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# Sex differences in facial expressions of pain: results from a combined sample

Pia Schneider[a,*], Stefan Lautenbacher[b], Miriam Kunz[a,b]

## Abstract

Facial expressions of pain play an important role in pain diagnostics and social interactions. Given the prominent impact of sex on various aspects of pain, it is not surprising that sex differences have also been explored regarding facial expressions of pain; however, with inconclusive findings. We aim to further investigate sex differences in facial expressions of pain by using a large, combined sample to maximize statistical power. Data from 7 previous studies of our group were merged, combining in total the data of 392 participants (male: 192, female: 200). All participants received phasic heat pain, with intensities being tailored to the individual pain threshold. Pain intensity ratings were assessed, and facial responses were manually analyzed using the Facial Action Coding. To compare facial and subjective responses between sexes, linear mixed-effects models were used, with study ID as a random effect. We found significant sex differences in facial responses, with females showing elevated facial responses to pain, although they received lower physical heat intensities (women had lower pain thresholds). In contrast, pain intensity ratings did not differ between sexes. Additionally, facial and subjective responses to pain were significantly associated across sexes, with females showing slightly stronger associations. Although variations in facial expressions of pain are very large even within each sex, our findings demonstrate that women facially communicate pain more intensively and with a better match to their subjective experience compared with men. This indicates that women might be better in using facial communication of pain in an intensity-discriminative manner.

**Keywords:** Gender differences, Pain encoding, Nonverbal communication, Merged dataset, Experimental pain, Facial expression of pain

## 1. Introduction

Sex (The majority of the studies being cited, either used the term sex or gender or used these terms interchangeably.[50,51] Given that it seems that "sex" was most often assessed, we primarily use the term "sex" throughout the article.) has been shown to affect various aspects of pain,[51] including nociceptive, cognitive, and emotional processing as well as analgesic responses.[27,42,45,53,59] Also, the communication of pain is a matter of interest when studying sex differences in pain. So far, studies investigating sex differences in pain communication have often focused on verbal expressions and found that women use more pain words and a wider range of descriptors.[20,21,27,61]

Although sex differences in verbal expressions have been found, the evidence for nonverbal expressions is sparser. Most studies focused on facial expressions[8,55] and have predominantly been conducted in specific, mostly nonverbal populations, such as individuals with cognitive impairments,[2,9,65] children,[44] and infants.[60] Here, mixed outcomes were found, with indication for no sex differences as well as indication for increased or decreased facial expressions of pain in females. Regarding a more general, cognitively healthy adult population, we could only identify 2 studies in healthy adults[28,56] and 2 studies in chronic pain patients,[7,55] with again conflicting findings of increased,[7] decreased,[55] and comparable facial expressions of pain in women compared with men.[28,56] Besides investigating how sex affects the degree of facial expressiveness, we also investigated whether sex affects the relationship between facial expression and self-report of pain and found closer associations between these 2 response channels in women.[28] Thus, women seem to encode their pain experience more congruently in their facial expression. However, this is just a single study, and no replication has been done. Thus, altogether research on sex differences in facial expressions of pain is extremely sparse and inconclusive so far.[26] Reasons for the inconclusive findings might be differences in pain protocols, stimulus intensities, and samples as well as limited sample sizes. Therefore, to investigate sex differences in facial expressions of pain, it would be ideal to use established and

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*P. Schneider and S. Lautenbacher contributed equally to this work and share first authorship.*

*[a] Department of Medical Psychology and Sociology, University of Augsburg, Augsburg, Germany, [b] Bamberger Living Lab Dementia (BamLiD), University of Bamberg, Bamberg, Germany*

**Corresponding author. Address: Department of Medical Psychology and Sociology, Medical Faculty, University of Augsburg, Universitätsstraße 2, 86159 Augsburg, Germany. Tel.: +49 821-598-3778. E-mail address: pia.schneider@med.uni-augsburg.de (P. Schneider).*

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comparable pain-induction and facial-analyses protocols in large, heterogenous samples.

Our laboratory has a long research tradition in facial expressions of pain. This has led to a large database of manually coded facial responses (using the Facial Action Coding System [FACS]) to experimental pain stimulation (using similar pain protocols), which provides a basis for joined analysis of sex differences in a combined sample. This combined sample has the advantage that it provides a large sample size while also allowing for testing how stable sex effects are across studies.

The aim of our study was to investigate possible sex differences in facial expressions of pain in a combined sample from different studies conducted in our laboratory. Sex differences were analyzed with regard to (1) pain sensitivity (pain threshold), (2) subjective responses (ratings), (3) facial expressions (FACS), as well as with regard to (4) the relationship between subjective and facial responses to pain.

