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**Angaben zur Veröffentlichung / Publication details:**

Basten Günther, J., Miriam Kunz, M. Peters, and S. Lautenbacher. 2020. "The effect of optimism on facial expression of pain: implications for pain communication." *European Journal of Pain* 25 (4): 817–30. https://doi.org/10.1002/ejp.1712.

DOI: 10.1002/ejp.1712

ORIGINAL ARTICLE

EJP European Journal of Pain

# The effect of optimism on the facial expression of pain: Implications for pain communication

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**Abstract**

**Background:** There is a broad range of evidence on optimism dampening the pain experience, as assessed by subjective self-report. Facial expression of pain conveys supplementary information about the pain experience, is an integral part of pain communication and assists psychosocial pain coping. Nevertheless, the effect of induced optimism on facial activity during pain has to our knowledge not been examined.

**Methods:** In our experiment, 40 healthy participants underwent two blocks of thermal stimulation containing phasic non-painful and painful stimuli. Between the two blocks, the *Best Possible Self* imagery and writing task was performed to induce situational optimism, while a control group wrote about their typical day. Facial activity and self-report ratings of intensity and unpleasantness were recorded. Facial activity was analysed using the Facial Action Coding System.

**Results:** The optimism manipulation was successful in increasing state optimism. It did not affect self-report ratings, but resulted in a stronger facial expression of pain, caused especially by increases in Action Units 4 (furrowed brows) and 6_7 (narrowed eyes).

**Conclusions:** All Action Units, which were affected by the optimism induction, are known to be prevalent during pain stimulation. The increase in facial expression might reflect reduced inhibition of pain communication in temporarily optimistic participants. Optimism might lead to expecting positive and helpful reactions from others and, by that, to great readiness to elicit these reactions by non-verbal social behaviour.

**Significance:** This study is the first to indicate that state optimism increases the facial expression of pain as a social signal for help and empathy without concomitant changes in the subjective pain experience.

## 1 | INTRODUCTION

Optimism is commonly defined as positive expectancies concerning the future (Scheier & Carver, 1985). Positive effects of optimism on various health-related outcomes have been demonstrated (e.g. well-being, cancer progression, cardiovascular and immune functioning, mortality; for overviews, see Avvenuti et al., 2016; Carver et al., 2010; Forgeard & Seligman, 2012; Rozanski et al., 2019; Scheier & Carver, 2018). There are numerous reports of optimism's dampening effect both on experimental and on clinical pain as well as on pain-related distress (Basten-Günther et al., 2019; Garofalo,

2000; Geers et al., 2008; Goodin & Bulls, 2013). The underlying mechanisms of this relationship are not yet fully clear. There are hints that optimism leads to lower pain catastrophising, which in turn decreases pain reports (cf. Pulvers & Hood, 2013). Furthermore, optimism might be associated with adaptive coping (problem- or emotion-focused coping, cf. Solberg Nes & Segerstrom, 2006) and in turn, diminish pain experience. Alternatively, optimists could tend to divert their attention from the negative aspects of a situation (Peters et al., 2016) and subsequently report less pain.

While a large part of previous studies has investigated the association between dispositional i.e. trait optimism and pain, there are more recent attempts to manipulate state optimism both experimentally and as a clinical intervention. These approaches might be helpful to demonstrate causality in the optimism-pain relation (Hanssen et al., 2013). One of the techniques to foster state optimism is the *Best-Possible-Self* task (*BPS*; King, 2001), an imagery and writing exercise which has proven successful in increasing optimism temporarily (Hanssen et al., 2013; Peters et al., 2010). Two previous studies have investigated the effect of the *BPS* task on experimental pain. One showed decreased pain ratings after the optimism induction (Hanssen et al., 2013), the other did not find an effect on self-reported pain intensity and conditioned pain modulation (Traxler et al., 2019).

Studying facial reactions during pain could provide new insights into the optimism-pain relationship. Facial reactions can be seen as an independent source of information as their intensities have been shown to be only weakly to moderately correlate with subjective pain ratings (Kunz et al., 2004). Several experimental studies have revealed that facial reactions to pain can be influenced by cognitive and affective factors such as fear of pain or pain catastrophising (Vervoort et al., 2008; Vlaeyen et al., 2009). Their function is the nonverbal communication of pain in order to warn the interaction partner or appeal for help and compassion as a way of psychosocial coping (Hadjistavropoulos et al., 2011; Sullivan et al., 2001). Consequently, facial expressions of pain also vary with the social context, i.e. they are enhanced in the presence of the partner and reduced in the presence of an unfamiliar person or in situations of social threat (Karmann et al., 2014; Karos et al., 2019). This might be one mechanism of action of optimism because optimism has been associated with more social support seeking and a greater real or perceived availability of social support (Brissette et al., 2002; Dougall et al., 2001). Accordingly, the facial expression of pain might be influenced by optimism independently from and additionally to the subjective experience of pain.

The effect of optimism on the facial expression of pain may be twofold. On the one hand, the facial expression of pain might be weakened after the induction of state optimism as a consequence of a decreased pain experience. On the other hand, since situational optimism is likely associated with increased trust in the social environment, readying individuals to manifest otherwise hidden signs of weakness and appeals for help, optimism may in contrast lead to the opposite, namely stronger facial expressions of pain. Thus, the aim of the present study was to decide which of the two theoretically derived, contrary effects of situational optimism on the facial expression of pain prevails.

# 2 | METHODS

## 2.1 | Participants

A total of 40 healthy, pain-free individuals (20 men and 20 women, ten from each decade between 20 and 60); mean [± *SD*] age 39.9 ± 13.5 years) participated in the current study. The participants were recruited via advertisements in the local newspaper (Bamberg, Germany). Exclusion criteria were current experience of acute or chronic pain, psychological or physical illnesses, pregnancy or pain-influencing medication. Participants were asked not to take alcohol or analgesic and psychotropic drugs on the day of the experiment and to postpone the appointment if pain occurred or if any pain influencing substances had to be taken on that day. All participants provided informed consent and received monetary compensation. The study protocol was approved by the ethics committee of the University of Bamberg (Bamberg, Germany).

## 2.2 | Procedure

### 2.2.1 | Design and general protocol

We conducted a randomized controlled trial. In a mixed-design, an experimental group receiving an optimism manipulation and a control group performing a neutral task (between-subject factor) were compared across two timepoints which acted as pre- and post-induction measurements (within-subject factor). Group assignment was randomized, and the two groups were balanced regarding age, sex, phase of the menstrual cycle and time of day of the session.

