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Are both the sensory and the affective dimensions of pain encoded in the face?

Miriam Kunz [a,b,*], Stefan Lautenbacher [a], Nadine LeBlanc [b], Pierre Rainville [b]

[a] *Physiological Psychology, Otto-Friedrich University Bamberg, Germany*
[b] *Department of Stomatology and Centre de recherche de l'Institut universitaire de gériatrie de Montréal, Université de Montréal, Canada*

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ABSTRACT

The facial expression of pain plays a crucial role in pain communication and pain diagnostics. Despite its importance, it has remained unknown which dimensions of pain (sensory and/or affective) are encoded in the face. To answer this question, we used a well-established cognitive strategy (suggestions) to differentially modulate the sensory and affective dimensions of pain and investigate the effect of this manipulation on facial responses to experimental pain. Twenty-two subjects participated in the study. Their facial expressions, pain intensity, and unpleasantness ratings as well as skin conductance responses to tonic and phasic heat pain were assessed before and after suggestions directed toward increase in affective and sensory qualities of pain, respectively, were provided. Facial expressions were analyzed with the Facial Action Coding system. As expected, suggestions designed to increase the sensory dimension produced a selective increase in pain intensity ratings, whereas suggestions designed to increase pain affect produced increased unpleasantness ratings and elevated skin conductance responses. Furthermore, suggestions for either increased pain affect or pain sensation produced selective modulations in facial response patterns, with facial movements around the eyes mostly encoding sensory aspects, whereas movements of the eyebrows and of the upper lip were closely associated with the affective pain dimension. The facial expression of pain is a multidimensional response system that differentially encodes affective and sensory pain qualities. This differential encoding might have evolved to guarantee that the specific characteristics of one's pain experience are facially communicated, thereby ensuring adequate help and support from others.

1. Introduction

The facial expression of pain has recently attracted considerable interest in experimental and clinical research. It has been shown that facial pain displays play a crucial role in social interactions [41] and are of great clinical relevance in pain diagnostic [6,17,19]. Given their important role, it might seem surprising that little is known about which aspects of one's pain experience are exactly encoded in the face.

Pain is a multidimensional experience involving sensory, affective-motivational, and cognitive dimensions. The sensory-discriminative dimension encompasses the perception of the location, intensity, and quality of pain, whereas the affective-motivational dimension refers to the unpleasantness inherent to pain and to emotions related to future implications [21]. Although the sensory and affective dimensions are intimately related and self-ratings of pain intensity and unpleasantness are often highly correlated with each other, the distinction between these dimensions has proven useful to describe both clinical and experimental pain [25,33]. For example, the psychophysical functions describing pain intensity and unpleasantness in relation to stimulus intensity are not simply overlapping [25]. Moreover, psychological interventions involving emotions seem to modulate the unpleasantness more than the perceived intensity of pain [30], while those involving distraction seem to modulate more directly the perceived intensity of pain [38,39]. Furthermore, imaging studies have shown that there are – at least partly – differential brain networks involved in the processing of affective and sensory qualities of pain [13,31]. Although these clinical and experimental observations do not imply orthogonality, independence, or strictly parallel processes [23,31], they do support at least a partial separation of sensory and affective pain dimensions.

Few attempts have been made to investigate which pain dimension is reflected in the face by correlating facial expressions with subjective ratings of pain intensity and pain unpleasantness. Mainly comparable (mostly weak) associations were found between facial expressions and pain unpleasantness as

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[*] Corresponding author. Address: Physiological Psychology, University of Bamberg, Markuspl. 3, 96045 Bamberg, Germany. Tel.: +49 951 8631848; fax: +49 951 8631976.

E-mail address: miriam.kunz@uni-bamberg.de (M. Kunz).

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well as pain intensity ratings [27,29,16], thus suggesting that affective and sensory qualities of pain might both be reflected in facial expressions accompanying pain. Given that the facial expression of pain is composed of various muscle movements [28,29], it is also possible that certain muscle movements encode sensory qualities, whereas others encode affective qualities of pain.

One major difficulty when trying to investigate which dimensions of pain are encoded in the face is that the affective and sensory dimensions of pain are most often highly correlated. However, we have previously shown that it is possible to disentangle these 2 pain dimensions experimentally by using (hypnotic) suggestions designed to target pain intensity or pain unpleasantness [31,32]. By means of these suggestions, we could demonstrate that not only the pain report of the subjects changed in the expected directions, but also that brain activation patterns and autonomic responses to pain changed depending on the type of suggestion [13,31,32].

Here, we sought to use the above-mentioned suggestions to differentially modulate the sensory and the affective dimension of pain and investigate the effect of this manipulation on facial responses. This differential modulation of the 2 pain dimensions allowed us to investigate whether and how facial expressions evoked by noxious stimuli encode pain intensity and unpleasantness.

2. Methods

2.1. Subjects

Twenty-two healthy volunteers (10 women and 12 men) between the ages of 18 and 33 years (mean ± standard deviation [SD] age 22.7 ± 3.8 years) without a history of neurological or psychiatric disease or of chronic pain participated in this study. Four women took oral contraceptives; of the remaining women, 2 were in the first third, 3 in the second third, and 1 in the third third of their menstrual cycle.