## 2. Materials and methods

Data (including demographic data, pain threshold, subjective and facial responses to pain) of 7 studies (6 of these studies have already been published; **Table 1**) were merged to form one new dataset (combined sample). Selection criteria for the included studies were as follows: pain was induced using phasic heat stimulation (this is a well-established pain protocol and most frequent protocol in our laboratory), intensities were tailored to individuals' pain sensitivity (to control for differences in pain sensitivity), facial expressions were assessed and manually analyzed using the FACS (FACS is the gold standard for facial expression analyses), and participants were healthy, pain-free adults. None of the included studies focused on sex differences in facial expressions of pain, and thus, analyzing the data now for sex differences is novel and has not been published before. However, being aware that sex affects various aspects of pain, sex-balanced samples were recruited in all studies (**Table 1**).

### 2.1. Participants of the combined sample

Overall, 392 participants were included across the 7 studies (male: N = 192, female: N = 200; mean age = 32.3 years; SD = 13.1; sex and age were assessed by self-report). Four of the 7 studies targeted primarily student populations, whereas 3 studies also included middle-aged individuals. There were no significant sex differences for age between studies ($t(390) = 1.35$; $P = 0.177$). **Table 1** provides the details for each of the individual studies. Exclusion criteria in the original studies were current experience of acute or chronic pain, psychological or physical illnesses, and pain influencing medication or substances. Sixty-two percent of female participants were on hormonal birth control or in menopause and 38% (N = 76) were in their natural menstrual cycle. Of these 76 females, 18 were in the menstrual phase, 35 were in the postmenstrual or follicular phase, and 22 were in luteal or premenstrual phase of their natural menstrual cycle. All studies included received ethical approval by the local ethical committee, and all participants provided written informed consent.

### 2.2. Procedure

In all studies, participants received phasic heat pain stimulation and subjective and facial responses to each stimulus were assessed. The experimenter was always present in the room with the participants, but seated in a way that no direct eye contact was possible during heat stimulation. The experimenters were, with one exception (study 4), always female.

### 2.2.1. Stimulation

Heat stimuli were always delivered by use of a Peltier-based, computerized thermal stimulator (Medoc TSA-2001; Medoc Ltd, Ramat Yishai, Israel) with a $3 \times 3\text{-cm}^2$ contact probe. The contact probe was attached either to the left lower leg (studies 1-5) or to the left forearm (studies 6 and 7).

### 2.2.1.1. Assessment of pain threshold (pain sensitivity)

To ensure that all participants experienced comparable levels of pain during the pain stimulation, temperature intensities were tailored to the individual pain threshold. Thus, heat pain thresholds were determined first, using the method of adjustment. Participants were asked to adjust a temperature starting from 38°C (all studies but study 6 and 7) or 35°C (studies 6 and 7), using heating and cooling buttons, until they obtained a level that was

**Table 1**

**Descriptive information on the studies and descriptive statistics of participants and pain outcomes (mean, SD).**

| | Year of assessment | City of assessment | Sex | N | Age | Pain outcomes, mean (±SD) | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Pain threshold (°C) | Pain rating (0-10) | FACS composite score |
| Study 1[30] | 2007/2008 | Bamberg (Germany) | ♂ | 22 | 22.4 (±2.4) | 45.8 (±1.1) | 7.7 (±0.7) | 1.51 (±1.59) |
| | | | ♀ | 22 | 21.2 (±2.5) | 45.1 (±1.1) | 7.8 (±0.8) | 2.08 (±1.77) |
| Study 2[31] | 2008 | Montréal (Canada) | ♂ | 13 | 25.2 (±5.8) | 45.7 (±1.4) | 7.5 (±0.8) | 1.72 (±1.01) |
| | | | ♀ | 19 | 23.2 (±2.6) | 44.8 (±1.7) | 7.6 (±1.9) | 2.10 (±1.25) |
| Study 3[34] | 2009 | Bamberg (Germany) | ♂ | 30 | 24.2 (±4.3) | 46.4 (±1.0) | 7.4 (±1.3) | 1.64 (±1.54) |
| | | | ♀ | 30 | 21.7 (±4.1) | 45.4 (±1.2) | 7.2 (±1.1) | 1.72 (±1.52) |
| Study 4[24] | 2010 | Bamberg (Germany) | ♂ | 63 | 40.9 (±13.8) | 46.8 (±1.0) | 8.2 (±1.4) | 1.46 (±1.79) |
| | | | ♀ | 63 | 38.8 (±13.2) | 45.9 (±1.2) | 8.0 (±1.3) | 1.83 (±1.81) |
| Study 5[25] | 2011/2012 | Bamberg (Germany) | ♂ | 25 | 22.6 (±2.7) | 46.5 (±1.1) | 8.1 (±0.9) | 1.13 (±1.15) |
| | | | ♀ | 24 | 21.8 (±3.4) | 45.4 (±1.7) | 8.1 (±1.0) | 1.72 (±1.29) |
| Study 6 (this study has not been published yet) | 2017 | Bamberg (Germany) | ♂ | 19 | 45.4 (±9.5) | 45.4 (±1.4) | 7.7 (±2.3) | 1.95 (±1.95) |
| | | | ♀ | 22 | 44.2 (±9.4) | 45.3 (±0.9) | 7.9 (±1.7) | 2.85 (±1.67) |
| Study 7[3] | 2017/2018 | Bamberg (Germany) | ♂ | 20 | 41.4 (±13.2) | 45.8 (±2.4) | 7.0 (±2.0) | 1.18 (±1.32) |
| | | | ♀ | 20 | 39.4 (±10.9) | 45.7 (±2.0) | 7.7 (±1.6) | 4.00 (±2.65) |
| | Heterogeneity index: $I^2$ | | | | | 30.7 | 0.0 | 13.1 |

barely painful. A constant press of either button produced a heating or cooling rate of 0.5°C/second. After a familiarization trial, there were 4 trials, and the average of these trials was used to constitute the threshold estimate.

