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Vicarious facilitation of facial responses to pain

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Abstract

Introduction: Observing facial expressions of pain has been shown to lead to increased subjective, neural and autonomic pain responses. Surprisingly, these vicarious facilitation effects on its corresponding response channel, namely facial responses to pain have mostly been neglected. We aim to examine whether the prior exposure to facial expressions of pain leads to a facilitation of facial responses to experimental pain; and whether this facilitation is linked to the valence (pain vs. neutral expression) or also linked to specific motor-features of the facial pain expressions (different facial muscle movements).

Method: Subjective (intensity and unpleasantness ratings) and facial responses (Facial Action Coding System) of 64 participants (34 female) to painful and non-painful heat stimuli were assessed. Before each heat stimulus, video clips of computer-generated facial expressions (three different pain expressions and a neutral expression) were presented.

Results: The prior exposure to facial expressions of pain led to increased subjective and facial responses to pain. Further, vicarious pain facilitation of facial responses was significantly correlated with facilitation of unpleasantness ratings. We also found evidence that this vicarious facilitation of facial responses was not only linked to the presentation of pain versus neutral expressions but also to specific motor-features of the pain cue (increase in congruent facial muscle movements).

Discussion: Vicarious pain facilitation was found for subjective and facial responses to pain. The results are discussed with reference to the motivational priming hypothesis as well as with reference to motor priming.

Significance: Our study uncovers evidence that facial pain responses are not only influenced by motivational priming (similar to other types of pain responses), but also by motor-priming. These findings shed light on the complexity - ranging from social, affective and motor mechanisms - underling vicarious facilitation of pain.

1 | INTRODUCTION

Facial communication of pain plays an important role in social communication and in clinical context (Kunz et al., 2019). It has been shown that observing another person in pain (e.g. videos of facial expressions of pain) results in increased subsequent pain responses in the observers. This vicarious facilitation could be shown for a variety of pain responses, including subjective, autonomic (Williams & Rhudy, 2009), motor (Mailhot et al., 2012; Vachon-Presseau et al., 2011) and neural responses (Khatibi et al., 2014; Khatibi et al., 2023; Weiss et al., 2003; Xiang et al., 2018) to experimental pain. It has been suggested that the vicarious facilitation of pain responses might partly be explained with the motivational priming theory, which postulates that the display of a negative prime (e.g. observing facial expressions of pain) activates the aversive system, which leads to elevated processing of congruent stimuli (e.g. increased responses to pain) (Lang, 1995). Although facial expressions of pain have often been used as affective visual stimuli (primes) (Botvinick et al., 2005; Chiesa et al., 2015; Yamada & Decety, 2009), it is surprising that the corresponding response channel, namely facial responses to pain have mostly been neglected (Reicherts et al., 2013). Although facial responses to pain are mainly automatic/reflexive responses (Craig et al., 2010), they are also highly susceptible to social (Kappesser, 2019; Karmann et al., 2014; Kunz et al., 2018) and affective (Basten-Günther et al., 2021; Lautenbacher et al., 2017) influences. Thus, it seems reasonable that facial responses are also susceptible to vicarious pain facilitation.

Investigating vicarious pain facilitation of facial responses to pain is especially interesting because it allows us to not only investigate how facial responses are affected by the valence of the preceding pain cue (facial expression of pain) but also by its motor-features. Facial expressions of pain do not represent a uniform set of facial responses, but there are at least three variations, being composed of different motor-features (Kunz et al., 2021; Kunz & Lautenbacher, 2014): (1) narrowed eyes with furrowed brows and upper lip raise, (2) opened mouth with narrowed eyes and (3) furrowed brows with narrowed eyes. This variability in motor-features, allows us to investigate motor-associated priming. Motor priming refers to the phenomena that observed motor-behaviour activates an equivalent internal motor-representation (Iacoboni et al., 1999), which facilitates the corresponding motor-behaviour in the observer (Decety & Jackson, 2004). In our study, we used computer-generated avatars displaying the three variations of facial expressions of pain (Kunz & Lautenbacher, 2014) to ensure highly controllable stimuli that are not confounded by age, attractiveness and the intensity of the expression. The stimuli were validated in previous studies showing that they are perceived as valid pain faces by observers (Göller et al., 2022; Meister et al., 2021).

The aim of our study was to examine whether the prior exposure to variations of facial expressions of pain leads to increased pain ratings and most importantly to a facilitation of facial responses to experimental pain; and whether this facilitation is mainly linked to the valence of the priming stimulus (pain vs. neutral expression) or also modulated by its motor-features (facilitation of corresponding facial muscle responses).

2 | METHOD

2.1 | Participants

Overall, 64 participants (34 female; mean age: 22.7 years) were recruited via e-mail at the University of Augsburg. The sample included mostly students who received course credit for participating. All participants provided written informed consent. The study protocol was approved by the ethics committee of the University of Bamberg (#2020-11/34).

2.2 | Procedure

The experiment took around 60 min. First, the thermal pain threshold was determined. Then participants were seated alone in front of a screen and observed videos of avatars displaying facial expressions of pain or a neutral expression prior to receiving painful and non-painful thermal stimuli. The facial expression of the participants in response to these thermal stimuli was recorded via video for offline data analyses. Participants were asked to rate the pain intensity and unpleasantness of each thermal stimulus.