The experiment consisted of one session taking place at 1.30 p.m. for half of the participants and at 3.30 p.m. for the other half. After providing informed consent and filling out several questionnaires (Life Orientation Test-Revised: *LOT-R*; Future Expectancies Scale: *FEX*; Positive and Negative Affect Schedule: *PANAS*), participants underwent two identical blocks of thermal stimulation during which their facial activity, heart rate (results not reported here) and self-report ratings were recorded (Figure 1). During the pain blocks, the experimenter sat behind the subject and was not visible. In between the two pain blocks of stimulation, the experimental manipulation (optimism versus neutral imagery and writing

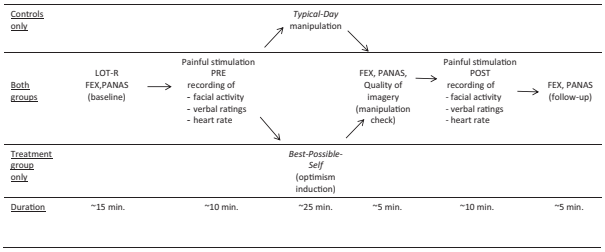


**FIGURE 1** Overview of the general protocol of the experiment

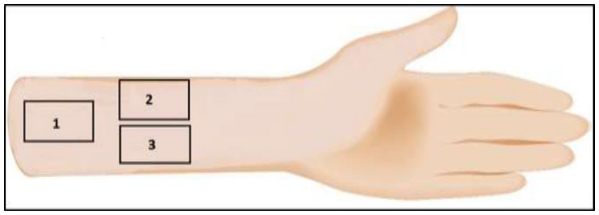


**FIGURE 2** Positions of thermode during (1) threshold determination, (2) first block of stimulation (pre-measurement), (3) second block of stimulation (post-measurement). The upper edge of thermode at position 1 is located 1 cm distal from the elbow pit. Thermode at positions 2 (lateral) and 3 (medial) is located 1 cm distal from the lower edge of thermode at position 1. Illustration adapted from Mücke et al. (2014).

task) was executed (independent variable). The state questionnaires *FEX* and *PANAS*, which served as a manipulation check, were filled out three times in order to record changes in affect and situational optimism: before the first pain block (baseline), immediately after the BPS/TD intervention and after the second pain block (follow-up). After roughly 2 hr, the participants were thanked and debriefed and the session was concluded.

### 2.2.2 | Painful stimulation

Thermal stimulation was applied to three designated sites on the left volar forearm (see Figure 2) by a Peltier-based contact stimulation device (TSA-2001, Medoc, Israel) with a 30 mm × 30 mm contact thermode. To ensure that temperature intensities were perceived as painful but not too painful in all participants (to prevent floor as well as ceiling effects), 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 35°C, using heating and cooling buttons, until they obtained a level that was barely painful. A constant press of the buttons produced a heating or cooling rate of 0.5°C/s. Following a familiarisation trial, there were four trials and the average of these four trials was used to constitute the threshold estimate. Following the assessment of pain thresholds, phasic heat stimuli (trapezoid form, 5 s [plateau]; rate of change: 4°C/s; baseline temperature: 38°C; inter-stimulus intervals of 15 s) were applied to the volar forearm (different sites for the determination of threshold and the two blocks of stimulation, respectively). Two different stimulus intensities were applied; namely, painful (+3°C above the pain threshold) and non-painful (−1°C below the pain threshold) intensities. Including non-painful intensities and comparing non-painful and painful intensities allowed for the determination of which types of facial responses are specific for painful experiences. After three familiarisation stimuli (intensities: threshold, threshold +1°C, threshold −2°C), participants received two blocks of stimulation (one before and one after the experimental manipulation), which each consisted of 10 painful and 10 non-painful stimuli in the same random order.

### 2.2.3 | Optimism manipulation

In between the two blocks of heat stimulation, the experimental optimism induction was performed. Optimism was induced by BPS manipulation, a positive future thinking technique based on work by King (2001). The BPS task has been proven effective in increasing positive affect and positive future expectancies (Peters et al., 2010). Participants were instructed to carry out a writing and imagery exercise. Half of the participants were assigned to the BPS condition ($n = 20$), which required them to write about their life in the future where everything has turned out for the best. The other half of the participants were assigned to the control condition ($n = 20$), whose task consisted of writing about a typical day (TD). The instructions for BPS and TD were as follows (cf. Sheldon & Lyubomirsky, 2006).

- BPS condition:

*Thinking about your best possible self means that you imagine yourself in the future, after everything has gone as well as it possibly could. You have worked hard and succeeded at accomplishing all the goals of your life. Think of this as the realization of your dreams, and that you have reached your full potential.*

- TD condition:

*Thinking about your typical day means that you take notice of ordinary details of your day that you usually don't think of. These might include particular classes or meetings you attend to, people you meet, things you do, typical thoughts you have during the day. Think of this as moving through your typical day, hour after hour.*

Both manipulations had the same procedural format: participants were requested to think for 1 min about what to write, then to write uninterrupted for 15 min, followed by 5 min of imagining the story they had just been writing. Instructions were given both verbally and in writing. The manipulation check followed immediately by asking the participants to complete the FEX and PANAS a second time and to answer a questionnaire about the quality of their writing and imaginations (*Quality of imagery*, Peters et al., 2010).

### 2.2.4 | Questionnaires

*Trait questionnaires*

The validated German version (Krohne et al., 1996) of the *Life Orientation Test-Revised* (*LOT-R*; Scheier et al., 1994) was used to assess the level of dispositional optimism. The LOT-R has 10 items that are rated on a 5-point Likert scale, ranging from 0 ('strongly disagree') to 4 ('strongly agree'). There are three positively phrased items (optimism subscale), three negatively phrased items (pessimism subscale) and four filler items. A total trait optimism score is calculated over the six items with either positive or negative content after reversing the negatively phrased items. Internal consistency as measured by Cronbach's alpha was $\alpha = 0.76$.