#### 2.2.1.2. Phasic thermal pain stimulation

After the assessment of pain thresholds, phasic painful stimuli (5-second plateau; rate of change: 4°C/second; baseline temperature: 38°C (all studies but study 6) or 35°C (study 6); interstimulus intervals of 15 seconds to 20 seconds) were applied. The temperature was set to +3°C above the pain threshold (all studies but studies 1 and 2; here a psychophysical intensity was estimated to determine the target temperature that also resulted approximately in an intensity of +3°C above threshold).[30,31] In total, participants received either 10 (studies 3-7) or 8 (studies 1 and 2) painful stimuli. To increase vigilance, painful stimuli were applied together with the same number of nonpainful stimuli in a pseudorandom order. However, the nonpainful stimuli are not of interest in the present context (comparisons between sexes for the nonpainful intensities can be found in the supplementary material, Figure S1, available at http://links.lww.com/PAIN/B998).

### 2.2.2. Assessment of subjective responses to pain

Pain intensity ratings were obtained after each stimulus using well-established pain rating scales.[22,54] Studies 1, 2, 4, and 5 used an electronic visual analogue scale (VAS; 100 mm). The scale was labeled with a verbal anchor of "faintly painful" in the center, and all participants were instructed to rate all painful sensations on the right sight of the anchor (>50 mm). In study 3, an electronic visual analogue scale (VAS; 100 mm) was used as well; however, here the endpoints of the scale were labelled "no pain" and "extremely strong pain." Studies 6 and 7 used an 11-point Likert scale with the endpoints "no pain" and "extremely strong pain."

Because the scales for the pain ratings differed, all scales were transformed linearly to the scale with the smallest scale range[49]—namely, an 11-point Likert scale, with 0 representing "no pain" and 10 representing "extremely strong pain."

### 2.2.3. Assessment of facial expressions of pain

Participant's faces were videotaped throughout the pain induction procedures from frontal view. Participants were informed about the recording. To enable offline segmentation of the videos, an LED light visible to the camera, but not to the participant, was lit concurrently with the 5-second thermal stimulation, beginning when the target temperature was reached. To ensure that the face would always be upright and in a frontal view during stimulation, participants were asked to look at the computer screen (studies 2, 3, 4, 6, and 7) in front of them or to focus on an emotionally neutral picture (studies 1 and 5) throughout the whole session. Participants were also instructed not to talk during thermal stimulation.

Facial expressions were coded from videos recordings using the FACS.[11] The FACS is based on anatomical analysis of facial movements and distinguishes 44 different "action units" (AUs) produced by single muscles or combinations of muscles. Certified FACS coders (qualified by passing an examination given by the developers of the system) or coders trained by certified FACS coders identified the frequency and the intensity (5-point scale) of the different AUs. Interrater reliability within each study ranged between 0.84 and 0.90, which compares favorably to previous studies.[10,11,24,37,56] Software designed for the analysis of observational data (Observer Video-Pro; Noldus Information Technology, Wageningen, the Netherlands) was used to segment the videos and to enter the FACS codes into a time-related database. Time segments of 5 seconds beginning just after the stimulus had reached the target temperature (period during which the LED was lit) were selected for coding.

#### 2.2.3.1. Pain-relevant action units

For further analyses, pain-relevant action units were selected based on an extensive literature review by Kunz et al.[35] Those AUs are as follows: lowering the brows (AU04), cheek raise/lid tightening (AUs06_07), nose wrinkling/raising the upper lip (AUs09_10), and opening of the mouth (AUs25_26_27) (**Fig. 1**). To ensure that the selected AUs indeed represent pain-relevant responses in the present context for both males and females, we additionally computed the percentage of occurrence as well as effect sizes of the differences between nonpainful and painful heat stimulation for all AUs. These findings can be found in the supplementary material (Table S1, available at http://links.lww.com/PAIN/B998) and confirm that our AU selection included the most relevant AUs for both sexes. For further analyses, we combined intensity and frequency score for each pain-relevant AU (product term). Because the distributions for the product terms are left-skewed, the products terms were then square-root transformed, as done in previous studies.[24,32,33] Furthermore, a composite score of pain-relevant AUs was calculated by averaging the 4 square-root-transformed AUs.

## 2.3. Statistical analyses

### 2.3.1. Creation of the combined sample

Data on sex as well as the different pain outcomes, including pain threshold, pain intensity ratings, and facial expressions (pain-relevant AUs) of each study (including study ID) were merged into one data file to form the combined sample.

