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Emotional misattribution: Facial muscle responses partially mediate behavioral responses in the emotion misattribution procedure

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Abstract

There is ongoing debate regarding the degree to which, and the conditions under which, physiological, affect-related (i.e., embodied) processes contribute to emotion information processing. Whereas most studies focus on clearly visible and intentional processing conditions, the present study targeted this issue by studying the implicit processing of emotional (angry, fearful, joyful, neutral) faces in a masked emotion misattribution procedure. That is, participants had to categorize neutral-looking faces with regard to the allegedly felt emotion, which were preceded by a very briefly presented emotional expression. In addition to behavioral measures, facial muscle responses were obtained as an index of physiological, affect-related processes. Linear mixed-model mediation analyses confirmed that facial muscle responses partially mediated the behavioral responses to the masked primes in the misattribution task.

KEYWORDS

emotion, facial electromyography, facial expression, masked presentation, misattribution, priming

1 | INTRODUCTION

What happens when we see an emotional facial expression? Does such a quickly vanishing and thus often marginally perceptible emotional face trigger only a semantic categorization process (e.g., this is a happy expression)? Or does it trigger affect-related, physiological processes (i.e., processes indicating embodied simulation or a rudimentary emotional reaction) as well? And if so, are these processes merely byproducts, or do they in any way influence the outcome of the categorization process? These questions are intriguing, and the topic of emotion information processing is of much debate in the field of cognition and emotion (e.g., Barrett & Bar, 2009; Moors, 2007). While several studies have shown some involvement of affect-related, physiological processes, such as facial muscle responses, when the information is clearly visible and intentionally processed (e.g., Korb, Grandjean, & Scherer, 2010; Niedenthal, Winkielman, Mondillon, & Vermeulen, 2009), evidence concerning more automatic processing conditions is scarce. However, in daily life we typically process such information under limited time and processing resources.

The present paper aimed at illuminating the processes involved in such automatic processing of marginally perceptible emotional facial expressions. We did this by assessing trial-by-trial behavioral and facial muscle responses in the masked emotion misattribution procedure (Rohr, Degner, & Wentura, 2015), a variant of the affect misattribution procedure (Payne, Cheng, Govorun, & Stewart, 2005; see also Murphy & Zajonc, 1993), which allows for detailed, emotion-specific misattribution. Our study provides new insights into the masked processing of emotional facial information by applying linear mixed-model mediation analyses to test not only for the occurrence of affect-related processes, but also to stringently test for their possible influence on the categorization process. In the following sections, we will first outline the emotion misattribution procedure's theoretical and empirical background, including a discussion of potential underlying mechanisms, before delineating the insights that might be gained from assessing facial muscle reactions in this task.

We recently introduced the emotion misattribution procedure (Rohr et al., 2015) in order to clarify whether misattribution can also be emotion-specific, especially under short and masked presentation conditions, and to examine whether rudimentary emotional reactions underlie the effects (see also Blaison, Imhoff, Hühnel, Hess, & Banse, 2012; De Houwer & Smith, 2013; Gawronski & Ye, 2014, for further approaches to this issue). Specifically, we asked participants to judge the allegedly subtle emotion of neutral target faces, which were preceded by masked or unmasked facial expressions (i.e., primes) from four specific emotion categories (joy, anger, fear, sadness). In the paradigm, misattribution (and thus automatic processing of the primes) is inferred when responses to the neutral targets are biased toward the (valence or emotion of the) prime.

The study revealed that emotion-specific processing of each emotion category was only given at unmasked presentation conditions. Under masked presentation conditions, we found that happy and sad primes enhanced their corresponding responses, while anger and fear primes indistinguishably increased both anger and fear responses. Given that we could rule out perceptual confusion of the primes (i.e., the pattern did not show up in a forced-choice recognition task), we interpreted this pattern as preliminary evidence for the involvement of affect-related processes, that is, for the extraction of valence and arousal (i.e., "core affect" according to Barrett, 2006; Russell, 2003; Russell & Barrett, 1999) in the masked version of the procedure. According to this theory, valence and arousal can be considered the basic building blocks of emotional experience and perception; only when conceptual knowledge is added, category-specific perception arises. However, these results, although plausible, provided only indirect evidence for the involvement of affect-related processes in the misattribution procedure. Thus, with the present study, we aimed at providing more conclusive evidence for the involvement of affect-related processes by assessing facial muscle responses in addition to behavioral responses.