*State questionnaires*

The *Future Expectancies Scale* (*FEX*; Hanssen et al., 2013) was administered to assess state optimism. A German translation of the questionnaire was used which has been translated in a standard 'forward-backward' procedure and used in a prior study by the authors (Peters et al., 2016). The FEX consists of 10 statements describing a positive future event and 10 statements describing a negative future event. Participants rated the likelihood that they will experience each specific event on a 7-point Likert scale, ranging from 1 ('not at all likely to occur') to 7 ('extremely likely to occur'). The FEX has previously been demonstrated to be responsive to optimism manipulations (Boselie et al., 2014; Hanssen et al., 2013). The subscores FEX positive and FEX negative were used for further analyses. Internal consistency at the three assessment times ranged from Cronbach's $\alpha = 0.89$ to $\alpha = 0.91$ for the subscale FEX positive and from $\alpha = 0.83$ to $\alpha = 0.87$ for the subscale FEX negative.

Mood was assessed with the *Positive and Negative Affect Schedule* (*PANAS*; Watson et al., 1988). The PANAS consists of 20 items measuring positive (10 items) and negative (10 items) affect. Participants indicate the degree to which a certain feeling is present at that moment on a 5-point Likert scale ranging from 1 ('not at all') to 5 ('extremely'). The subscores PANAS positive (PANAS_PA) and PANAS negative (PANAS_NA) were used for further analyses. For the PANAS, a validated German version was available (Glaesmer et al., 2008). Internal consistency at the three assessment times ranged from Cronbach's $\alpha = 0.86$ to $\alpha = 0.93$ for PANAS_PA and from $\alpha = 0.66$ to $\alpha = 0.83$ for PANAS_NA.

*Quality of imagery*

Two visual analogue scales (Peters et al., 2010) were used to rule out qualitative (in contrast to content-related) differences in participants' imagery between the BPS and the TD group. Participants were asked two questions which have been used in previous studies (Hanssen et al., 2013): 'How well could you imagine yourself in the situation you described in your writing' (not at all – extremely well) and 'How vivid were the pictures you imagined?' (not vivid at all – very vivid). A third VAS was administered to determine whether imagery in the BPS group was more positive than in the TD group: 'How negative or positive were your imaginations?' (very negative – very positive). This third question was meant to serve as an additional manipulation check as we wanted to rule out that imaginations and writing content were equally positive in the TD group as in the BPS group.

### 2.2.5 | Pain-related parameters

*Facial activity*

Participants' faces were videotaped throughout the heat stimulation. The camera was located approximately 1.5 m in front of the participant to allow for a frontal view. To prevent effects of social desirability on facial expressions, participants were told that the main focus of interest was heart rate measurement whereas video recordings served only for the control documentation of the regular procedure. To enable the offline segmentation of the videos, an LED light visible to the camera, but not to the participant, was lit concurrently with the 5 s heat stimuli, 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 avoid movements and to look at the fixation cross on the computer screen in front of them which appeared during each plateau phase of heat stimulation. Participants were also instructed not to talk during heat stimulation. Facial expressions were coded from the video recordings using the Facial Action Coding System (FACS) (Ekman & Friesen, 1978), which is based on an anatomical analysis of facial movements and distinguishes 44 different 'action units' (AUs) produced by single muscles or combinations of muscles. A certified FACS coder (qualified by passing an examination given by the developers of the system) who was blind to the experimental conditions identified the frequency and the intensity (five-point scale) of the different AUs. Software designed for the analysis of observational data (Observer Video-Pro; Noldus Information Technology,

Netherlands) was used to segment the videos and to enter the FACS codes into a time-related database. Time segments of 5 s beginning just after the stimulus had reached the target temperature (time period during which the LED was lit) were selected for scoring. In total, 2 × 20 segments of heat stimulation (10 non-painful and 10 painful segments in both the first (pre, i.e. prior to the optimism manipulation) and the second (post, i.e. after the optimism manipulation) block) were analysed for each participant. For the purpose of necessary data reduction, AUs that represent similar facial movements were combined, as has been performed in previous studies without any loss of information (Kunz et al., 2008, 2012). Those combinations include AUs 1_2, 6_7, 9_10 and 25_26_27. In order to determine interrater reliability, five percent of the video segments, taken from both the experimental and the control group, including facial responses to both painful and non-painful stimuli during pre- and post-measurement were coded by a second certified observer also blind to the experimental conditions. Interrater reliability was calculated using the Ekman–Friesen formula (Ekman & Friesen, 1978; number of AUs agreed upon ×2 and divided by the overall amount of AUs coded). Interrater reliability was 0.83, which compares favourably with other research in the FACS literature (e.g. Karmann et al., 2019; Priebe et al., 2015).

Pain-relevant AUs were selected similar to the procedures developed in previous studies (e.g. Karmann et al., 2019; Kunz et al., 2007, 2008) using the following steps (see also Table 1): (a) AUs had to occur in more than 5% of the painful trials in at least one of the two groups during at least one of the two stimulation periods (pre and post) and (b) AUs had to be substantially more frequent during painful than during non-painful trials (Cohen's $d$ effect size of $d \geq 0.5$ for this frequency difference; the effect sizes fulfilling this criterion are marked in bold in Table 1) in at least one of the two groups during at least one of the two stimulation periods. The resulting subset of pain-relevant AUs is consistent with previous findings regarding facial responses to pain (Kunz et al., 2019) and consists of the following AUs: AU 1_2 (raised eyebrows), AU 4 (furrowed brows), AU 6_7 (narrowed eyes), AU 9_10 (wrinkled nose and raise of the upper lip), AU 14 (dimpler) and AU 25_26_27 (opened mouth and jaw drop). Then mean AU-frequency and mean AU-intensity values were combined by multiplication (product terms) and averaged across all selected AUs to form a composite score. These composite scores were not distributed normally in any of the four experimental conditions (TD group: Kolmogorov–Smirnov $Z = 0.307$ (pre), $Z = 0.243$ (post); BPS group: $Z = 0.242$ (pre), $Z = 0.203$ (post); all $p < 0.05$). To avoid losing power by switching to non-parametric tests, we used square root transformed composite scores for all further analyses as has also been performed in previous studies (Karmann et al., 2014; Karmann et al., 2019; Kunz et al., 2012). These transformed data were normally distributed (TD group: Kolmogorov-Smirnov $Z = 0.169$ (pre), $Z = 0.138$ (post); BPS group: $Z = 0.128$ (pre), $Z = 0.128$ (post); all $p > 0.12$). In case of significant effects for the composite scores, analyses of the underlying single AUs were also conducted on the basis of square root transformed values.