### 2.3.2. Sex differences in pain threshold, subjective responses (pain intensity ratings), and facial responses to pain

To investigate sex differences in pain threshold, subjective and facial responses to phasic heat pain, respectively, linear mixed-effects models with sex as the between-subjects factor were conducted, separately for each outcome variable. Given that our combined sample is derived from different studies, we wanted to account for possible heterogeneity between studies in our statistical models, and thus, the study ID was included as random effect factor in all mixed models. SPSS Statistics (IBM, version 28) and R (version 4.1.0) using R studio (version 1.1.463) were used for the statistical analyses. More precisely, SPSS was used for combining the datasets, whereas mixed-effects analyses were performed with the R-packages lme4[4] and lmerTest.[38] Graphs were produced using ggplot2.[66]

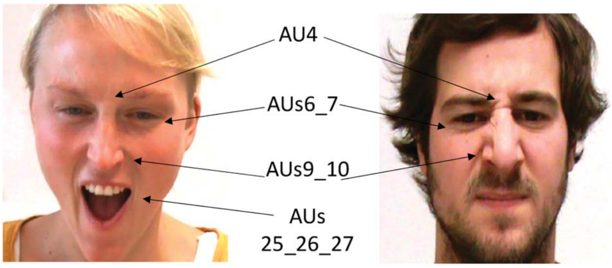

**Figure 1.** Pain-relevant action units are depicted in a female (left) and male (right) participant receiving painful heat stimulation. AU, action units.

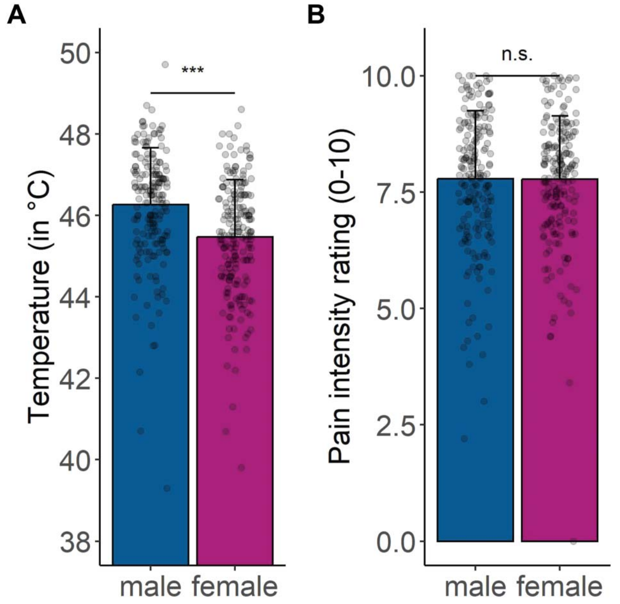

**Figure 2.** (A) Mean pain threshold (in degrees °C) for female and male participants, error bars: SD. (B) Mean pain intensity ratings for female and male participants, error bars: SD; $^{***}P < 0.001$, n. s.: $P > 0.05$.

Moreover, we did not only want to account for possible heterogeneity between studies but also wanted to assess the degree of heterogeneity with regard to sex effects between studies. To this aim, an indicator of heterogeneity, "$I^2$,"[18] was computed. $I^2$ is a measure that is commonly used in meta-analyses to measure heterogeneity in effect sizes between studies. It was calculated using R and an Excel-table provided by Neyeloff et al.[46]

### 2.3.3. Sex differences in the association between subjective and facial responses to pain

To investigate whether the relationship between facial responses to pain (composite score) and subjective pain intensity ratings varied by sex, we conducted a mixed model analysis predicting the facial responses to pain. Subjective pain intensity ratings and sex were included as independent variables, along with their interaction term.

Findings were considered to be statistically significant at $\alpha < 0.05$. To estimate the effect sizes of the mean sex differences, Cohen *d* was calculated.

## 3. Results

### 3.1. Sex differences in pain threshold and subjective responses to pain (pain intensity ratings)

A significant main effect of sex on pain threshold was shown ($t(385) = -5.64$; $P < 0.001$, Cohen $d = 0.57$). As can be seen in **Figure 2A**, pain thresholds were lower for females compared with males. When analyzing how stable the sex difference in pain thresholds was across studies, the indicator of heterogeneity $I^2$ showed low-to-moderate heterogeneity between studies ($I^2 = 30.7\%$). Thus, the significant lower pain threshold in women was a relatively stable finding across studies. Given that the painful heat intensities applied for assessing subjective and facial responses were tailored to the pain threshold, this means that women (48.39°C; SD = 1.39) received significantly lower heat intensities compared with men (49.18°C; SD = 1.43) ($t(384) = -5.69$; $P < 0.001$).