2.3 | Pain stimulation

At the beginning of the experiment, we introduced the participants to the TSA II [Peltier-based contact heat stimulation device (TSA-2001, (Medoc) with a 30 × 30 mm contact thermode] and the thermode was attached to the outside of the left lower leg with an elastic bandage.

To ensure that temperature intensities were perceived as moderately painful by the 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 the temperature of the thermode starting from 38°C using heating and cooling buttons (the right button on the mouse was the designated cooling button and the left button was the heating button), until they obtained a level that was perceived as barely painful. A constant press of the buttons produced a heating or cooling rate of 0.5°C/s. Following a familiarization trial, the average of four consecutive trials was used to constitute the pain threshold.

Following the assessment of pain threshold, phasic heat stimuli (trapezoid form, 5 s [plateau]; ramp-up and down: 4°C/s; baseline temperature: 38°C) were applied to the left lower leg. Two different stimulus intensities were applied, painful (+3°C above the pain threshold) and non-painful (−1°C below the pain threshold) intensities.

There were 48 quasi-randomized heat stimuli (32 painful, 16 non-painful) split up in 3 blocks (18/18/12 trials). Before each block, the position of the thermode was changed to a new patch of skin on the lower leg to prevent sensitization.

2.4 | Facial expression stimuli

The faces of the avatars were modelled with the software FaceGen Modeller Core 3.5 (Version of 2019). The used avatars had different hairstyles and different skin colours, to make them as realistic as possible. The videos of different dynamic facial expressions were created with the software FACSGen3 (Version of 2019), for which Krumhuber et al. (2012) and Roesch et al. (2011) have demonstrated that it produces emotionally valid and reliable facial expressions. Here, we used three different variations of facial expressions of pain and a neutral expression, which have been shown to validly convey pain and neutral expressions, respectively (Göller et al., 2022; Meister et al., 2021). The three different variations in facial expressions of pain were: (1) narrowed eyes in combination with furrowed brows and upper lip raise, (2) opened mouth in combination with narrowed eyes and (3) furrowed brows in combination with narrowed eyes (Kunz & Lautenbacher, 2014). One male and one female avatar were animated, with identical facial activity patterns.

Each video had a duration of 5000 ms (resting state 1500 ms, unfolding of the expression for 1000 ms, full expression for 500 ms, decline again for another 1000 ms, and another resting state for 1000 ms). Each trial started with the appearance of a fixation cross (white cross on a black background) for 10 s. The videos started 1500 ms before the heat stimulation and overlapped with the ramp-up of the heat stimulation (see Figure 1). The videos were presented using the software Presentation (Neurobehavioral Systems, Version 21.1; Build 09.05.19). Altogether, 48 videos, 36 depicting facial expressions of pain (18 × male, 18 × female) and 12 showing neutral facial expressions (6 × male, 6 × female), were presented in quasi-randomized order, balanced across non-painful (N = 16 (pain: 6♂/6♀; neutral: 2♂/2♀)) and painful heat stimuli (N = 32 (pain: 12♂/12♀; neutral: 4♂/4♀)).

2.5 | Pain ratings

After each heat stimulus, participants were asked to rate the intensity and unpleasantness of pain via visual analogue scales (VAS). The pain intensity scale reached from "no pain" to "extremely strong pain" and the pain unpleasantness scale reached from "no pain" to "extremely strong unpleasantness." The two scales, each divided in 100 steps, appeared together on the computer screen and participants moved a slider to indicate their ratings. To familiarize subjects with the rating procedure, one practice trial was conducted. For statistical analyses, VAS ratings were averaged across non-painful stimuli and painful stimuli, respectively.

2.6 | Facial responses to pain

Participants' faces were videotaped throughout the whole experiment using a camera located approximately 2 m in front of the participant to allow for a frontal view. To enable the offline segmentation a sound trigger (not audible to the participant) marked the start and end of each heat stimulus. 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 computer screen. Participants were also instructed to avoid talking during the experiment.

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

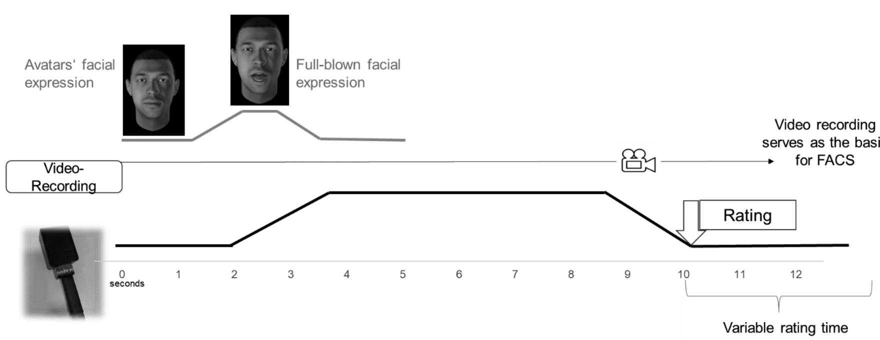

FIGURE 1 Exemplary representation of a trial. In total, 32 trials with painful heat + 1 × 16 trials with non-painful heat were presented. FACS, Facial Action Coding System.