These 22 participants were selected out of 60 subjects who were recruited via advertisements posted on the campuses of the Université de Montréal and McGill University and participated in a 1-h preselection session. Because our aim was to use suggestions to increase the sensory and the affective dimension of pain and investigate the effect of the manipulation on facial pain displays, subjects had to be suggestible as well as facially expressive in response to pain. Suggestibility was assessed in the preselection session by the Carleton University Responsiveness to Suggestion scale (CURSS [36]), with the hypnotic induction removed [5]. Subjects who had a CURSS-O score lower than 3 (CURSS-O scores range 0–7; scores <3 indicate a low level of suggestibility) were excluded. The CURSS-O score had to be 3 or greater in order to be selected (mean ± SD score of the 22 selected subjects was 4.41 ± 1.2). To assess subjects' facial expressiveness to pain, experimental pain was applied during the preselection, session and participants who displayed few or no facial responses to the noxious stimulation (facial responses occurring in less than 20% of painful trials) were excluded from the study. The preselection session took place 1–6 weeks before the study commenced. Out of the 38 subjects excluded from the study, 14 were excluded because of CURSS-O scores <3, 11 were excluded because of low facial expressiveness, and 13 were excluded because they were neither suggestible nor facially expressive.

None of the subjects had taken any analgesic medication or alcohol for at least 24 h before the test session. All subjects provided written informed consent and received monetary compensation for their participation. The study protocol was approved by the ethics committee of the Centre de recherche de l'Institut universitaire de gériatrie de Montréal.

2.2. Materials and procedure

Subjects were carefully familiarized with the methods to be used before the start of the experiment. During the whole session, which lasted for approximately 1.5 h, subjects sat upright in a comfortable armchair. The testing procedure included the application of tonic (part 1) and of phasic painful heat stimuli (part 2). We decided to use experimental pain of both phasic and more tonic duration because it has been shown that these types of stimuli differ in their characteristic contributions to the sensory and affective components of pain. Experimental pain of short duration (usually lasting between milliseconds and seconds) is most often accompanied by low levels of unpleasantness relative to its sensory intensity, whereas experimental pain of more tonic duration ($\geqslant 1$ min) elicits comparable levels of pain intensity and pain unpleasantness ratings [18,33]. Thus, the use of these 2 types of experimental pain stimuli allowed us to investigate whether the effect of suggestions on facial and subjective responses is similar in 2 types of pain stimuli that clearly differ with regard to their affective-sensory ratio. We decided to always start with tonic pain stimulation, given that it elicits comparable levels of pain intensity and pain unpleasantness ratings, and thus modulation of the 2 pain dimensions (especially the affective dimension) might be easier during tonic pain compared to phasic pain. Part 1 (tonic) and part 2 (phasic) were both composed of an assessment of pain thresholds, 2 training phases (here, subjects were trained to change their pain experience based on suggestions for increased pain sensation or increased pain affect, respectively), and 3 test blocks (baseline block, increased pain sensation test block, and increased pain affect test block) (Fig. 1).

2.2.1. Stimulation

Pain was induced experimentally by use of a Peltier-based, computerized thermal stimulator with a 3×3 cm^2 contact probe (Medoc TSA-2001; Medoc, Ramat Yishai, Israel). The contact probe was attached to the right (tonic stimulation) and left (phasic stimulation) lower leg. To ensure that temperature intensities were perceived as painful but not too painful in all subjects (to prevent both floor and ceiling effects), temperature intensities were tailored to the individual pain threshold. Thus, heat pain thresholds were determined first using the method of adjustment. Subjects were asked to adjust a temperature starting from 38 °C, using heating and cooling buttons, until they obtained a level that was barely painful. A constant press of the buttons resulted into a heating or cooling rate of 0.5 °C/s. After a familiarization trial, there were 5 trials, and the average of these trials was used to constitute the threshold estimate. Thresholds were assessed on the right and left sides of the body (Fig. 1).

Tonic heat stimuli (part 1) were administered according to the protocol of the Tonic Heat Pain Model [18]. Tonic heat stimuli (1-min duration) were applied once in each test block as well as once in each training phase (resulting in five 1-min stimulation phases in part 1 of the study). Small heat pulses with an amplitude of 1.3 °C were administered for 1 min at a constant frequency of 30 pulses per minute (this results in a stable subjective experience) (Fig. 1). The pulses were tailored to have a base of 0.3 °C below the individual pain threshold and a peak temperature of 1 °C above it. The temperature increased from baseline (38 °C) with a heating rate of 0.5 °C/s to the preset temperature. To avoid local sensitization, the site of heat stimulation was changed after each tonic stimulation phase.

Phasic heat stimuli (part 2) were applied to the left lower leg. Ten 5-s (plateau) heat stimuli with a temperature of +3 °C above the individual pain threshold were applied (rate of change 4 °C/s; baseline temperature 38 °C) with interstimulus intervals of 20–25 s. These 10 phasic stimuli were applied once in each test block