**TABLE 1** Facial Action Units (AUs) with a critical frequency of occurrence of more than 5% in painful segments

| | Pre | | Post | | Pre | | Post | |
|---|---|---|---|---|---|---|---|---|
| | %[a] | *d* | % | *d* | % | *d* | % | *d* |
| AU **1_2** (raised eyebrows) | 24 | **0.7** | 19 | **0.6** | 20 | 0.4 | 26 | **0.5** |
| AU **4** (furrowed brows) | 28 | **1.0** | 15 | **0.5** | 48 | **1.2** | 52 | **1.1** |
| AU **6_7** (narrowed eyes) | 73 | **0.9** | 54 | **1.9** | 98 | **1** | 129 | **1.2** |
| AU **9_10** (wrinkled nose and raise of the upper lip) | 3 | **0.5** | 20 | **1.6** | 41 | **1.1** | 49 | **0.8** |
| AU **25_26_27** (opened mouth and jaw drop) | 21 | **0.8** | 21 | **0.9** | 49 | **0.8** | 59 | **0.9** |
| AU **14** (dimpler) | 10 | 0.4 | 9 | 0.1 | 11 | **0.6** | 11 | −0.3 |

*Note:* Effect sizes for frequency differences between "non-painful" and "painful" trials are given. Medium and strong effect sizes ($d \geq 0.5$) are marked in bold. TD = typical day (control group), BPS = Best Possible Self (treatment group).

[a]% denotes the percentage of occurrence in the painful trials given separately for each group (BPS/TD) and each point in time (pre/post).

*Self-report ratings*

Participants were asked to provide self-report ratings of pain intensity (sensation scale) and pain unpleasantness (affect scale) of the thermal stimuli using two eleven-point electronic scales (0–10), which appeared horizontally on a computer screen after each stimulus. The endpoints of the scales were labelled with German adaptations of the designations proposed by Price et al. (1983): 'no sensation' and 'the most intense sensation imaginable' for the sensation scale, 'not bad at all' and 'the most intense bad feeling possible for me' for the affect scale. Participants were asked to rate stimulus intensity and stimulus unpleasantness proportionately (e.g. a number twice as big for intensity or unpleasantness twice as strong) by clicking with the mouse on 1 of the 11 numbered buttons. Ratings had to be given within 15 s after stimulus offset.

*Heart rate*

During the two blocks of heat stimulation, participants' heart rate was recorded continuously (recording device: SIGMA Plpro/Type Databox DB 36). Two electrodes were fixed on the upper and lower end of the patients' sternum, the ground electrode was placed on the hip. Data were not analysed and are not reported here because heart rate recording mainly served as a 'cover story' to disengage the subject's interest from the videotaping of facial responses.

### 2.2.6 | Statistical analyses

Sample description: In order to assess differences in demographic or baseline variables between the BPS and the TD group, independent samples *t* tests comparing the two groups were applied. Means with standard deviations were given for basic description.

Manipulation check: To control whether the optimism induction was successful, four separate 2 × 2 (time × group) repeated measures ANOVAs were computed, with either the PANAS or the FEX sub-scales as the dependent variable, experimental condition as fixed factor and time (pre-post) as within-subject factor. Independent samples t tests were used to investigate group differences as regards the quality of writing and visualisation.

Hypotheses testing: In order to examine the effect of the optimism induction on the pain parameters, we tested for a time × group interaction effect in separate 2 × 2 repeated measures ANCOVAs for the two dependent variables (self-report ratings and composite score of facial activity). Experimental condition was entered as fixed factor. All analyses were repeated with the LOT_R optimism sub-score as a covariate because it differed prior treatment between the BPS and TD groups (see the results). This did not change the results. In case of significance, post-hoc testing with *t* tests for dependent or independent samples was applied. For the description of the potential influence of trait optimism, correlational analyses between the *LOT-R* score and pain-related variables were conducted. In case of significant results for the composite score of facial activity, the underlying AUs were tested for their single contributions by *t* tests on changes from pre- to post-measurements (Δpost-pre; before and after optimism treatment).

Analyses were conducted with SPSS 24 and the alpha-level was 0.05 throughout.

## 3 | RESULTS

### 3.1 | Descriptive statistics

Means and standard deviations for demographic variables, heat pain threshold and dispositional optimism (*LOT-R*) are shown in Table 2. The LOT-R mean score is exactly the same as the population-based norm recently reported by Schou-Bredal et al. (2017). The heat pain threshold is very similar to the scores found in prior studies (for example, Horn-Hoffmann & Lautenbacher, 2015; Karmann et al., 2014).

| | TD, *n* = 20 | BPS, *n* = 20 | | | |
|---|---|---|---|---|---|
| **Sex, male** | **10 (50%)** | **10 (50%)** | ***t*-test for independent samples (TD versus BPS)** | | |
| | **Mean (*SD*)** | **Mean (*SD*)** | ***t*(38)** | ***P*** | ***d*** |
| Age (years) | 40.50 (11.69) | 40.20 (12.60) | 0.08 | 0.94 | 0.03 |
| Pain treshold (°C) | 46.09 (2.53) | 45.45 (1.83) | 0.93 | 0.36 | 0.29 |
| *LOT-R* | 16.40 (3.17) | 18.05 (4.06) | 1.43 | 0.16 | 0.45 |
| *LOT-R* optimism subscale | 9.70 (1.98) | 8.40 (2.09) | 2.02 | 0.05* | 0.64 |
| *LOT-R* pessimism subscale | 4.00 (1.69) | 3.65 (2.75) | 0.48 | 0.63 | 0.15 |

**TABLE 2** Demographics, heat pain threshold and trait optimism.
BPS = best possible self (treatment group); TD = typical day (control group)