Males and females did not differ in their subjective responses to pain as shown by a nonsignificant main effect of sex ($t(385) = -0.02$; $P = 0.998$; Cohen $d < 0.01$) (**Fig. 2B**). Thus, adjusting the phasic heat stimulation to the individual pain threshold was successful in eliciting comparable subjective responses to pain (pain intensity ratings) in male and female participants. The lack of sex difference in pain intensity ratings was very stable across studies, as shown by the indicator of heterogeneity ($I^2 = 0\%$; please note that $I^2$ is set to 0 for negative values, so that $I^2$ ranges from 0% to 100%[19]).

### 3.2. Sex differences in facial responses to pain

Regarding differences between males and females facial responses to pain, we found a significant sex effect

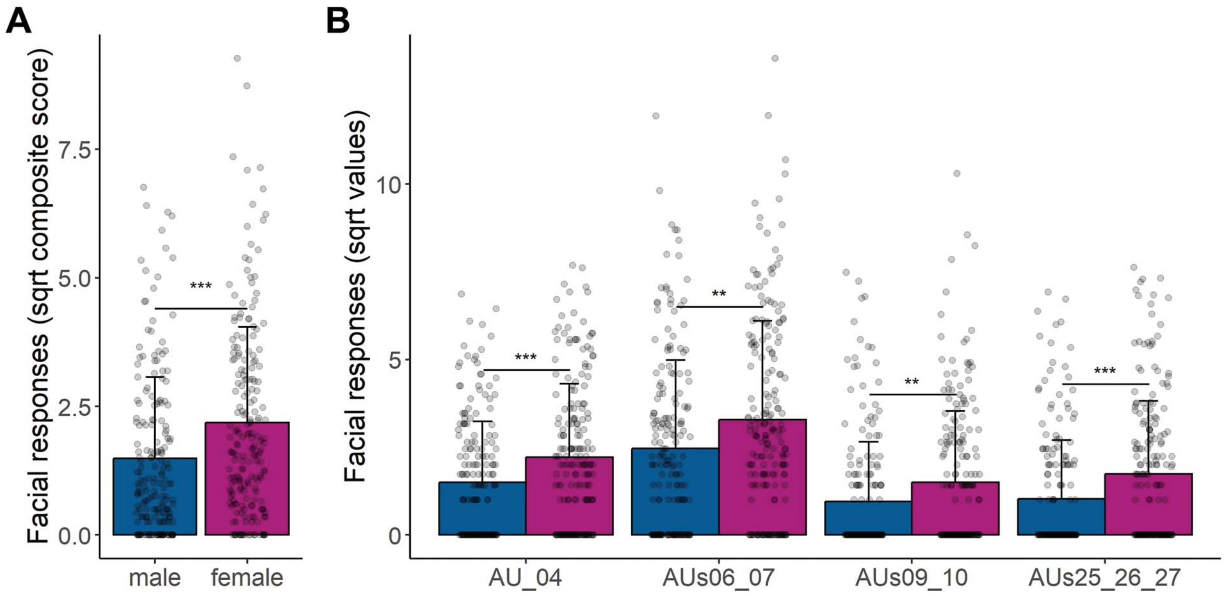

**Figure 3.** (A) Mean facial expressions of pain (composite score of square root transformed pain-relevant AUs) for female and male participants, error bars: SD. (B) Single pain-relevant AUs (square-root-transformed AUs) during painful stimuli for female and male participants, error bars: SD; $^{***}P < 0.001$, $^{**}P < 0.01$, n. s.: $P > 0.05$. AU, action units.