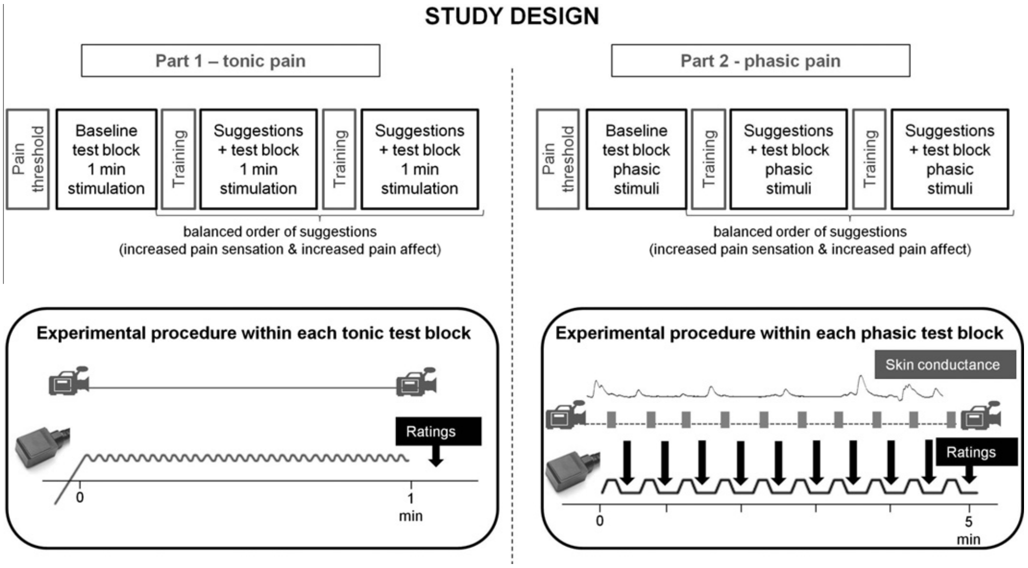

Fig. 1. Study design and detailed description of the experimental procedures of part 1 (tonic stimulation) and part 2 (phasic stimulation) of the study.

(Fig. 1), as well as once in each training phase (resulting in 5 × 10 phasic stimuli in part 2 of the study). To avoid local sensitization, the stimulation site of the thermode was always changed after 10 stimuli.

2.2.2. Training phases and suggestions

In contrast to previous studies of our group [13,31,32], suggestions for the modulation of pain were provided without using hypnotic induction. Hypnotic inductions contain instructions to keep one's eyes closed (eg, "your eyelids feel especially heavy"; SHSS-A [40]) and to relax all muscles, which could affect the degree of facial expressiveness enormously. Given that it has been shown that nonhypnotic suggestions are also effective in modulating individual pain perception [22], we decided to use suggestions without hypnotic induction. Each subject received suggestions for increased pain affect and increased pain sensation. Suggestions designed to increase the affective quality (↑pain affect) or the sensory quality (↑pain sensation) of the noxious stimuli were adapted from Rainville et al. [31] and can be found in the Appendix. The order of training for increased pain affect and increased pain sensation was balanced across subjects (Fig. 1). This order was kept stable across tonic and phasic pain stimulation.

To enhance the subjects' ability to modulate their subjective pain experience in accordance to the suggestions given, we included training phases that always preceded the increased pain sensation and increased pain affect test blocks during both parts of the study. During each training phase, suggestions for the modulation of pain (either pain affect or pain sensation) were read before pain stimulation. The same protocol for pain stimulation was used as was used during the test blocks (tonic [part 1] and phasic [part 2] pain; Fig. 1), with the exception that subjects' responses (facial expression, ratings, skin conductance) were not assessed. Moreover, subjects were instructed to keep their eyes closed during the suggestions and during the pain stimulation to help them to better focus on the suggestions. At the end of each training phase, subjects were asked whether they understood the suggestions and could relate to them. All subjects answered in affirmative.

2.2.3. Test blocks and dependent variables

During each test block, subjects were asked to keep their eyes open and look toward the computer screen during the painful stimulation (to ensure a frontal view of the face during video recording). Right before each "↑pain affect" and "↑pain sensation" test block, suggestions were repeated once again (Fig. 1). During the suggestions, subjects kept their eyes closed and were instructed to open their eyes at the end of the suggestions. After the instructions, the painful stimulation started. To help subjects better concentrate on the suggestions provided, subjects wore noise-canceling headphones (Bose QuietComfort 15, Framingham, MA, USA) during "↑pain affect" and "↑pain sensation" test blocks (Fig. 2). As dependent variables, we assessed self-report ratings (parts 1 and 2), facial expressions (parts 1 and 2), and skin conductance responses (part 2) during each test block (Fig. 1).

2.2.3.1. Self-report ratings. Subjects were asked to provide self-report ratings only during the test blocks. Self-report was obtained with computerized visual analog scales (VAS) of sensory intensity and unpleasantness displayed using E-Prime (Psychology Software Tools, Pittsburgh, PA, USA). VAS sensory and unpleasantness scales successively appeared horizontally on a computer screen with a cursor that could be moved laterally. The VAS for sensory intensity of pain was labeled with verbal anchors from "no pain" (0) to "extremely strong pain" (100). Pain unpleasantness was labeled with "no pain" (0) to "extremely unpleasant pain" (100). All subjects were instructed in the conceptual distinction between sensory intensity of pain and pain unpleasantness using the instructions provided by Price et al. [24]. In short, subjects were told that the intensity of pain refers to how strong the pain feels, whereas the unpleasantness refers to how unpleasant or disturbing the pain is. To make the distinction more clear, we used the radio example as suggested by Price et al. [24]; the intensity of pain was compared to the loudness of the sound, and the unpleasantness of pain was compared to how much one likes or dislikes what is playing on the radio.

During part 1, subjects provided VAS ratings only once during each test block, namely at the end of the 1-min tonic stimulation interval. During part 2, subjects provided VAS ratings after each phasic stimulus; for further analyses, ratings were averaged across the 10 phasic stimuli per test block (Fig. 1).

2.2.3.2. Facial expression of pain. The face of the subject was videotaped throughout each test block. The camera was placed in front of the subject in a distance of approximately 2.5 m. A LED visible to the camera, but not to the subject, was lighted concurrently with the thermal stimuli to mark the onset of stimulation.