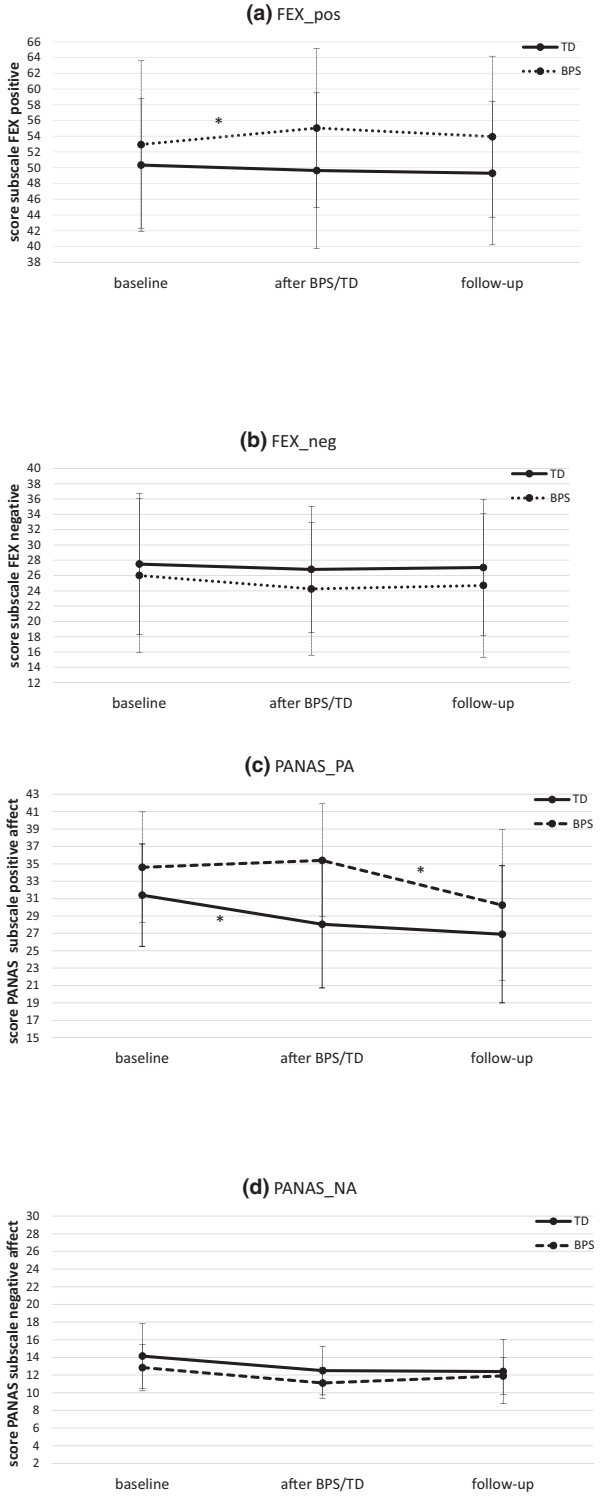


**FIGURE 3** Mean values for state optimism (FEX_pos (a) and FEX_neg (b)) and positive/negative affect (PANAS_PA (c) and PANAS_NA (d)) at baseline, after the experimental manipulation and at follow-up at the end of the experiment. Error bars represent standard deviations. TD = Typical day, BPS = Best Possible Self. *significant contrast ($p \leq .05$) between the respective times of assessment in within-condition repeated measures ANOVA

The BPS and TD groups did neither significantly differ in their pain threshold nor in any demographic, trait or baseline state variable except for the optimism subscale of the *LOT-R*, where the TD group scored significantly higher (medium effect size).

Of the 20 female participants, five took oral contraceptives, five were post-menopausal and one participant had undergone hysterectomy. Of the remaining nine, three were in the follicular, three in the periovulatory and three in the luteal phase of their menstrual cycle at the time of the experiment. There were no significant differences between BPS and TD groups regarding the intake of contraceptives or the distribution of menstrual phases

## 3.2 | Influence of optimism induction

### 3.2.1 | Effects on mood and cognition (manipulation checking)

There was a significant, medium-sized, time x group interaction effect for PANAS_PA (subscale positive affect; $F(2,76) = 3.89$, $p = 0.03$, $\eta p^2 = 0.09$) and FEX_pos (subscale positive future expectancies; $F(2,76) = 3.07$, $p = 0.05$, $\eta p^2 = 0.08$). Within-condition analyses of repeated measurements with planned contrasts were performed to compare changes in these scales between the pre-manipulation (baseline) and the post-manipulation assessment and between the pre-manipulation and the follow-up assessment at the end of the experiment. As illustrated in Figure 3, results indicated that in the BPS condition (optimism induction), FEX_pos was significantly larger at the post-manipulation assessment ($F(1,19) = 6.5$, $p = 0.02$, $\eta p^2 = 0.255$; large effect size) but not at the follow-up assessment at the end of the experiment ($F(1,19) = 1.7$, $p = 0.20$, $\eta p^2 = 0.083$) compared to the pre-manipulation (baseline) assessment, respectively. In the TD group, there were no differences between the three assessments. Corresponding analyses for the PANAS_PA scale showed a significant decrease of positive affect in the TD group at the post-manipulation and follow-up assessments compared to baseline (post-manipulation: $F(1,19) = 7.6$, $p = 0.01$, $\eta p^2 = 0.287$; follow-up: $F(1,19) = 14.2$, $p = 0.001$, $\eta p^2 = 0.427$; both large effect sizes) whereas positive affect in the BPS group remained stable directly after the manipulation but was only significantly lower compared to baseline at the follow-up assessment (post-manipulation: $F(1,19) = 1.2$, $p = 0.29$, $\eta p^2 = 0.058$; follow-up: $F(1,19) = 10.1$, $p = 0.005$, $\eta p^2 = 0.348$, large effect). There were no significant differences between the three assessment times in the negative subscales of FEX and PANAS (cf. Figure 3).

Given the relative increases in situational optimism and positive affect directly after the BPS treatment, leading in each case to large effects, we can assume that the optimism manipulation was successful.

The BPS and the TD groups did not significantly differ in the VAS (0-100mm) about the quality and the vividness of their imaginations ('how well could you imagine yourself in the situation you described in your writing': BPS: $M = 77.35$, $SD = 15.09$, TD: $M = 74.05$, $SD = 21.75$; $t(38) = 0.56$; $p = 0.58$; $d = 0.18$ and 'how vivid were the pictures you imagined?': BPS: $M = 77.15$, $SD = 22.73$, TD: $M = 69.25$, $SD = 22.09$; $t(38) = 1.12$; $p = 0.27$; $d = 0.35$). This is in accordance with prior research (Hanssen et al., 2013). On the third question asking the emotional valence ('how negative or positive were your imaginations?'), the BPS group scored as expected significantly higher than the TD group (BPS: $M = 86.60$, $SD = 14.73$, TD: $M = 61.15$, $SD = 25.09$; $t(38) = 3.91$, $p < 0.005$, $d = 1.24$, *large effect size*).