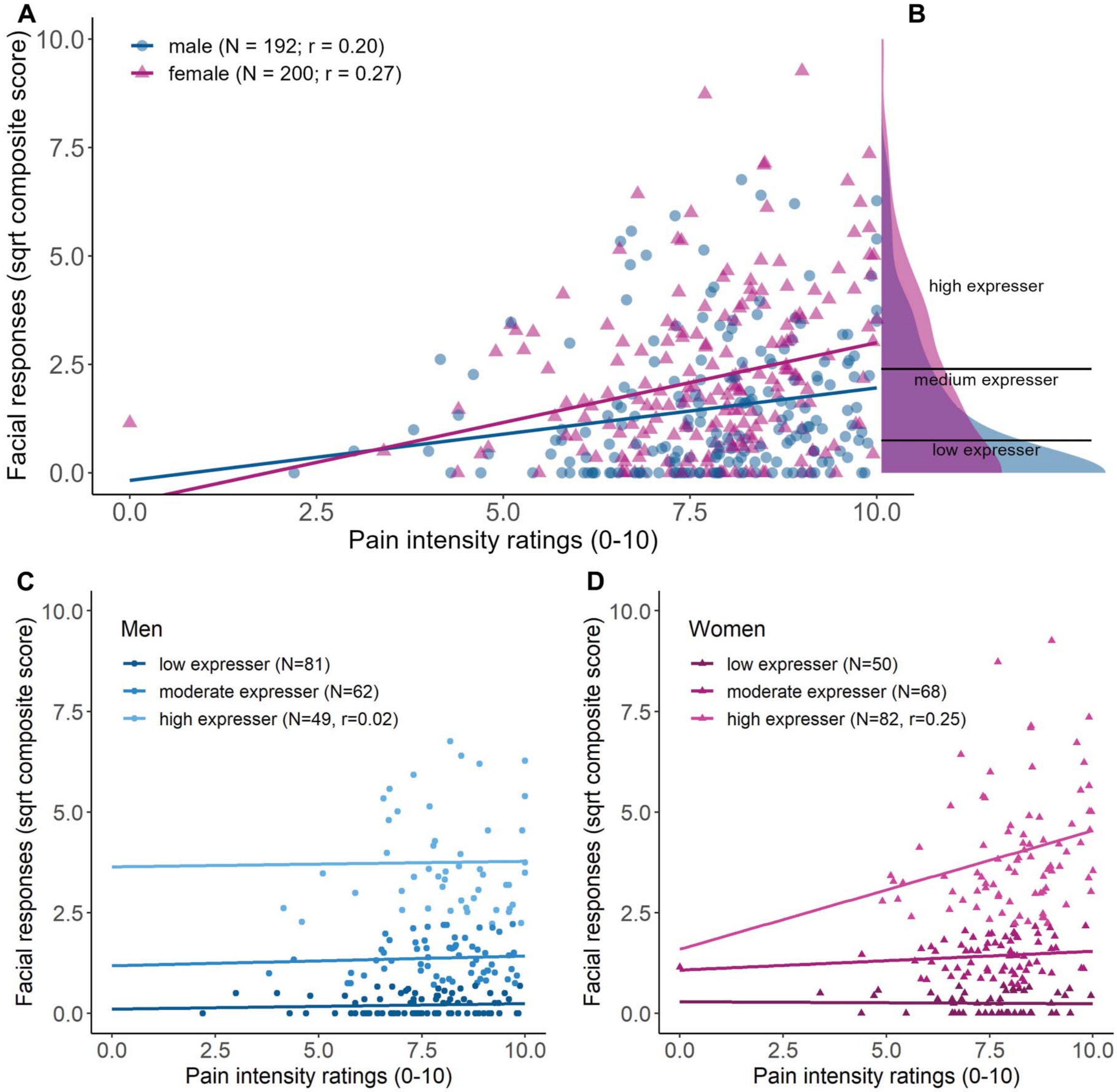

**Figure 4.** (A) Relationship between facial responses and pain intensity ratings for female and male participants. (B) Rotated density plot of facial responses for males and females. (C and D) Association between facial responses and pain intensity ratings for low, moderate, and high expressing males (C) and females (D).

($t(385) = 4.00$; $P < 0.001$; Cohen $d = 0.40$). As can be seen in **Figure 3A**, females responded with heightened facial responses (sqrt composite score) to the painful stimuli compared with males. The indicator of heterogeneity between studies, $I^2$, showed low heterogeneity for the sex effect on facial responses to pain ($I^2 = 13.1\%$); thus, the increased facial responses to pain in females was very stable across studies.

To analyze whether the increased composite score of facial responses to pain in female participants is brought about by specific facial muscle movements, we additionally compared the single pain-relevant AUs (AU04, AUs06_07, AUs09_10, AUs25_26_27) between males and females (**Fig. 3B**). In response to pain, all pain-relevant facial responses were increased in females compared with males as shown by a significant main effect of sex on the respective AUs (AU04: $t(390) = 3.66$; $P < 0.001$; Cohen $d = 0.37$/AUs06_07: $t(384) = 3.03$; $P = 0.003$; Cohen $d = 0.30$/ AUs09_10: $t(384) = 2.93$; $P = 0.004$; Cohen $d = 0.29$/ AUs25_26_27: $t(383) = 3.72$; $P < 0.001$; Cohen $d = 0.38$).

In a last step, we wanted to account for the fact that the physical intensity of the heat pain stimuli was lower for women compared with men (see section 3.1). Thus, we computed residuals of the facial response scores, which were statistically freed from the influence of the physical heat intensity. We did this by conducting linear mixed models with stimulus temperature as the predictor variable and the facial response as the dependent variable (incorporating study ID as a random effect) and computed the residuals from this model. These residual scores were then entered as outcome variables into the mixed models with sex as the between-subjects factor. Using these residual scores, we found increased effect sizes for the difference in facial responses to pain in males and females. Regarding the composite score, the sex difference was of a moderate effect size (effect size increase of 28%) after controlling for the physical heat intensity ($t(390) = 5.07$; $P < 0.001$; Cohen $d = 0.51$). The effect size increase for the individual AUs ranged between 19% and 40% and now showed close to moderate effects (AU04: $t(390) = 4.31$; $P < 0.001$; Cohen $d = 0.44$/AUs06_07: $t(390) = 4.19$; $P < 0.001$; Cohen $d = 0.42$/AUs09_10: $t(390) = 3.73$; $P < 0.001$; Cohen $d = 0.38$/ AUs25_26_27: $t(390) = 4.45$; $P < 0.001$; Cohen $d = 0.46$).