Fig. 2. Examples of facial responses accompanying tonic (top row) and phasic (bottom row) pain stimulation during the baseline block, and during the increased pain sensation and increased pain affect test blocks.

Software designed for the analysis of observational data (Observer XT; Noldus Information Technology, Wageningen, Netherlands) was used to segment the videos and to enter the Facial Action Coding System (FACS) codes into a time-related database. During tonic stimulation (part 1), time epochs of 60 s beginning just after stimulus had reached the target temperature were analyzed off-line. During phasic stimulation (part 2), time epochs of (10×) 5 s (stimulation plateau) were analyzed.

We quantified facial responses by using the FACS [11], a fine-grained anatomically based system that is considered the gold standard when decoding facial expressions, including the facial expression of pain [6]. The FACS is based on the anatomic analysis of facial movements and distinguishes 44 different action units (AUs) that are produced by a single muscle or a combination of muscles. These are the minimal numbered units of facial activity that are anatomically separate and readily distinguishable visually. Here, we focused on those 4 pain-indicative AUs that have been found to represent a common facial response to pain [28,29] and have also been shown to be pain indicative for thermal heat pain [14]. These 4 pain-relevant AUs include the following: brow lowering (AU 4), tightening of the orbital muscles surrounding the eye (AUs 6_7), nose wrinkling/upper lip raising (AUs 9_10), and eye closure (AU 43). The intensity for each AU (except AU 43, which does not allow for intensity coding) was rated on a 5-point scale (A–E), with A being the least intense of the action and E the maximum strength of the action. (Given that phasic stimuli are only 5 s long, the duration of each AU is less informative than it is during tonic stimulation; therefore, frequency values were used during phasic stimulation.) The intensity and duration (part 1) or the intensity and frequency (part 2) of these AUs were rated by 2 coders, one a certified FACS coder and the other trained by the certified FACS coder. Five percent of the video segments were coded by both observers. Interrater reliability, as calculated by the Ekman-Friesen formula [11], was 0.85, which compares favorably with other research in the FACS literature.

For further analyses, product terms were conducted by multiplying intensity and duration values (part 1) or intensity and frequency values (part 2). This was performed separately for each of the 4 pain-relevant AUs and separately for each test block. These product terms were square-root transformed to yield unskewed response variables. These transformed FACS scores were then entered into analysis.

2.2.3.3. Skin conductance. We additionally assessed the skin conductance response (SCR, a measure of sympathetic nervous system activation) as an autonomic measure in part 2 of the study (Fig. 1). Autonomic activation has been shown to be more closely linked to the affective component of pain [7,30,31]. We therefore expected SCRs to pain to be greatest during the increased pain affect condition. Thus, assessing SCR allowed us to have a further indicator (next to self-report ratings) of whether the experimental paradigm used had been successful in selectively modulating the sensory and affective dimension of pain.

SCR was recorded by two 10-mm radiotranslucent electrodes placed on the thenar and hypothenar eminences of the subject's left hand. Data were amplified, digitized, and recorded at 1000 Hz by a computerized data acquisition system (MP150; Biopac System, CA, USA). SCR were analyzed off line, starting with successive transformations of the raw signal. First, a running average of 1 s was performed on the raw data to remove high-frequency noise. Second, to control for individual differences in baseline skin conductance levels, the signal was subtracted from itself at each data point with a 1-s delay to obtain an index sensitive to acute changes in skin conductance activity [1]. Third, to obtain a signal reflecting more specifically the increases in SCR, negative values were replaced by a value of 0. After this, the integral of the SCR to each stimulus was calculated within a time window of 10 s (starting with stimulus onset until stimulus offset). For further analyses, SCR were averaged across the 10 painful stimuli; this was performed separately for each test block.

2.3. Statistical analysis

To evaluate the effect of suggestions on VAS intensity and unpleasantness ratings (parts 1 and 2), analyses of variance were conducted with 2 within-subject factors (testing block$_{\text{baseline, }\uparrow\text{pain sensation, }\uparrow\text{pain affect}}$ and type of VAS$_{\text{intensity, unpleasantness}}$). To evaluate the effect of suggestions on facial expressions (parts 1 and 2), multivariate (type of AU) analyses of variance were conducted with 1 within-subject factor (testing block$_{\text{baseline, }\uparrow\text{painsensation, }\uparrow\text{painaffect}}$). Changes in SCR across test blocks (part 2) were evaluated by an analysis of variance with 1 within-subject factor (testing block$_{\text{baseline, }\uparrow\text{painsensation, }\uparrow\text{painaffect}}$).

Findings were considered to be statistically significant at $\alpha < 0.05$. In case of significant effects, post hoc univariate analyses of variance (facial expressions) as well as *t* tests were computed for single comparisons.

3. Results

Pain thresholds for part 1 (46.0 ± 0.8 °C) and part 2 of the study (46.3 ± 1.0 °C) did not differ significantly from each other ($P < .05$).

3.1. VAS intensity and unpleasantness ratings

Tonic pain (part 1). Analyses of variance revealed a nonsignificant main effect for the factors "testing block" ($F(2,42) = 2.738$; $P = .076$) and "type of VAS" ($F(1,21) = 0.404$; $P = .532$). However, as expected, we found a highly significant interaction effect between these 2 factors ($F(2,42) = 25.602$; $P < .001$). Results of post hoc *t* tests are displayed in Fig. 3 (left). Suggestions for increased pain sensations produced a significant increase in VAS intensity ratings (compared to the baseline and the ↑pain affect block), whereas VAS unpleasantness ratings remained unchanged (compared to the baseline block). In contrast, suggestion for increased pain affect produced a significant increase in VAS unpleasantness ratings (compared to the baseline and the ↑pain intensity block), whereas VAS intensity ratings remained unchanged (compared to the baseline block).