### 3.2.2 | Effects on pain (hypotheses testing)

*Ratings of painful stimuli*

As shown in Table 3, the 2 × 2 repeated measures ANCOVAs did not show any significant effects on ratings, neither on ratings for stimulus intensity nor on ratings for stimulus unpleasantness. This means that there was no effect of induced optimism on subjective pain experience (Figure 4).

### 3.2.3 | Facial activity

As regards the composite score, the 2 × 2 repeated measures ANCOVA showed that the time × group interaction effect reached significance (see Table 3). The square root transformed composite scores did not significantly differ between BPS and TD group in the pre-measurement ($t(38) = 1.35$, $p = 0.185$, $d = 0.25$; *small effect*) but indicated significantly more facial activity in the BPS group than in the TD group in the post-measurement ($t(38) = 2.28$, $p = 0.028$, $d = 0.68$; *medium to large effect*) (see Figure 5). These findings suggest a relative augmentation of pain-related facial activity after the optimism induction.

In order to find out which of the pain-relevant AUs contributed to the augmentation in facial activity indicated by the composite score, we computed, separately for each of the six underlying Action Units (using square root transformed values), change scores (Δpost-pre) and conducted *t* test for independent samples to compare the difference in changes between the BPS and TD groups. As can be seen in Figure 6, facial responses decreased during the post-testing in the TD group (this was especially apparent for AU 4). In contrast, the BPS group showed more stable facial responses to pain in the pre- and post-measurements, with one exception, namely AU 6_7 which

**TABLE 3** Results of the ANCOVAs with the factors "condition" (between-subjects, levels: BPS and TD), "time" (within-subject, levels: pre and post) and the covariate "dispositional optimism (*LOT-R*)" for all pain-related variables

| | Condition | Time | LOT-R | Condition x time | Time x LOT-R |
|---|---|---|---|---|---|
| Stimulus intensity | $F(1,37) = 2.935$; $p = 0.095$; $\eta p^2 = 0.073$ | $F(1,37) = 0.535$; $p = 0.469$; $\eta p^2 = 0.014$ | $F(1,37) = 0.056$; $p = 0.814$; $\eta p^2 = 0.002$ | $F(1,37) = 0.007$; $p = 0.936$; $\eta p^2 = 0.000$ | $F(1,37) = 2.431$; $p = 0.127$; $\eta p^2 = 0.062$ |
| Stimulus unpleasantness | $F(1,37) = 1.671$; $p = 0.204$; $\eta p^2 = 0.043$ | $F(1,37) = 0.778$; $p = 0.383$; $\eta p^2 = 0.021$ | $F(1,37) = 0.456$; $p = 0.503$; $\eta p^2 = 0.012$ | $F(1,37) = 0.026$; $p = 0.873$; $\eta p^2 = 0.001$ | $F(1,37) = 2.480$; $p = 0.124$; $\eta p^2 = 0.063$ |
| FACS composite score | $F(1,37) = 3.734$; $p = 0.061$; $\eta p^2 = 0.092$ | $F(1,37) = 1.715$; $p = 0.198$; $\eta p^2 = 0.044$ | $F(1,37) = 1.260$; $p = 0.269$; $\eta p^2 = 0.010$ | $F(1,37) = 4.941$; $p = \mathbf{0.032}$, $\eta p^2 = 0.118$ | $F(1,37) = 1.986$; $p = 0.167$; $\eta p^2 = 0.051$ |

*Note:* Significant effects ($p \leq 0.05$) are marked by bold text and gray-shaded background.

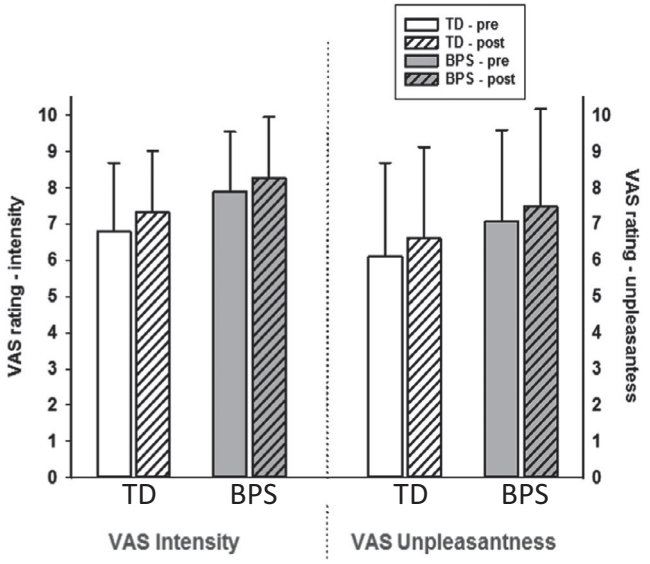


**FIGURE 4** Mean self-report ratings of stimulus intensity (a) and stimulus unpleasantness (b). Error bars: standard deviation; TD = Typical day, BPS = Best Possible Self.

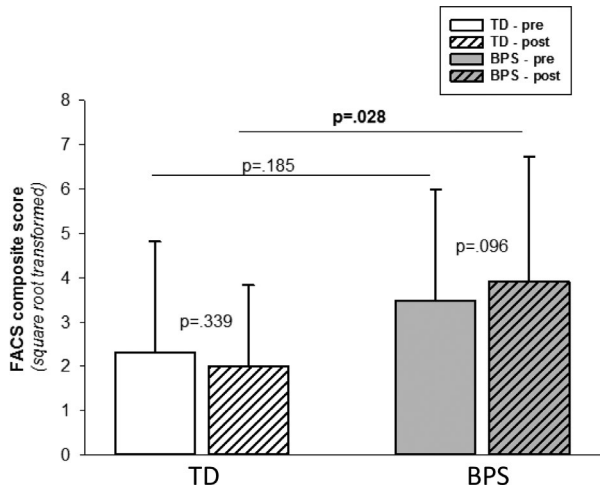


**FIGURE 5** Mean facial activity (FACS composite score) during painful stimulation. Error bars: standard deviation; TD = Typical day, BPS = Best Possible Self.

showed a strong increase after optimism induction. Not surprising, only the change scores for AU4 ($t(38) = -2.92$; $p = 0.006$) and AU 6_7 ($t(38) = -2.87$; $p = 0.007$) were significantly different between the two groups ($p > 0.463$ *for all other 4 AUs*). Thus, the overall divergence in the composite score of facial responses between BPS and TD groups was mostly driven by optimism induced changes in AU 4 and especially in AU 6_7.