### 3.3. Sex differences in the association between pain ratings and facial responses to pain

We investigated the potential influence of sex on the relationship between facial responses to pain (composite score) and subjective pain intensity ratings (**Fig. 4A**). Our results showed that pain intensity ratings significantly predicted facial expression ($t(387) = 3.238$; $P = 0.001$), indicating that as pain rating increased, facial expression also increased. As for the strength of the association, post hoc correlation analyses showed weak associations for males and weak-to-moderate associations for females (**Fig. 4A**).[1] In spite of that, the interaction term between sex and pain intensity rating was not significant ($t(384) = 0.986$; $P = 0.325$), suggesting that there was no substantial difference in the association between pain rating and facial movement based on the participant's sex.

However, when inspecting the scatter plot in **Figure 4A**, it is apparent that individuals differ immensely in their degree of facial expressiveness to pain, ranging from a complete lack of facial responses to high expressiveness. Given that it is possible that the level of facial expressiveness might impact the association between the 2 response channels (subjective and facial), we decided to include the degree of facial expressiveness into our analysis. To this aim, we split all participants (regardless of sex) in 3 equally sized subgroups depending on their facial expressiveness to pain (low expressers, moderate expressers, and high expressers) (**Fig. 4B**). We incorporated the degree of facial expressiveness (low, moderate, and high) as a numerical variable into our mixed model, treating it as a between-subjects factor in the context of the association between subjective and facial responses to pain. Additionally, we tested for interactions related to sex. We discovered a statistically significant 3-way interaction between facial expressiveness, pain rating, and sex ($F(1,379) = 4.26$; $P = 0.040$). To provide further insight into this interaction, we conducted post hoc analyses, contrasting the effect of pain intensity ratings on facial expressions of pain for males vs females separately for each level of expressiveness. The results of these analyses revealed a significant contrast at the upper level of the model for highly expressive males vs females ($t(379) = -2.56$; $P = 0.010$). No significant contrasts were found for the low ($t(380) = 0.57$; $P = 0.568$) and moderate ($t(379) = -1.62$; $P = 0.105$) levels. The significant contrast for the most expressive males vs females prompted us to further investigate the relationship within this group.

Thus, we conducted correlational analyses separately for highly expressive males and highly expressive females. Among highly expressive females, we found a significant and positive correlation ($r = 0.25$; $P = 0.024$) between their facial and subjective response to pain (**Fig. 4D**). Conversely, highly expressive males did not exhibit a significant correlation ($r = 0.02$; $P = 0.914$) in this respect (**Fig. 4C**).

## 4. Discussion

In the present study, we combined datasets from 7 previous studies of our laboratory to investigate sex differences in facial expressions of pain in a large, combined sample. Our main findings are that: (1) women show increased facial responses to experimental heat pain compared with men and (2) facial responses to pain are associated with self-reported pain in both sexes; however, the association is slightly stronger for females, especially for highly facially expressive females. These findings will be discussed in detail below.

### 4.1. Increased facial expressions of pain in women compared with men

In our combined sample, we found consistent sex differences, with women displaying increased facial responses to experimentally induced heat pain compared with men. This increased facial expression of pain was not simply because of higher pain experiences in women, given that the stimulus intensities were adjusted to the individual pain threshold and given that the pain intensity was rated similarly by women and men. Moreover, it is noteworthy that adjusting stimulus intensities to the individual pain threshold resulted in lower stimulus intensities being administered to women. Thus, it was really the facial expressiveness of a comparable pain experience (to a lower physical intensity) that was greater in women. We found an effect size of Cohen $d = 0.40$, which corresponds to a small effect. However, when we controlled for the differences in physical heat intensity, the effect size increased by 27% to Cohen $d = 0.51$, which indicates a moderate effect. We are confident that our findings of increased facial responses to pain in women are not simply a chance finding or a statistical artefact given the consistency of the observed sex difference across multiple studies.

Sex differences in facial expressions have also been found for other types of affective states. Women have repeatedly been found to smile more.[16,17,39] This clear sex difference, however, is not as apparent when considering facial encoding of negative emotions.[43] There is evidence that certain negative affective states, such as anger, are facially expressed less in females,[12,13] whereas expressions of sadness seem to be slightly increased in females.[6,14] Thus, with the exception of "smiling," gender difference in facial expressions tend to be small to moderate,[6] with evidence for increased (eg, pain, sadness) and decreased (eg, anger) facial expressiveness in females. It has been hypothesized that these sex differences relate to learned gender norms. Boys and girls may have learned different display rules for the expression of emotions; although boys learn to especially inhibit the expression of "tender" affective states, such as sadness, fear, shame, and pain, girls mainly learn to inhibit socially unacceptable emotions, such as anger.[5,6] According to Fischer and LaFrance,[14] such gender norms are less influential when the intensity of the affective state is very strong. The present data were assessed in an experimental setting where we applied moderate pain intensities. Accordingly, it is possible that the small-to-moderate sex differences we found in the present study might be less prevalent for stronger pain experiences. It is, however, also possible, that other social settings (eg, being together with one's partner) and other types of pain (eg, clinical pain states) might lead to even stronger sex differences in facial expressions of pain than we found.[24]