Phasic pain (part 2). Very similar results were obtained during phasic stimulation. Again, no significant main effects were found for "testing block" ($F(2,42) = 3.300$; $P = .052$) and "type of VAS" ($F(1,21) = 4.190$; $P = .053$); both factors showed a highly significant interaction ($F(2,42) = 34.551$; $P < .001$). Results of post hoc *t* tests are displayed in Fig. 3 (right). Suggestions for increased pain sensations produced a significant increase in VAS intensity ratings (compared to the baseline and the ↑pain affect block), whereas VAS unpleasantness ratings remained unchanged (compared to the baseline block). In contrast, suggestion for increased pain affect produced a significant increase in VAS unpleasantness ratings (compared to the baseline and the ↑pain intensity block), whereas VAS intensity ratings remained unchanged (compared to the baseline block).

These results indicate that the effect of suggestions for ↑pain affect and ↑pain sensation produced selective changes in the subjects' ratings of pain intensity and pain unpleasantness, both for tonic and phasic pain stimulation.

3.2. Facial expressions

Tonic pain (part 1). We found a significant main effect for the factor "testing block" ($F(8,78) = 4.849$; $P < .001$). As univariate analyses revealed, this effect was due to significant changes in AU 4 ($F(2,42) = 3.983$; $P = .026$), AU 6_7 ($F(2,42) = 7.742$; $P = .001$) and in AU 9_10 ($F(2,42) = 5.340$; $P = .009$) between testing blocks. Given these significant univariate effects, we computed post hoc *t* tests for changes between testing blocks for AU 4, AU 6_7, and AU 9_10. Suggestions for increased pain sensations led to significant increase in AU 6_7 (contraction of the muscles surrounding the eyes) compared to the baseline and the ↑pain affect block; Fig. 4, left). In contrast, suggestions for increased pain affect led to significant increase in AU 4 (contraction of the eyebrows) and in AU 9_10 (wrinkling of the nose) compared to the baseline block (and the ↑pain sensation block; AU 4). Examples of changes in facial responses across testing blocks are also provided in Fig. 2.

Phasic pain (part 2). We found similar findings for facial expressions to phasic pain. Again, a significant main effect was found for the factor "testing block" ($F(8,78) = 2.598$; $P = .015$). As univariate

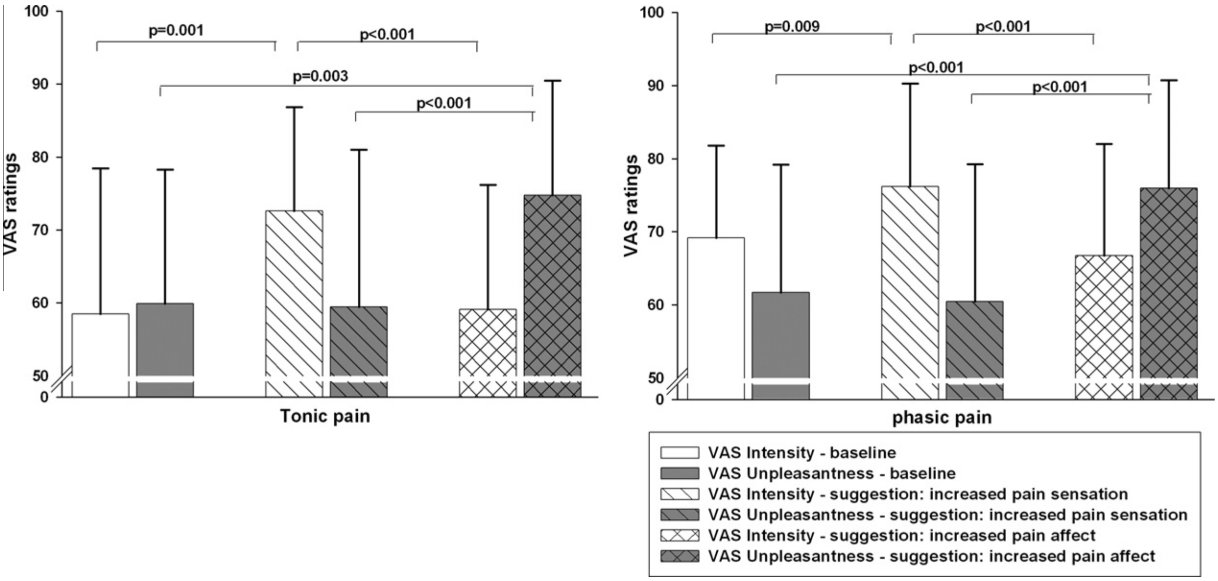

Fig. 3. Mean values ± SD VAS pain intensity and VAS pain unpleasantness ratings of tonic (left panel) and phasic (right panel) painful heat stimulation. Ratings are provided separately for the baseline block, and for the increased pain sensation and increased pain affect test blocks.