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.

Segments of 7s beginning just after the stimulus had reached the target temperature were selected for scoring. In total, 48 segments of heat stimulation (16 non-painful and 32 painful segments) 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; Kunz, Faltermeier, & Lautenbacher, 2012). Those combinations include AUs 6_7, 9_10 and 25_26_27. In order to determine interrater reliability, five percent of the video segments, including facial responses to both painful and non-painful stimuli were coded by a second certified observer also blinded to the experimental conditions. Interrater reliability was calculated using the Ekman–Friesen formula (Ekman & Friesen, 1978). Interrater reliability was $r=0.79$, which compares favourably with other research in the FACS literature (Karmann et al., 2015; Priebe et al., 2015). For further analyses, we focused on those AUs that have been described to be pain relevant in a previous review article (Kunz et al., 2019), namely AU4, AU6_7, AU9_10 and AU25_26_27. AU-frequency (sum score across stimuli) and AU-intensity (mean score across stimuli) values of these pain relevant AUs were multiplicated to form product terms.

2.7 | Statistical analysis

Self-report ratings: (1.i) To investigate whether the pain cues in general compared to neutral expression (dichotomous content of the pain cue) affected self-report ratings, mean pain intensity and unpleasantness ratings were analysed using multivariate repeated measure MANOVAs including the within-subject factors “dichotomous expression” (neutral, pain expression) and “intensity of stimulus” (non-painful vs. painful heat intensities). (1.ii) To further investigate, whether the three variations of pain cues (three facial pain expressions) had a different effect on intensity and unpleasantness ratings of pain, a repeated measure MANOVA was computed again, this time differentiating between the “variations of avatars' facial expression of pain” (4 levels: neutral, pain variation 1, pain variation 2, pain variation 3) as a within-subject factor.

Facial responses: (2.i) To investigate whether the pain cues in general compared to neutral expression (dichotomous content of the pain cue) affected facial responses, all pain relevant AUs were entered into multivariate repeated measures MANOVAs including the within-subject factors “dichotomous expression” (neutral, pain expression) and “intensity of stimulus” (non-painful vs. painful heat intensities). (2.ii) To further investigate, whether the three variations of pain cues (three facial pain expressions) had a different effect on facial responses to pain, a repeated measure MANOVA was computed again, this time differentiating between the “variations of avatars' facial expression of pain” (4 levels: neutral, pain variation 1, pain variation 2, pain variation 3) as a within subject factor. As outcome variable we only included those pain relevant AUs that showed a significant difference in 2.i (dichotomous comparison neutral vs. pain).

Vicarious modification of subjective and of facial responses: are both correlated? As a last step, we wanted to investigate the relation between the amount of change caused by the dichotomous content of avatars' expression (neutral vs. pain expression) in pain ratings and in facial responses. To do this, difference scores (trials of avatars' neutral vs. pain expression) were calculated for pain intensity and pain unpleasantness ratings as well as for those pain relevant AUs that showed a significant difference in “2.i.” These difference scores were then entered into regression analyses (AUs were entered as predictors, and self-report were entered as criteria).

Post-hoc tests for single comparisons were Bonferroni-adjusted. Significance was assumed at an alpha level ≤0.05. Data were analysed using SPSS (version 28.0).

3 | RESULTS

3.1 | Self- report ratings

Dichotomous expression (pain vs. neutral) (1i): The MANOVA showed a significant main effect of the “intensity of stimulus” (non-painful vs. painful heat intensities) ($F(2, 62)=467.56$, $p<0.001$) and a significant main effect for the factor “dichotomous expression” (pain vs. neutral) ($F(2, 62)=22.28$, $p<0.001$). There was also a significant interaction of “intensity of stimulus” and “dichotomous expression” ($F(2, 62)=58.01$, $p<0.001$). Because of the significant interaction effect, we conducted separate MANOVAs for painful and non-painful heat stimuli. For non-painful heat, the MANOVA showed a main effect for the factor “dichotomous expression” (pain vs. neutral) ($F(2, 62)=38.29$, $p<0.001$). As univariate outcomes showed, both intensity ($F(1, 63)=66.06$, $p<0.001$) as well as unpleasantness ratings ($F(1, 63)=6.86$, $p=0.011$) for the non-painful stimuli significantly decreased when participants viewed an avatars' facial expression of pain compared to a neutral expression (see Figure 2). For painful heat, the MANOVA also showed a main effect for the factor "dichotomous expression" (pain vs. neutral) ($F(2, 62) = 42.06$, $p < 0.001$). As can be seen in Figure 2, viewing an avatars' facial expression of pain resulted in higher pain intensity ($F(1, 63) = 34.14$, $p < 0.001$) as well as unpleasantness ratings ($F(1, 63) = 84.18$, $p < 0.001$) compared to viewing a neutral expression. Hence, viewing an avatars' facial expression of pain led to reduced pain ratings for non-painful heat and to higher pain ratings for painful heat (thus, the significant interaction effect between "intensity of stimulus" and "dichotomous expression").

