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On the mutual effects of pain and emotion: Facial pain expressions enhance pain perception and vice versa are perceived as more arousing when feeling pain

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ABSTRACT

Perception of emotional stimuli alters the perception of pain. Although facial expressions are powerful emotional cues – the expression of pain especially plays a crucial role for the experience and communication of pain – research on their influence on pain perception is scarce. In addition, the opposite effect of pain on the processing of emotion has been elucidated even less. To further scrutinize mutual influences of emotion and pain, 22 participants were administered painful and nonpainful thermal stimuli while watching dynamic facial expressions depicting joy, fear, pain, and a neutral expression. As a control condition of low visual complexity, a central fixation cross was presented. Participants rated the intensity of the thermal stimuli and evaluated valence and arousal of the facial expressions. In addition, facial electromyography was recorded as an index of emotion and pain perception. Results show that faces per se, compared to the low-level control condition, decreased pain, suggesting a general attention modulation of pain by complex (social) stimuli. The facial response to painful stimulation revealed a significant correlation with pain intensity ratings. Most important, painful thermal stimuli increased the arousal of simultaneously presented pain expressions, and in turn, pain expressions resulted in higher pain ratings compared to all other facial expressions. These findings demonstrate that the modulation of pain and emotion is bidirectional with pain faces being mostly prone to having mutual influences, and support the view of interconnections between pain and emotion. Furthermore, the special relevance of pain faces for the processing of pain was demonstrated.

1. Introduction

Emotions and pain are highly interconnected [37] and represented in widely overlapping networks of the human brain [49]. These shared neural networks most likely constitute the biological substrates of pain-modulating effects of emotions [51].

The influence of various affective stimuli like affective pictures [17,18,28,36], pain-related pictures [11], or odors [48] on pain has been demonstrated such that negative emotions lead to increased pain perception, while positive emotions result in decreased pain perception. However, a crucial feature in nonverbal emotion communication – facial expressions – has been widely neglected so far. Only recently, emotional compared to neutral facial expressions have been demonstrated to increase pain perception accompanied by alterations of pain-related brain oscillations [39]. Similarly, pain, compared to neutral, expressions were found to augment pain perception [27], however, the opposite effect of pain on emotion was not quantified.

Research on the impact of pain on emotion processing is rather scarce. One study found that pain led to decreased pleasantness ratings of positive pictures, while negative pictures were unaffected [12]. Likewise, it was observed that pain disrupts performance in an emotional evaluation task for happy faces only, while fearful faces remained unaffected [10]. Also, a current study addressing the influence of pain on face processing showed attention effects of pain, but no modulation of emotion-related brain potentials [52].

Pain and emotion both come along with distinct facial expressions [8,19,32,33,54]. Pain expressions, in particular, are supposed to be of great importance for social interactions [3,14] and for the communication of danger and sorrow. Moreover, pain faces receive elevated cortical processing compared to other facial expressions [13,35], which points at a special relevance of facial pain expressions.

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However, the influence of pain faces on pain processing and the opposite effect has not yet been systematically investigated.

Consequently, in the present study we aimed at elucidating the mutual influence of pain and emotional face processing, with a special focus on the expression of pain. Spontaneous, subtle facial reactions can be reliably measured by facial electromyography (EMG) in response to emotional stimuli, thus providing a suitable measure of emotion processing on the one hand [5,7,25,35,50] and pain processing on the other hand [23,27]. Therefore, we recorded facial EMG in response to dynamic facial expressions of pain, fear, joy, and a neutral expression during painful and nonpainful thermal stimulation. To disentangle emotional from attentional pain modulation, we also presented fixation crosses as a low-level control condition. To document pain modulation by emotion, each thermal stimulus was to be rated regarding its intensity, while alterations of emotion processing should be reflected in ratings of valence and arousal of each video. In addition, to control for potential modulation by state or trait variables, psychometric key measures were assessed. We assumed that negative emotional faces result in increased pain perception, with pain faces having the greatest effect. In addition, thermal heat pain was hypothesized to alter implicit (EMG) and explicit (valence and arousal ratings) measures of emotion processing.