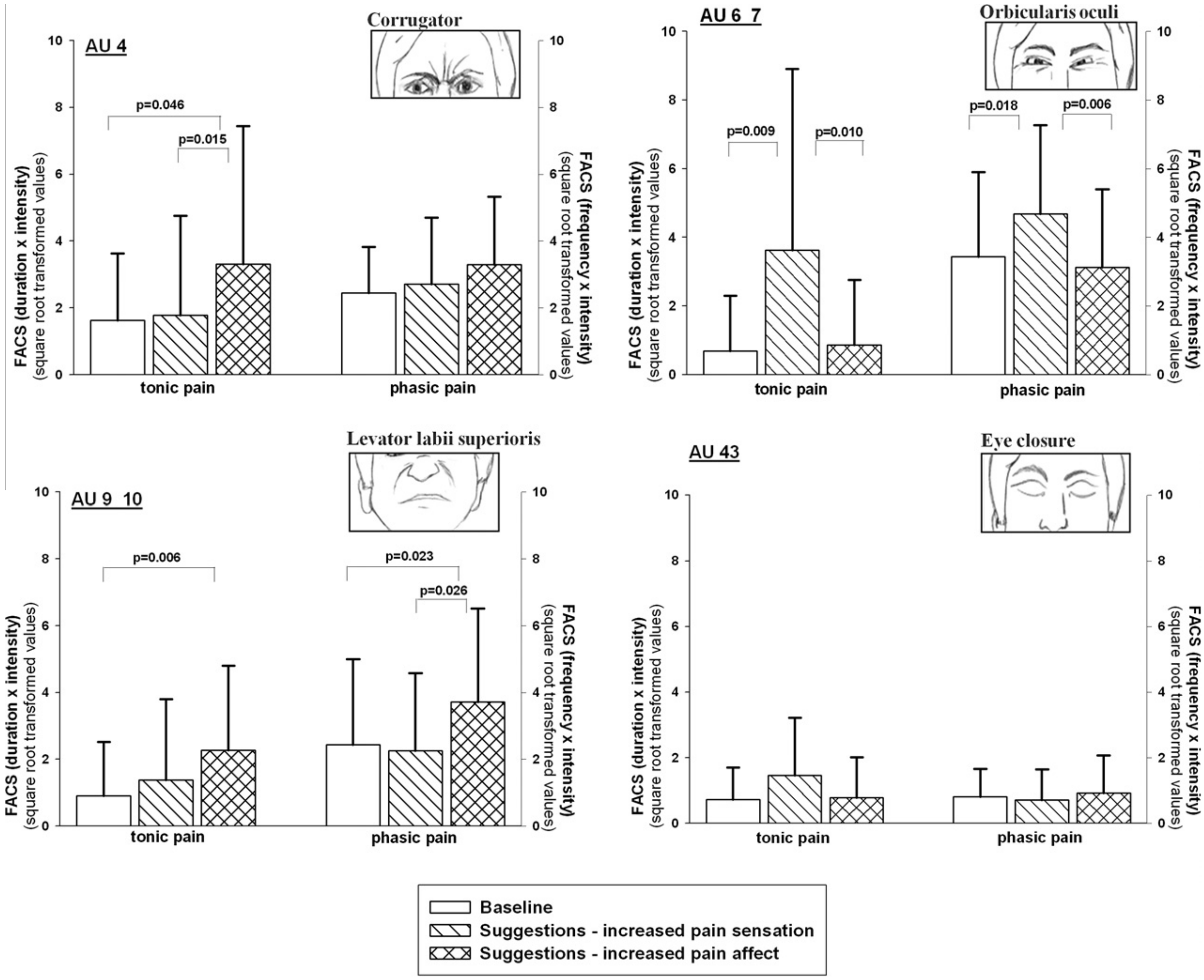

Fig. 4. Pain-related facial expressions (AU 4, AU 6_7, AU 9_10, AU 43; mean values ± SD during tonic (left) and phasic (right) painful heat stimulation. Facial expressions are provided separately for the baseline block, and for the increased pain sensation and increased pain affect test blocks.

analyses revealed, this effect was due to significant changes in AU 6_7 ($F(2,42) = 5.731$; $P = .007$) and in AU 9_10 ($F(2,42) = 5.340$; $P = .031$) between testing blocks. Given these significant univariate effects, we computed post hoc *t* tests for changes between testing blocks for AU 6_7 and AU 9_10. Suggestions for increased pain sensations led to a significant increase in AU 6_7 (contraction of the muscles surrounding the eyes) compared to the baseline and the ↑pain affect block (Fig. 4, right). In contrast, suggestions for increased pain affect led to a significant increase in AU 9_10 (wrinkling of the nose) compared to the baseline and the ↑pain sensation block.

In summary, the effects of suggestions designed to increase ↑ pain sensation or ↑ pain affect on facial responses accompanying pain were similar for tonic and phasic pain stimulation. Suggestions for ↑pain sensation led to augmented contraction of the muscles surrounding the eyes (AU 6_7), whereas suggestions for ↑pain affect led to greater levator activity (resulting in wrinkles on top of the nose; AU 9_10) and partly to more contraction of the eyebrows (AU 4) (Fig. 2). Thus, the facial expression of pain seems indeed to be a multidimensional response system, differentially encoding pain sensation and pain affect.

3.3. Skin conductance

Analysis of variance revealed a significant main effect for the factor "testing block" ($F(2,42) = 4.227$; $P = .022$). Suggestions for increased pain affect produced a significant increase in skin conductance activity compared to the baseline and the increased pain sensation block (Fig. 5). Suggestions to increase pain sensation produced no changes in SCRs compared to baseline. Thus, in accordance with our expectations, only pain-affect modulation led to changes in pain-evoked autonomic responses.