Variations of avatars' facial expression of pain: The MANOVA investigating whether the three variations in the avatars' facial expressions of pain had a different effect on how participants rated the painful stimuli showed a significant main effect (F(6, 378) = 16.10, $p < 0.001$). As univariate outcomes showed, both intensity ($F(3, 189) = 12.10$, $p < 0.001$) and unpleasantness ($F(3, 189) = 41.07$, $p < 0.001$) were significantly affected by the within-subject factor "variations of avatars' facial expression of pain." Bonferroni corrected post-hoc tests were computed for simple comparisons and the results are displayed in Figure 3. As can be seen in Figure 3, especially avatar's pain expression variation 1 and 3 led to significantly increase in pain intensity ratings compared to viewing a neutral expression. With regard to unpleasantness ratings, all three variations of avatars' facial expression of pain led to higher ratings compared to viewing a neutral expression.

3.2 | Facial responses

Dichotomous expression (pain vs. neutral) (2i): The MANOVA showed a significant main effect of the "intensity of stimulus" (non-painful vs. painful heat intensities) ($F(1, 63) = 55.55$, $p < 0.001$) and a significant main effect for the factor "dichotomous expression" (pain vs. neutral) ($F(1, 63) = 4.76$, $p = 0.033$). There was also a significant interaction of "intensity of stimulus" and "dichotomous expression" ($F(1, 63) = 12.06$, $p < 0.001$). Because of the significant interaction effect, we conducted separate MANOVAs for painful and non-painful heat stimuli. For non-painful heat, the MANOVA showed no significant main effect for the factor "dichotomous expression" (pain vs. neutral) on facial responses to non-painful heat ($F(4, 60) = 1.04$, $p = 0.392$). In contrast, facial responses to painful heat were significantly affected by the factor "dichotomous expression" (pain vs. neutral) ($F(4, 60) = 2.56$, $p = 0.048$). As can be seen in Figure 4, prior exposure to facial expressions of pain resulted in significantly higher facial responses; including increased contraction of the eyebrows (AU4: $F(1, 63) = 8.53$, $p = 0.005$), increased contraction of the muscles surrounding the eyes (AU6_7: $F(1, 63) = 8.38$, $p = 0.005$) as well as increased upper lip raise (AU9_10: $F(1, 63) = 5.62$, $p = 0.021$), compared to viewing a neutral expression. Only the opening of the mouth in response to painful heat was not affected by the "dichotomous expression" (AU25_26_27: $F(1, 63) = 0.541$, $p = 0.465$). Hence, viewing an avatars' facial expression of pain did not change facial responses to non-painful heat but led to higher facial responses to painful heat (thus, the significant interaction effect between "intensity of stimulus" and "dichotomous expression").

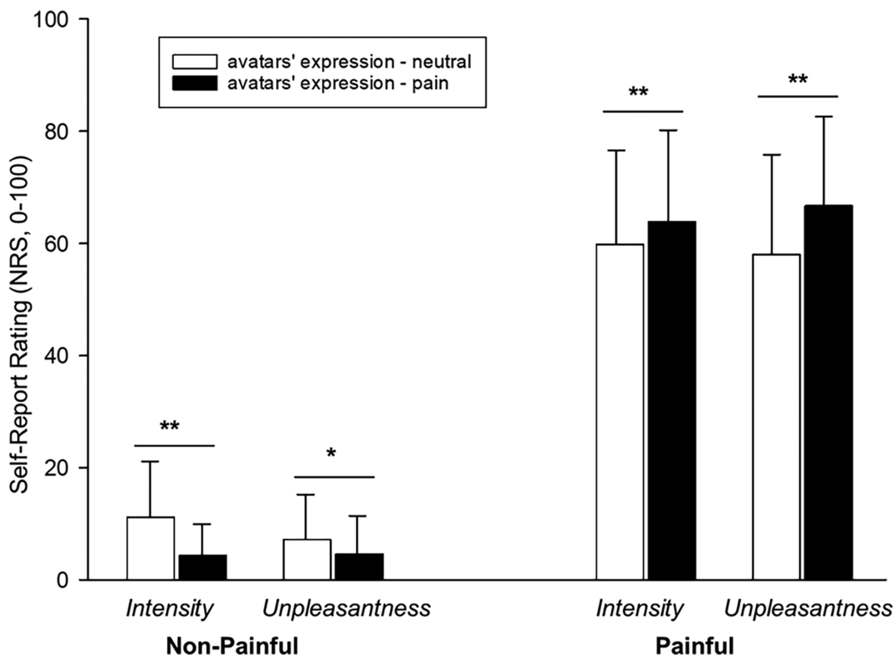

FIGURE 2 Effect of "dichotomous expression" on intensity and unpleasantness ratings (mean, SD). Ratings are presented separately for the two heat intensities (painful and non-painful heat) and separately for trials with prior exposure to a neutral or a painful expression (dichotomous expression). *$p < 0.05$; **$p < 0.001$; SD, standard deviation.