### 3.2.4 | Intercorrelations between pain-relevant variables

As shown in Table 4a, absolute values of ratings and facial activity (averages of pre- and post- measurements) were correlated

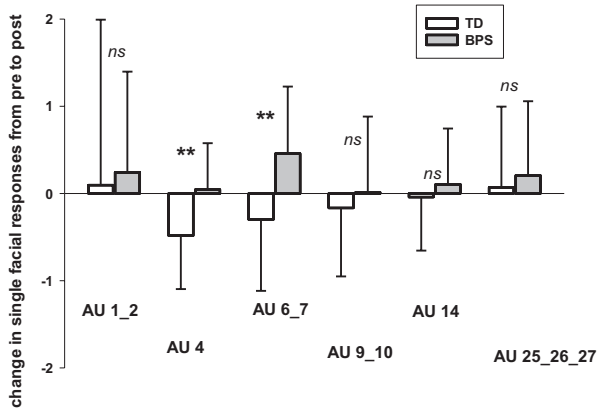


**FIGURE 6** Mean chance scores in facial activity pre- and post-treatment (Δpost-pre for the AUs underlying the composite score). Error bars: standard deviation; TD = Typical day, BPS = Best Possible Self.

moderately for the whole sample and for the TD group: higher ratings were associated with more facial activity as measured by the FACS composite score (square root transformed values). In the BPS group, pain ratings were not significantly and only weakly correlated with the facial responses to pain. These findings replicate the well-known only weak-to-moderate associations of these two pain indicators. In Table 4b, correlations between pre-post-change scores (Δpost-pre) are shown. They reveal a similar pattern to the correlations between absolute values. In the whole sample and the TD, change scores of pain ratings and facial responses were moderately correlated, whereas, in the BPS group, correlations were only weak and not significant. This clearly points to the independent effects of BPS on pain ratings and facial activity.

## 4 | DISCUSSION

The aim of the present study was to compare the effects of an experimental optimism induction (*Best Possible Self [BPS] treatment*) on subjective and facial responses to painful heat stimulation. The effects of optimism on the facial expression of pain are described here for the first time. While there was no effect of the BPS treatment on subjective pain ratings following painful stimuli, the facial expression of pain was significantly stronger in the BPS group compared to the control (*Typical Day [TD]*) group after the optimism induction.

### 4.1 | Facial activity

It is of note that optimism mainly affected Action Units which are part of the known facial pain response (Kunz et al., 2019), while not activating other facial muscles that might express other affective states like joy. Thus, the facial encoding of pain was not qualitatively altered as one might expect when

**TABLE 4** Intercorrelations between pain parameters (self-report ratings of stimulus intensity and stimulus unpleasantness, facial activity). Correlations between (a) absolute values, (b) change scores

| (a) | Whole sample | | TD | | BPS | |
|---|---|---|---|---|---|---|
| | Stimulus unpleasant-ness | FACS score | Stimulus unpleasant-ness | FACS score | Stimulus unpleasant-ness | FACS score |
| Stimulus intensity | 0.83** | 0.35* | 0.93** | 0.46* | 0.73** | 0.18 |
| Stimulus unpleasantness | – | 0.39* | – | 0.44* | – | 0.32 |
| **(b)** | **whole sample** | | **TD** | | **BPS** | |
| | **Stimulus unpleasant-ness** | **FACS score** | **Stimulus unpleasant-ness** | **FACS score** | **Stimulus unpleasant-ness** | **FACS score** |
| Stimulus intensity | 0.84** | 0.39* | 0.88** | 0.54* | 0.74** | 0.22 |
| Stimulus unpleasantness | – | 0.40* | – | 0.47* | – | 0.36 |

*Note:* Significant effects ($p \leq 0.05$) are marked by asterisk and gray-shaded background.
Abbreviations: BPS, best possible self; TD, typical day.

the induction would lead to a melting of pain with positive emotions. Instead, optimism appeared to only quantitatively change the facial expression of pain. It may be that optimism releases the brake that normally retains part of the facial expression of pain. These results are similar to earlier findings from our laboratory on the influence of feeling socially familiar (Karmann et al., 2014). The authors found changes in facial responses to pain to be dependent on the presence of other persons. Facial responses were significantly stronger in the presence of the partner compared to the conditions where either the experimenter or no one was present during painful stimulation. Self-report ratings were unchanged across the three social conditions. It seems that a stronger feeling of being safe—as produced by the presence of one's partner—leads to less inhibition of facial responses and thus an increased display of facial responses to pain. Similarly, a recent study showed that social threat (thus, a reduced feeling of being safe) led to a select reduction in facial expressions of pain whereas self-report ratings increased compared to a low threat condition (Karos et al., 2019). These findings strongly resemble those obtained in the present study in which temporarily optimistic individuals showed more facial expressions of pain though pain ratings did not mirror this increase.

It has been argued that individuals are more likely to communicate their vulnerability towards a familiar other such as the partner (Karmann et al., 2014) or a child's parent (Vervoort et al., 2008, 2011), from whom empathy and help can be expected. Optimism may thus lead to greater communicative openness as expectations regarding the social context become more positive. Being in a state of optimism, one may be inclined to expect empathy and help instead of rejection or abuse of one's weakness from others and therefore be more willing to express one's pain via facial responses. (As a methodological reminder, the experimenter was in the room but not visible to the subject during pain stimulation in the present study). This would also be in accordance with prior research, which reports that optimists show more social support seeking and a greater real or perceived availability of social support (Brissette et al., 2002; Dougall et al., 2001). Future studies should combine the optimism induction with an above-mentioned social manipulation (alone versus with a (un)familiar other) to further clarify our findings.