Facial responses to pain are a composition of certain facial muscle movements that have been found to be indicative of different pain states.[35] We also analyzed whether the increased facial expressions in women are visible in all pain-relevant facial muscle movements (AUs). We found clear evidence that women showed elevated responses in all these pain-relevant AUs, namely, AU04 (corrugator muscle), AUs06_07 (orbicularis oculi muscle), AUs09_10 (levator muscle), and AUs25_26_27 (orbicularis oris muscle). Previous findings of our group point out that these AUs seem to encode different aspects of the multidimensional pain experience, with AUs06_07 encoding the sensory aspects of pain, whereas AU04 and AUs09_10 seem more closely related to the affective dimension.[33,36] Thus, given that we found sex differences in AU06_07 (sensory dimension) as well as in AU04 and AUs09_10 (affective dimension) suggests that women facially encode both pain dimensions more vigorously than men.

### *4.2. Stronger association between facial and subjective responses to pain in women compared with men*

We observed an overall significant association between facial and subjective response to pain. Notably, sex did not significantly alter this association, although the correlation coefficient showed a slightly stronger association for females. Moreover, when we integrated the degree of facial expressiveness into our analysis, the association between subjective and facial responses to pain was influenced by sex among individuals displaying the highest degree of facial expressiveness. Among this subgroup, we observed a significant correlation between facial and subjective responses to pain in females, whereas a similar association was not present in males. Finding slightly closer associations between facial and subjective responses to pain in women aligns with previous findings from our group,[28] where we consistently found higher correlations between the 2 response channels in women. Moreover, greater associations between facial and subjective responses in women compared with men have also been found for other affective states. Schwartz et al.[58] and Lang et al.[41] found that women's self-reported affective states, such as happiness, sadness, and fear, were more strongly correlated with their facial expressions. One potential explanation for the greater coherence between self-report and facial responses in women could again be the influence of learned social display rules. Although both boys and girls learn to downregulate facial expressions of pain,[49] males, in particular, face social pressure to inhibit facial expressions of pain and other "tender" affective states.[3,7,8] Therefore, social pressure might reduce facial expressiveness in men to such extend[40,45] that floor effects occur which hamper the chance for correlations.

Our rational behind including the degree of facial expressiveness into our analyses was the assumption that the more facially talkative a person is, the higher is the drive to broadcast one's inner state to the outer world and that this effect might be dependent on sex. In agreement with these assumptions, we only found a significant sex difference in the associations between facial and subjective responses in highly expressive individuals. Only women showed a significant correlation between facial and subjective responses to pain. In contrast, no significant correlation between subjective and facial responses was found in men. Thus, even highly expressive males seem to only give "alarm" in an all-or-nothing fashion via their facial expression but do not encode their subjective intensity discriminatively.

### *4.3. Clinical implication of the found sex differences*

We only investigated pain-free individuals using an experimental pain, and thus, we can only speculate about possible clinical implication. One possibility is that women have an advantage in pain diagnostics because of their increased facial expressiveness. Such visible cues may aid the health care professional in assessing the patient's condition and providing appropriate treatment. Moreover, given that facial expressions of pain have the potential to serve as a "social lubricate" by eliciting empathetic responses and help in others,[3,15,40] women's increased facial expressiveness might also lead to increased social support. It is, however, also possible that the increased expressiveness of pain has its downside. Women might be perceived as exaggerating their pain experiences, and this bias could result in potential skepticism or reduced assistance from health care providers.[57,67] When trying to draw such clinical conclusions, it is important to keep in mind that although the found sex differences were stable and of small-moderate effect size, facial responses to pain show great variability even within a sex. Thus, health care workers should be aware that depending on various individual biopsychosocial factors,[3,23,25,29,47,48,52,62–64] individuals might be more or less facially expressive—with sex being just one factor.

### *4.4. Limitations*

Sex was only assessed on nominal level although, sex and gender not only exist on a continuous spectrum[50] but also can be regarded as multidimensional constructs.[27] Thus, a more dimensional assessment might further explain the association between facial expressions of pain, sex, and gender. The age range of the participants in our studies spanned from young- to middle-aged individuals, and thus, generalizability is not limited to an undergraduate student population. Nevertheless, our study falls short regarding generalizability to, eg, elderly patients or patients with chronic pain. Additionally, we did not collect data on the ethnic composition of the studies populations, which further restricts the generalizability of our findings.

### *4.5. Conclusions*

Although it has to be acknowledged that variations in facial expressions of pain are very large even within each sex, we could show in a large, combined sample that women show elevated facial responses to painful stimuli and encode their felt pain intensity more discriminatively using their facial expression compared with men. This indicates that women might be better in using facial communication of pain in an intensity-discriminative manner.

## Conflict of interest statement

The authors have no conflict of interest to declare.

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## Appendix A. Supplemental digital content

Supplemental digital content associated with this article can be found online at http://links.lww.com/PAIN/B998.

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