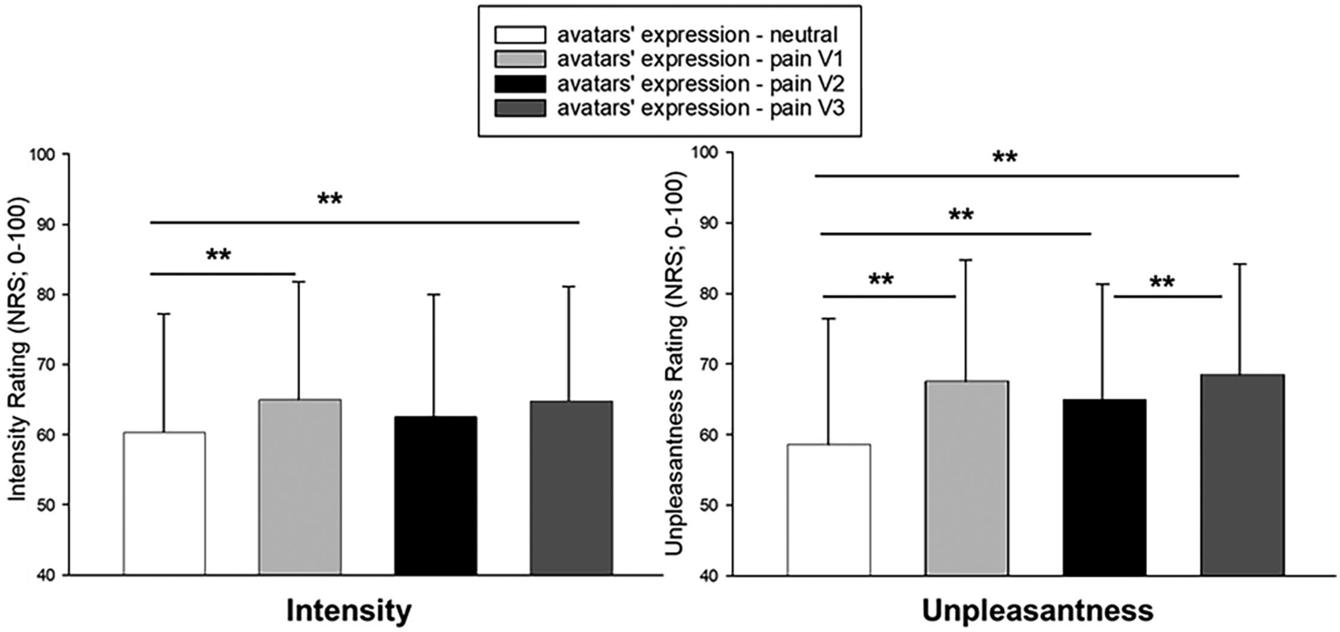

FIGURE 3 Effect of “variations of avatars' facial expression of pain” on intensity (left) and unpleasantness (right) ratings (mean, SD) to painful heat stimulation. Ratings are presented separately for trials with prior exposure to the variations of avatars´ facial expression of pain (neutral expression, variation 1, 2, 3 of pain expressions). *$p < 0.05$; **$p < 0.001$; SD, standard deviation.