The consequence of increased state optimism was thus hypothesized to be twofold and unfold contrary actions on facial responses to pain. Optimism may lower the experience of pain, (Basten-Günther et al., 2019) but may also increase the expressiveness of pain. The latter should not be misinterpreted as an augmentation of pain but should be interpreted as an enhanced readiness to non-verbally signalling one's pain. Persons engaged in pain management have to be informed that improving the social context of treatment or the attitudes towards this context could even result in more behavioural signs of pain. The optimism-driven increase in

facial expression of pain does not appear to differ qualitatively from the regular facial expressions of pain. Still, given the fact that pain catastrophising also leads to increased communication of pain (Sullivan et al., 2006), it would be interesting to explore whether there are qualitative differences in pain behaviour between high optimists and high pain catastrophizers—particularly since optimism has been proposed to act on pain via reduced pain catastrophising.

A finding worth being discussed is that the increase in facial expression of pain in consequence of temporarily induced optimism is mainly due to two AUs, namely AU 4 (furrowed brows) and especially AU 6_7 (narrowed eyes). The two AUs belong both to the sensory and the affective signals of pain encoded by the facial expression (Kunz, Lautenbacher, et al., 2012). Thus, optimism may strengthen both behavioural indicators of pain intensity and pain unpleasantness and improve the full presentation of the problem. Furthermore, the two AUs are very likely those facial means most commonly used to express pain (Kunz & Lautenbacher, 2014; Kunz et al., 2019; Prkachin, 1992; Prkachin & Solomon, 2008) and also those being sensitive to the familiarity of other people being present (Karmann et al., 2014). Thus, optimism does not act on rare facial expressions but on the frequent facial signals with social function.

It remains open why only induced (state) and not dispositional (trait) optimism was significantly associated with facial responses to pain. Potentially, our experiment represented an unambiguous situation where induced states played a bigger role than latent traits which would more likely manifest themselves under conditions providing more ambiguous situational characteristics (Fleeson & Gallagher, 2009).

## 4.2 | Ratings of painful stimuli

Pain ratings of intensity and unpleasantness were not influenced by the optimism induction. Prior studies using comparable experimental designs reveal mixed results: Hanssen et al. (2013) report pain-dampening effects of the BPS task, while another study (Traxler al., 2019) did not show changes in pain reports. We can only speculate why no pain-dampening effect of optimism was found in our study. To begin with, the temporary effect of our optimism manipulation may have been too weak to result in any detectable changes in pain ratings. However, given the significant effect of the optimism induction on facial responses and given prior significant effects in a study using the BPS procedure with the same efficacy (Hanssen et al., 2013), this explanation does not seem very likely. It appears more plausible that the effect of optimism on pain ratings is in general rather small, making significant results not reliable.

In a situation like this, pain modality and stimulus length might play a crucial role. The study by Hanssen et al. (2013) found lower pain reports after the BPS task applied pain by use of the cold pressor task and pain ratings were obtained at 20, 40 and 60 s during the 1 min immersion of the hand into cold water. The differences between the BPS and the TD group augmented continually and were highest at the last rating. We can, therefore, speculate that cognitions associated with optimism take a while to act—-e.g. mediated by cognitive appraisal processes—and that our 5 s heat stimuli were too short to see any optimism effect in the ratings.

Divergences between subjective pain ratings and facial expression of pain have already previously been reported (Karos et al., 2019; Kunz et al., 2007, 2015; Priebe et al., 2015) and do, therefore, not constitute a major challenge in understanding the zero results as regards the pain ratings in face of positive findings as regards the facial responses to pain. The two variables represent largely independent sources of information about pain, as also shown by our correlation analyses.

## 4.3 | Efficacy of optimism induction by the BPS treatment

Considering the increases in situational optimism (scale FEX positive) and positive affect (scale PANAS-PA) directly after the induction of optimism by the BPS treatment, we can assume that the optimism manipulation was successful. This is in accordance with prior studies using the same paradigm (Carrillo et al., 2019; Hanssen et al., 2013; Peters et al., 2010, 2016). As expected, the BPS exercise creates only short-lasting changes in optimism: at follow-up at the end of the experiment, the FEX positive and PANAS_PA scores dropped to values similar to those of the TD group. As shown by the VAS about the quality of imagery, we can assume that there were no significant qualitative differences between the BPS and the TD group concerning the success and vividness of the subjects' imaginations. The observed differences between the groups in terms of positive affect and state optimism, therefore, seem to be specifically due to a more positive content in the writing and imagery of the BPS group. This is in line with the aims of the BPS paradigm and further corroborates the assumption that BPS treatments can be successful. Though the experimental induction of optimism may seem somewhat 'artificial', we would like to stress the clinical relevance of changes in expectations, as can be seen, for example, from effects that are known to occur during placebo responses. In fact, there are some promising reports of longer-term effects of optimism trainings in healthy and clinical populations (Flink et al., 2015; Meevissen et al., 2011; Peters et al., 2017).

### 4.4 | Methodological strengths and weaknesses

The present study is to our knowledge the first to examine the effect of optimism on the facial expression of pain. While the sample was balanced in regard to sex and age, it has to be taken into account that the study only included healthy participants. Therefore, no conclusions regarding clinical populations can be derived. Furthermore, results in our experimental setting—allowing for causal conclusions and control of many confounding variables—might not be in every respect applicable to more natural everyday contexts. Thus, the generalisability of our conclusions to clinical contexts and clinical pain models has yet to be examined.

## 5 | CONCLUSIONS

The present study found a specific increase in facial expression during pain after an optimism induction, not accompanied by corresponding changes in pain rating. This effect could possibly be interpreted in terms of a greater readiness to communicate one's pain in hope of empathy and help when in an optimistic state. Studies applying an explicit social manipulation (e.g. alone versus others being familiar or not), as well as other pain models, could provide further insights into the general consequences of state optimism on social non-verbal pain behaviour. The interaction between trait and state optimism in their effects on pain remains to be clarified. If our findings are confirmed, clinicians should take into account that optimistic persons might signal more pain, while pain starts to fade in their positive expectation to still receive help and empathy from their others.

### ACKNOWLEDGEMENTS

We gratefully acknowledge the contributions of Eva Capito and Sonja Pähl to data analysis.

### CONFLICT OF INTEREST

The authors state that there is no conflict of interest.

### AUTHOR CONTRIBUTIONS

We declare that all authors discussed the results and commented on the manuscript.

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**How to cite this article:** Basten-Günther J, Kunz M, Peters M, Lautenbacher S. The effect of optimism on the facial expression of pain: Implications for pain communication. *Eur J Pain*. 2021;25:817–830. https://doi.org/10.1002/ejp.1712