4. Discussion

We found that suggestions directed toward increase in either sensory or affective qualities of one's pain experience produced a remarkably selective modulation in facial responses accompanying pain, whereas suggestions designed to change the sensory aspect of pain led to increased contraction of the muscles surrounding the eyes. Suggestions designed to change the affective pain dimension resulted in increased raising the upper lip and partly in increased contraction of the eyebrows. Furthermore, suggestions also produced significant changes in subjective pain ratings of pain intensity and pain unpleasantness as well as in SCRs.

4.1. Self-report ratings and SCR

We assessed subjective and autonomic responses to pain to verify that our experimental procedure used to modulate the sensory and affective dimension of pain was successful. As expected, suggestions for altering the sensory quality resulted in a selective

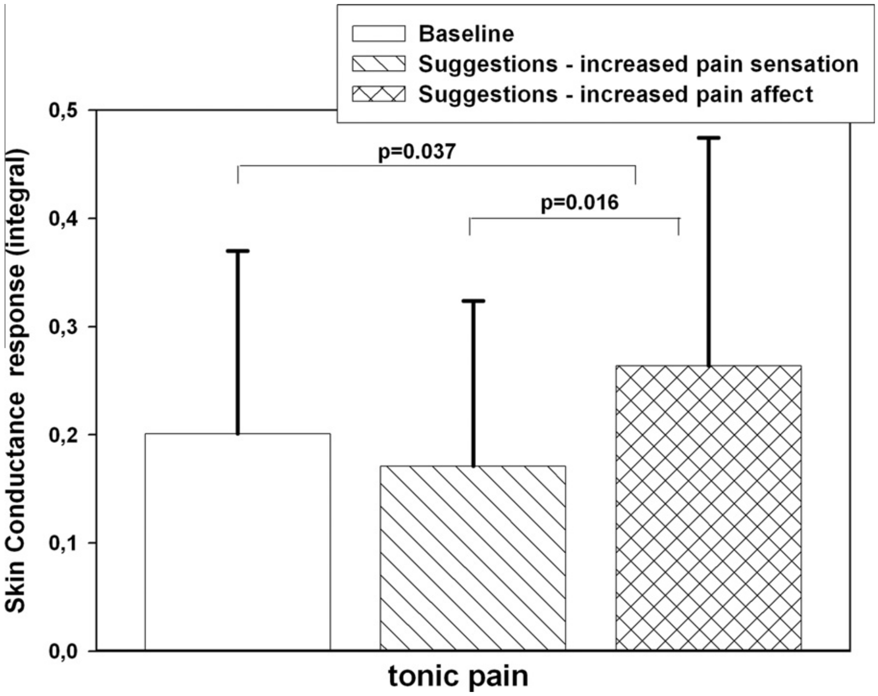

Fig. 5. SCRs (mean ± SD) to phasic painful heat stimulation. SCR are provided separately for the baseline block, and for the increased pain sensation and increased pain affect test blocks.

increase in pain intensity ratings, whereas unpleasantness ratings remained unchanged compared to the baseline conditions. Likewise, suggestions designed to alter the affective quality produced a selective increase in pain unpleasantness ratings, whereas intensity ratings remained unchanged. Although the affective-sensory ratio of tonic and phasic pain stimulation differs markedly from each other, with tonic pain eliciting comparable levels of pain intensity and unpleasantness ratings, and phasic stimuli elicit relatively low unpleasantness levels [18,33], suggestions effectively modulated pain ratings in response to both types of pain stimulation. In contrast to earlier studies of our group [13,31,32], we used nonhypnotic suggestions to selectively modulate pain sensation and pain affect, given that during hypnotic induction, one is instructed to keep the eyes closed, and this would have interfered with facial pain displays. In accordance with previous findings demonstrating that nonhypnotic suggestions are effective in modulating the pain experience [22], we found nonhypnotic suggestions to produce remarkable and consistent changes in subjective pain responses.

We also assessed the effect of our experimental procedure on pain-evoked SCRs as an autonomic measure that is more difficult to control voluntarily compared to subjective pain responses. We found the SCR to be significantly increased only when suggestions for altering the affective quality of pain were provided. This further corroborates the effectiveness of the experimental procedure to alter the affective state of the subject [13,31], and it also supports the assumption of a close linkage between pain affect and sympathetic activation [37].

4.2. Facial responses accompanying pain

Our data provide clear evidence that the facial expression of pain is a multidimensional response system that encodes both the affective as well as the sensory dimension of pain. Given that facial expressions are most often discussed in the context of emotions [8,9], one could expect facial responses accompanying pain to be more closely associated with the affective dimension of pain; however, our data contradict this assumption. Interestingly, we found in a recent imaging study that the occurrence of facial pain displays was associated with activity in brain areas involved in processing affective qualities of pain (eg, anterior cingulate cortex [ACC]) as well as in areas processing sensory qualities (eg, primary somatosensory cortex [S1]) of pain [15]. The novelty of the present study is that it not only confirms that facial expressions accompanying pain encode both pain dimensions, but also indicates that there are separate facial muscle movements that seem to encode more specifically the sensory qualities of one's pain experience, whereas others encode the affective qualities.

Suggestions directed toward changes in the sensory quality of pain resulted in increased activity of the orbicularis oculi muscle (AU 6_7; contracting the muscles surrounding the eyes). This same pattern was observed during both phasic and tonic pain induction procedures, suggesting strong reliability of our findings. Activation of the orbicularis oculi muscle serves several purposes: it ensures protection and moistening of the eyes, but it also plays an important role in emotional expressiveness. Especially during authentic smiles (Duchenne smile [10]), activity of the orbicularis oculi has been observed. Thus, activation of this muscle is not specific to pain. However, in the context of pain, activity of the orbicularis oculi muscle has been discussed to reflect efforts to protect the eyes (by narrowing the opening) and simultaneously still maintain enough vision to engage in protective behavior if necessary [6]. Our findings suggest that this potentially defensive facial pain response increases along with increased intensity of the pain experience.