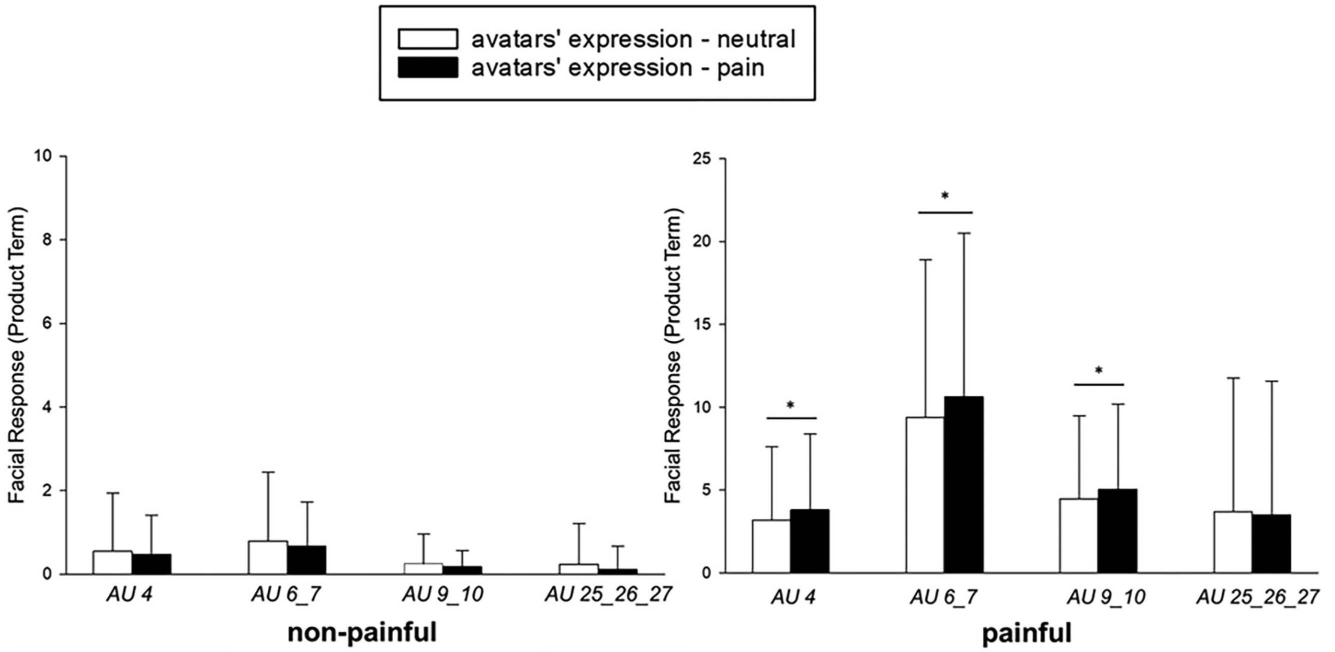

FIGURE 4 Effect of “dichotomous expression” on facial responses (pain-relevant AUs mean, SD) to non-painful (left) and painful (right) heat stimulation. Facial responses are presented separately for trials with prior exposure to a neutral or a painful expression (dichotomous expression). *$p < 0.05$; AUs, Action Units; SD, standard deviation.

Variations of avatars' facial expression of pain (2ii): The MANOVA investigating whether the three variations in the avatars' facial expressions of pain had a different effect on how participants facially responded to the painful heat stimuli showed a significant main effect ($F(12, 564) = 2.75$, $p = 0.001$). For this analysis, we included those pain relevant AUs (AU4, AU6_7, AU9_10, AU25_26_27). As univariate outcomes showed, for the three AUs, namely AU4 ($F(3, 189) = 6.96$, $p < 0.001$), AU6_7 ($F(3, 189) = 5.32$, $p = 0.002$) and AU9_10 ($F(3, 189) = 5.47$, $p = 0.001$) were significantly affected by the within- subject factor “variations of avatars' facial expression of pain.” AU25_26_27 was not significantly affected ($F(3, 189) = 1.55$, $p = 0.202$). Bonferroni corrected post-hoc tests were computed for simple comparisons and the results are displayed in Figure 5. With regard to AU4, it was especially variation 3 (furrowed brows in combination with narrowed eyes) that led to an increase in contraction of the eyebrows. With regard to AU6_7, it was especially variation 1 (narrowed eyes in combination with furrowed brows and upper lip raise) that led to an increase in contraction of the muscles surrounding the eyes. With regard to AU9_10, it was especially variation 1 (narrowed eyes in combination with furrowed brows and upper lip raise) and variation 3 (furrowed brows in combination with narrowed eyes) that led to an increase in the muscles for the upper lip raise. In summary, variation 1 and variation 3 led to a partially congruent increase in facial responses of the participants,