2. Method

2.1. Participants

Twenty-four participants were recruited from the University of Würzburg and received course credit or €12 as compensation. None of them had taken any analgesic medication or alcohol for at least 12 hours prior to the test session (self-report). Two participants were excluded from further analysis due to psychopharmacological medication and vision disorder. All 22 remaining subjects (age M = 21.47 years, SD = 2.21; 17 women) had normal or corrected-to-normal vision, and no current or prior history of chronic pain, or neurological or psychiatric disorders (self-report). Participants were given a detailed explanation of the experimental procedure and signed a written informed consent before participating in the study. Participants filled out questionnaires on candid psychological variables that were found to impact emotion processing, such as state and trait anxiety (State-Trait Anxiety Inventory-T/S [24,42]), altered pain processing such as pain catastrophizing (Pain Catastrophizing Scale [29,43]), and that could have an influence on pain-related as well as emotion-related measures, such as dispositional empathy (Saarbrücker Persönlichkeitsfragebogen, German version of the Interpersonal Reactivity Index [4,31]). Furthermore, sociodemographic information and personal attitudes towards pain were collected. The experimental procedure was approved by the institutional review board of the medical faculty of the University of Würzburg.

2.2. Video stimuli

Affective stimuli consisted of joy, pain, fear, and neutral facial expressions (displayed by 4 male and 4 female actors) that were taken from a database of 1-second video clips [40]. A total of 128 videos and, additionally, 32 control trials (fixation cross) were randomly shown.

2.3. Thermal pain

Thermal heat stimuli were delivered using a Somedic MSA thermal stimulator (Somedic Sales AB, Hörby, Sweden) and a Peltier thermode with an active surface of 25 × 50 mm. The thermode was attached to the volar forearm of the nondominant hand. The individual thermal pain thresholds were assessed by applying 10 trials of gradually increasing temperature (1°C/second) from a baseline of 32°C; participants were asked to stop the stimulus delivery by a button press as soon as they felt pain. The average pain threshold temperature was M = 42.48°C, SD = 2.87. The individual thermal pain threshold was used as painful stimulus, whereas the same temperature minus 2°C was used as nonpainful stimulus in the following experimental session. During the actual experiment, heat stimuli were applied at a heating rate of 5°C/second starting from a baseline that was defined as 10°C lower than the individual pain threshold temperature. After 50 and 100 trials, the experimenter changed the position of the thermode on the participant's forearm (position order was counterbalanced across participants).

2.4. EMG measurement

EMG was recorded from *M. corrugator supercilii*, *M. orbicularis oculi*, and *M. zygomaticus major* on the left side of the face [6] using bipolar montages of 13/7-mm Ag/AgCl surface-electrodes according to the guidelines established by Fridlund and Cacioppo [9]. The EMG raw signal was measured with a V-Amp amplifier (Brain Products Inc., Munich, Germany) at a sampling rate of 1000 Hz. Raw signals were rectified and filtered off-line with a 30-Hz high-pass, a 500-Hz low-pass, a 50-Hz notch, and a 125-ms moving average filter. Visual stimulus-evoked EMG activity was scored as the mean activity during 2 time windows (0–1000 ms and 1000–2000 ms after video stimulus onset) as change in activity from a 1000-ms prestimulus baseline. Intervals were chosen due to a potential response delay when using dynamic stimuli [50], which in the present case show the peak of the target expression close to the stimulus end at about 1000 ms. Pain-evoked EMG activity was scored as the mean activity during 0 ms and 1000 ms, and 1000–2000 ms after thermal pain onset as change in activity from a 1000-ms prestimulus baseline. For the pain responses during fixation cross trials, the same intervals were chosen according to the time window when thermal stimulation reached the target temperature (0–1000 ms) and at a later period of equal length to measure slower facial responses to pain.

2.5. Procedure

After arrival, participants signed the informed consent, answered sociodemographic questions, and filled out the questionnaire on state anxiety. Subsequently, the individual pain threshold was assessed. After EMG electrodes were attached, the participants were instructed about the experimental procedure. The thermode was attached to their left forearm and participants were given a stop device to interrupt the thermal stimulation whenever they felt the heat being too painful (actually, this was never the case). Subsequently, the participants completed 3 training trials (including the painful thermal stimulation and the rating procedure for valence, arousal, and pain intensity), and were instructed to attentively watch the screen during the experiment, before the main experiment was started. Each trial consisted of a central fixation cross, which was presented for 6 seconds until the thermal stimulus reached the target temperature (thermal stimulation began 1.4 seconds after trial onset during painful trials and 2 seconds after trial onset during nonpainful trials in order to synchronize the time point when the temperature reached target level and the video stimulus began). Then the video stimulus or the fixation cross (control trials) was presented for 1 second followed by a blank screen for 0.5–2.5 seconds. After each trial, participants were asked to rate the video with regard to valence (−4 = very unpleasant, 0 = neutral, and +4 = very pleasant) and arousal (1 = not at all arousing and 9 = very arousing), and the ther-