In contrast, suggestions designed to change the affective dimension of pain produced a significant increase in the activity of the levator labii superioris muscle (AU 9_10 lip raiser/winkles on top of the nose) both during tonic and phasic pain stimulation, as well as an activity increase of the corrugator muscle (AU 4; contracting the eyebrows) during tonic stimulation. Again, activity of the levator and the corrugator muscles are not specific to pain but have been observed in the context of other affective states (eg, disgust, anger [9]). However, it is interesting that these facial muscle movements have consistently been linked to the processing of unpleasant stimuli (eg, disgust, mutilations [3,8,35]). This is in accordance with our findings – namely, that these facial movements are more closely linked to the affective or unpleasantness dimension of pain.

Regardless of why specific facial muscle movements might be associated with the different pain dimensions, it is striking that our data clearly suggest that facial pain displays are indeed a multidimensional response system; differentially encoding both affective and sensory qualities of pain. Why might this be the case? Facial expressions accompanying pain play a crucial role in pain communication and social interactions. They can rapidly warn onlookers of potential danger as well as elicit attention, empathetic reactions, and caring behavior in the observer [2,4,34,41], thereby ensuring help for the individual experiencing pain [26]. Given their important role in social interactions, it seems reasonable that individuals are able to encode the specific pain quality. Experiencing a type of pain with an intense sensory quality might require different types of social support and help than are required during a painful experience with a strong affective component. Moreover, the pain experience is often accompanied by other emotional reactions (secondary pain affect), such as sadness or anger arising from elaborating the meaning and evaluating future implications of the pain [23]. Interestingly, there is evidence that these secondary emotional reactions are also encoded in the face when an individual is experiencing pain [12,20]. We can thus conclude that the face seems to be a surprisingly precise channel of communication. Future studies should investigate whether these different qualities of pain encoded in the face also affect observers' responses. Can observers differentially decode the sensory and affective pain qualities in the face and do they respond differently toward the person in pain depending on whether the facial responses show more affective or sensory pain qualities?

4.3. Limitations

In the present study, we used heat stimuli to induce pain, and we cannot exclude the notion that our findings would have been different if other pain modalities would have been investigated. Clinical pain often has a threat value that is difficult to create in experimental settings. Therefore, although facial expressions of pain are surprisingly consistent across different types of experimental and clinical pain conditions [27,29], a straightforward extrapolation is unwarranted at present. Likewise, our sample was selected for being both suggestible and facially responsive to pain, and thus, we cannot know to what extent findings can be generalized to the population at large and to other experimental and clinical contexts. Given that this is the first study to investigate whether different pain dimensions are encoded in the face, we purposely tried to maximize the potential by our use of a highly selective sample. Replication of the study in a less selective sample and across a variety of conditions are obvious next steps. Moreover, we only focused on those 4 AUs that have been found to represent a common facial response to pain [28,29], and we thus did not consider a number of AUs that have also been observed in the context of pain [6,41]. It is conceivable that these other AUs also contribute to the differential encoding of pain affect and pain sensation in the face.

4.4. Conclusions

Our findings provide compelling evidence that the facial expression of pain is a multidimensional response system that differentially encodes the sensory aspect (mostly encoded by contractions of the muscles surrounding the eyes) as well as the affective aspects of pain (mostly encoded by upper lip raise and wrinkles on top of the nose as well as by contractions of the eyebrows). Given that different types of clinical pain are known to vary along both sensory and affective dimensions, this differential facial encoding of both sensory and affective qualities might have evolved to guarantee that the specific characteristics of one's pain experience are facially communicated (the affective-sensory ratio of the pain), which might be crucial to ensure adequate help and social support from others.

Conflict of interest statement

There are no conflicts of interest.

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Appendix A. Suggestions designed to increase the affective quality or the sensory quality of noxious stimuli

Increased pain unpleasantness: During the stimulation, you will be fully aware of the sensation of discomfort sweeping through your leg. .. Although you will continue to experience normal sensation, your experience will seem surprisingly more unpleasant. .. surprisingly more uncomfortable. .. surprisingly more disturbing than you might have expected. .. When you feel the stimulation, you can be mindful of its intensity. .. mindful of its burning, pricking, stinging quality. .. but mostly, you will feel particularly uncomfortable. .. Almost as if, when you feel the onset of the stimulus, you can feel an onset of discomfort quickly spreading into your lower leg. .. your whole leg. .. into your whole body. .. and all through your experience.

Increased pain intensity: When you feel the onset of the next stimuli, you may be surprised to notice how much more intense the sensation is than you expected it to be. .. Although you will continue to experience unchanged levels of discomfort and unpleasantness, your experience will seem surprisingly more intense. .. the sensation is so much more burning, stinging, or aching than you might have expected it to be. .. Almost as if, when you feel the stimulation rise in intensity, it continues to rise to levels higher than you expected. With each stimulus, you can turn up the dial of your own sensation, much like turning up the volume dial on a stereo. Each stimulus can remind you just how intense the sensation can be, how burning, aching, or stinging it can be,. .. and you can feel the burning, aching, and stinging sensations spread throughout your leg. .. As time goes on and with each stimulus you are becoming aware of how intense the sensation is. You are becoming aware of the burning, aching and stinging of the heat on your leg.

From Rainville et al. [31].

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