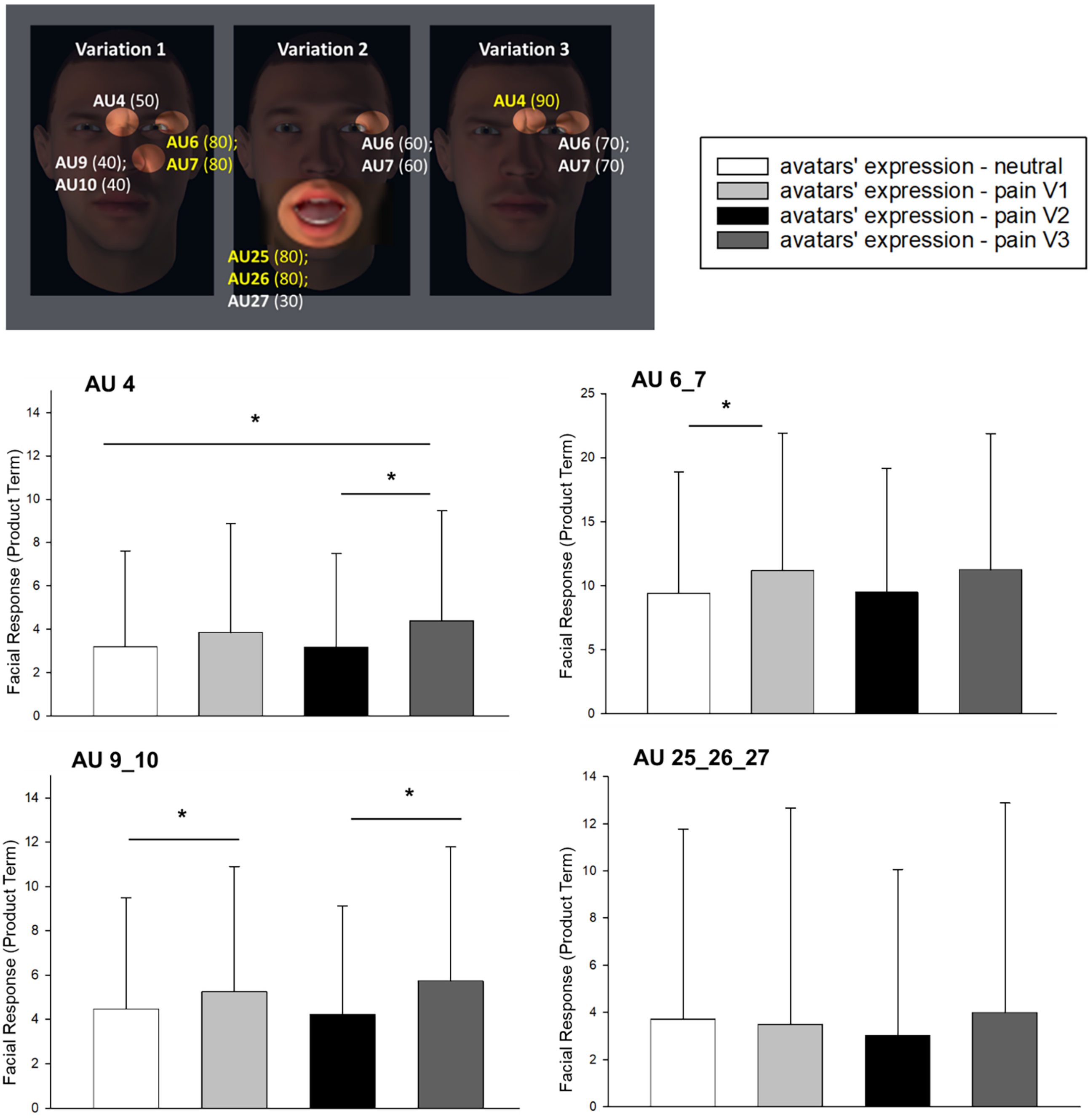

FIGURE 5 Effect of "variations of avatars' facial expression of pain" on facial responses (mean, SD) to painful heat stimulation. Facial responses are presented separately for trials with prior exposure to the variations of avatars´ facial expression of pain (neutral expression, variation 1, 2, 3 of pain expressions). *$p < 05$; SD, standard deviation. The AUs of each of the three variations in pain expressions are displayed on the upper right. Here, the AU with the highest intensity per variation is marked in yellow.

whereas variation 2 of the avatars' facial expression did not lead to noticeable changes in how participants facially responded to the painful heat stimuli.

Vicarious modification of subjective and of facial responses: are both related? As a last step, the relation between the amount of change caused by the "Dichotomous expression" (neutral vs. pain) in self-report ratings and in facial responses (AU4, AU6_7, AU9_10) was investigated. AU25_26_27 was excluded because it showed no significant change between pain and neutral facial expression. Regression analyses (AUs entered as predictors) were conducted separately for pain intensity and unpleasantness ratings. Changes in facial responses could not significantly predict changes in pain intensity ratings ($R^2=0.008$, $F(3, 63)=0.164$, $p=0.920$). In contrast, we did find a significant association between changes in facial responses and changes in pain unpleasantness ratings ($R^2=0.15$, $F(3, 63)=3.54$, $p=0.020$). The more facial responses increased after prior exposure to a pain expression the more unpleasant were the painful-heat stimuli rated.

4 | DISCUSSION

The aim of our study was to examine whether the prior exposure to variations of facial expressions of pain leads to a facilitation of facial responses to experimental pain; and whether this vicarious facilitation is only linked to the valence of the "priming" stimulus (pain vs. neutral facial expression) or also linked to its motor-features (facilitation of congruent facial muscle responses). Our findings showed that the prior exposure to an avatar's facial expression of pain increases facial responses to pain, which is in line with motivational priming of pain. Moreover, we found that the three variations of the avatars' expression of pain had different effects on participants' facial responses to pain, with some indication for motor priming. We will discuss these findings in detail below.

4.1 | Facial responses

The prior exposure to avatars' facial expressions of pain had no effect on facial responses to non-painful heat but led to significantly increased facial responses to painful heat. Participants responded with increased "contraction of the eyebrows" (AU4), increased "contraction of the muscles surrounding the eyes" (AU6_7) and increased "upper lip raise/nose wrinkle" (AU9_10) to painful stimulation when the stimulation was preceded by a pain expression. Only the "opening of the mouth" (AU25_26_27) was not affected by the avatars' expression. These results are well in line with the motivational priming theory (Lang, 1995). The prior exposure to facial expressions of pain might have induced a negative affective state, which has in turn facilitated facial responsiveness to painful stimulation in the observer. To our knowledge, there are only a few studies investigating priming effects on facial responses (Mailhot et al., 2012; Reicherts et al., 2013). Mailhot and colleagues, for example, investigated whether the prior exposure to facial expressions of pain leads to increased corrugator activity (via electromyography (EMG)) in response to electrical pain. In agreement with our study, they also found that corrugator activity was increased due to priming using pain expressions. Thus, one of our main findings is that facial responses are also susceptible to priming effects, as has been shown for other types of pain responses like self-report ratings, evoked potentials (Avenanti et al., 2010; Fan & Han, 2008; Han et al., 2009; Kirwilliam & Derbyshire, 2008; Meagher et al., 2001; Wieser et al., 2014; Yamada & Decety, 2009) as well as pain-reflexes (Khatibi et al., 2014; Mailhot et al., 2012; Vachon-Presseau et al., 2012). Given the variability of facial expressions of pain, we did not only use one type of facial expression but presented participants with three variations found in the literature (Kunz et al., 2019; Kunz & Lautenbacher, 2014). In a previous study of ours, we could show that observers judged these three variations to express a similar amount of pain (Meister et al., 2021). Thus, the three variations mainly differ with regard to their composition of facial movements (AUs) but less so regarding the affective content (pain intensity). Therefore, using these three variations allowed us to investigate whether priming effects on facial responses also depend on the perception of specific facial motor-movements (motor-associated priming (Castiello et al., 2002)) besides the affective content of the stimuli (motivational priming). Looking at the specific facial motor-movements displayed by the avatars, there is always one AU per variation that is displayed with the highest intensity (these are marked in yellow in Figure 5). AU4 "contraction of the eyebrows" for example is displayed with greatest intensity in variation 3. Thus, if facial responses are also affected by motor priming, we should find that especially the prior exposure to variation 3 should result in an increase of AU4 in response to pain. In line with this assumption, we found that only the prior exposure to variations 3 led to significantly increased "contraction of the eyebrows" compared to neutral expression, whereas variation 1 and 2 did not lead to a significant increase. As for "contraction of muscles surrounding the eyes" (AU6_7), this AU was present in all variations, although most pronounced in variation 1. Interestingly, only the prior exposure to variation 1 led to a significant increase in AU6_7 in response to pain, whereas variation 2 and 3 did not differ from prior exposure to neutral expression. As for "upper lip raise/nose wrinkle" (AU9_10) we again found evidence for motor priming. This AU was only present in variation 1 and participants only showed a significant increase in AU9_10 when being priorly exposed to variation 1 compared to neutral expression. In contrast, variation 2 and 3 did not lead to a significant increase in AU9_10 compared to neutral expression. In case of variation 3, participants displayed AU9_10 more strongly compared to prior exposure to variation 2, although AU9_10 is not present in any of the two variations. As for "opening of the mouth" (AU25_26_27), no indication for motor priming was found. In conclusion, we found some evidence for motor priming when looking at facial responses to pain, similarly to motor priming effects found for other types of behaviour (Castiello et al., 2002; Stoykov & Madhavan, 2015). However, more research is needed in order to disentangle motivational priming from motor priming with regard to facial responses to pain.

