karos et al. [23]. This conclusion has important clinical implications, as it suggests that it is crucial to create an actively supportive, safe and validating environment to facilitate the communication of pain [45,63,65] and counteract underestimation of pain in clinical practice [21,22,42].

We demonstrated again that social context can have dissociating effects on verbal pain reports and facial pain expression, suggesting that they might serve different functions [18,38] and / or are governed by separate processes. While facial pain expression can be deliberately controlled [40], it has been hypothesized that it is often the result of unconscious processes, whereas verbal pain reports might be more controlled [7,37,63]. In any case, the current findings are in line with operant models and evolutionary theory, which propose that the facial expression of pain is not a direct, automatic, and reliable device for communication but rather an "unconditioned behavior controlled by display rules" (Williams, 2002, p. 463).

Aside from detrimental effects on pain reports and pain expression, social threat also increased reactive aggression (hypothesis 4) [1], in line with earlier research showing that especially perceived injustice or provocation can be a strong motivator for aggression [13,36,53]. Strikingly, some participants were willing to administer twice as many painful stimuli to the

threatening confederate as they experienced themselves, demonstrating that the motivation to inflict pain on the confederate most likely reflected a sort of punishment rather than simply a "tit-for-tat" response [30]. Moreover, this finding is relevant in the context of other studies showing that perceived injustice in the context of pain is associated with anger and aggressive behavior [48,55]. While we operationalized aggression as the direct infliction of physical pain on someone else, punishing responses in reaction to perceived injustice might also take other forms that are clinically relevant, such as intentionally staying away from work.

In line with the aggression findings, empathy for the confederate was reduced in the high social threat condition (hypothesis 5). This reduction in empathy affected both the empathic distress experienced when thinking of the confederate's pain, as well as feelings of compassion and sympathy for the confederate. This finding supports our earlier study, where increased perceptions of social threat were correlated with reduced empathy [23]. Similarly, social exclusion has also been shown to reduce empathy for physical and emotional pain in others [10]. Moreover, a wealth of research demonstrates that empathy and emotional contagion is facilitated with intimate others (e.g., family and friends) but is reduced towards strangers, and even further towards outgroups, adversaries and competitors [8,15,33].

The present study demonstrates that the social environment can powerfully impact pain-related processes and interpersonal relationships but there are also some limitations to the present study. First, as in earlier studies [23,38], the present study relied exclusively on female participants and female confederates. There are substantial sex and gender differences in the experience and communication of pain [3,11,26,59]. Critically, gender is a socio-cultural construct and gender expectations and norms might powerfully affect display rules for pain as well [11]. For instance, there is research demonstrating that women generate more facial expressions and emotional utterances (e.g., crying) than men do, and at the same time women seem to be better at recognizing emotions in others' faces than men [26]. Evolutionary theory also suggests that it might be more relevant for males to inhibit the expression of vulnerabilities which could be exploited [63]. For instance, in a recent study by Edwards et al. [11], the presence of a male friend in particular increased pain tolerance in male participants, more so than in other dyadic relationships.

Second, the current research is applicable to experiences where pain is intentionally administered by others (e.g., physical bullying), but there are other forms of social threat which are more subtle but also very relevant for patients with chronic pain [25] such as

stigmatization, invalidation, or ostracism [44,45]. It is hard to generalize the current results to other forms of social threat but the current study can be understood as a strong argument for further scientific interrogation of the effects of social environments on the experience and communication of pain, especially in a clinical context where the accurate communication and assessment of pain is critical and underestimation is widespread [42].

Taken together, this study found that a threatening social context led to a dissociation between verbal pain reports and the facial expression of pain: Pain reports were increased but facial expression was decreased, leading to a possible double-burden for the person in pain. That is, pain is experienced as worse but there is also an increased possibility for underestimation of pain by others. In addition, social threat may facilitate interpersonal aggression and reductions in empathy. Consequently, the effects of the socio-cultural environment on persons with pain should be a primary concern in the understanding and treatment of acute and chronic pain complaints.

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6. Author contribution statement

K.K. conceived of the experimental study, carried out the data collection and analysis of the data. K.K. also wrote the manuscript and A.M., L.G., and J.W.S.V. provided feedback on the written manuscript and provided supervision during the conception of the study and during data collection.

7. Conflict of interest statement

The authors report no conflict of interest.

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