4.2 | Ratings

We found that prior exposure to facial expressions of pain leads to increased intensity and unpleasantness ratings to painful heat, compared to a prior exposure to a neutral expression. No vicarious facilitation was found for ratings to non-painful heat. These findings are consistent with the current literature on vicarious facilitation of self-report ratings, showing that pain ratings are susceptible to motivational priming effects (Fan & Han, 2008; Han et al., 2009; Ibáñez et al., 2011; Reicherts et al., 2013; Wieser et al., 2014; Yamada & Decety, 2009). We also investigated whether the vicarious facilitation of pain ratings differ between the three types of facial expression of pain (variation 1, 2, 3). Especially the prior exposure to variation 1 and 3 led to increased intensity and unpleasantness ratings to pain. A possible reason for this could be that variation 1 and 3 include AUs being closely linked to negative affective states; namely "contraction of the eyebrows" (AU4) and "upper lip raise/nose wrinkle" (AU9_10), which are often displayed in the context of disgust and anger (Kappesser & de C Williams, 2002; Kunz et al., 2013; Kunz et al., 2019; Kunz et al., 2021; Simon et al., 2008). Thus, variation 1 and 3 might have activated the negative affective system to a greater degree than variation 2, resulting in increased intensity and unpleasantness ratings.

4.3 | Relation between vicarious facilitation of the two pain response systems

We found a significant association between changes (pain vs. neutral expressions) in facial responses and changes in pain unpleasantness ratings. Thus, the more facial responses increased due to viewing an avatars' facial expression of pain the more unpleasantness ratings increased. We found no significant association between changes in facial responses and changes in pain intensity ratings. This suggests on the one hand, that the vicarious facilitation of both response systems (subjective and facial) share some variance. This is not surprising given that the motivational priming theory (Lang, 1995) postulates that the pain prime leads to a negative affective state, which facilitates sensitivity in general towards the following experimental pain stimulus, thus, including all types of pain responses. Moreover, weak associations between subjective and facial responses have also been found in previous studies (Göller et al., 2022; Kunz et al., 2004; Kunz et al., 2011; Kunz et al., 2020; Reicherts et al., 2013). On the other hand, this shared variance seems to only apply to the unpleasantness dimension of pain, suggesting a closer linkage between facial responses and unpleasantness ratings. This contrasts with previous findings showing that facial responses to pain are a multidimensional response system, encoding both the sensory and unpleasantness dimension of pain (Kunz, Lautenbacher, et al., 2012). Thus, the closer connection of facial responses to the unpleasantness dimension might only be true in the context of motivational priming.

4.4 | Limitations

There are some limitations, which need to be considered when interpreting the present findings. First, we did not include another negative, but non-pain associated stimulus category, reducing the specificity of the found response patterns. Thus, we cannot exclude that for instance anger or disgust expressions might have led to similar results; however, previous research on facial pain expression compared to other emotion categories revealed a pain increase especially by pain expressions (Reicherts et al., 2013). Moreover, the variation in motor-features were also limited to three variants of pain expressions, which limits our ability to investigate motor priming effects in detail.

4.5 | Conclusion

We could show that a prior exposure to facial expressions of pain leads to increased facial responses to pain in the observers, thus, indicating vicarious facilitation of facial responses to pain, as has been shown for a variety of other types of pain responses. The results are consistent with the motivational priming theory. In addition, we also find some evidence for motor priming playing a role in vicarious facilitation of facial responses to pain.

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