Facial muscle reactions to emotional faces are a well-studied type of physiological response and are often used as indicators for embodied simulation (see, e.g., Hess & Fischer, 2013; Wood, Rychlowska, Korb, & Niedenthal, 2016, for recent reviews). Thus, observers typically react with congruent facial muscle contractions when presented with an emotional face stimulus (i.e., facial mimicry); that is, the zygomaticus major, which stretches the corners of the mouth, is activated in response to a smiling face; the frontalis lateralis, which lifts the eyebrows, is activated in response to a fear or surprise expression; and the corrugator supercilii, which produces frowning, is activated in response to anger, but also fear and sadness expressions. The majority of existing evidence, which report facial muscle responses in the processing of emotional information, employed, however, clearly visible and/or intentional processing conditions (e.g., Niedenthal et al., 2009). Moreover, facial muscle responses were often found not to be related to emotion information processing (i.e., emotion recognition performance in most studies; e.g., Blairy, Herrera, & Hess, 1999) and often found to be nonspecific in the case of negative emotions (see Hess & Fischer, 2013, for an overview). Thus, it is still debated whether (and when) facial muscle responses as an indicator of embodied, affect-related processes play a role in emotion information processing (Hess & Fischer, 2013; Wood et al., 2016). Specifically, it is speculated that "at this point the most likely interpretation of the extant literature is that mimicry facilitates emotional understanding specifically when subtle distinctions have to be made or the recognition task is especially difficult" (Hess & Fischer, 2013, p. 150). However, systematic investigations of such processing conditions are scarce. With the present study, we examine this assumption for the masked emotion misattribution procedure, in which the processed information is only marginally perceptible and only indirectly (i.e., nonintentionally) processed.

Of note, there is already some evidence suggesting that facial muscle responses might be involved in the procedure. Rotteveel, de Groot, Geutskens, and Phaf (2001), for example, assessed facial muscle responses in a blocked version of the masked misattribution paradigm (i.e., prime emotion was constant in a given block) and found evidence for facial muscle reactions in response to the masked primes. However, no behavioral misattribution effects could be observed under these conditions, leaving open whether facial muscle responses contribute to behavioral effects. Foroni and Semin (2011), who had participants judge funny cartoons that were preceded by masked happy or angry faces, manipulated the contribution of facial muscle responses by blocking them through a pen manipulation. They found that cartoons were judged as more positive after happy primes compared to angry primes only in the no-blocking condition, suggesting that emotional facial expressions play a causal role for such priming effects to emerge. However, they used a blocked design as well, and thus it is possible that such contributions only emerge after repeated exposure to a face stimulus. Taken together, the existing evidence suggests that affect-related, physiological processes might be triggered under difficult processing conditions. Hitherto, however, no research has stringently tested in a within-subject trial-by-trial design whether facial muscle responses are related to behavioral responses under automatic processing conditions. Moreover, the existing implicit research focused on the differentiation of valence only, and the assessment of facial muscle responses was limited to the zygomaticus major and corrugator supercilii muscle.

1.1 | Overview

With the present study, we aimed at testing the involvement of facial muscle responses as indicators for physiological, affect-related processes in a modified misattribution paradigm. On each trial, participants were very briefly exposed to a happy, angry, or fearful facial expression; this prime was immediately followed (and thereby masked) by a neutral expression of the same person. Participants' task was to categorize the person's alleged emotional state as angry, happy, or fearful. We expected a happy prime to lead to specific happiness misattributions, and anger and fear primes to lead to generic anger/fear misattributions. That is, we expected no differentiation in behavioral responses between the two negative emotions under masked presentation conditions (see Rohr et al., 2015). If facial muscle responses contribute to masked emotion misattribution effects, facial muscle responses should match the behavioral result pattern. Specifically, we expected relatively stronger zygomaticus major responses after a masked happy prime compared to angry and fearful primes, and stronger corrugator supercilii responses after negative compared to happy primes. Regarding frontalis lateralis responses under masked presentation conditions, two results were conceivable: First, it was possible that no frontalis lateralis responses are observed. Neumann, Schulz, Lozo, and Alpers (2014), for example, did not find activation of facial muscles beyond the corrugator supercilii and the zygomaticus major under masked presentation conditions and suggested that only evaluative processes might occur under these conditions. Furthermore, if a differentiation of valence and arousal occurs as indicated by the behavioral results of our previous study (Rohr et al., 2015), then this differentiation might be reflected only in corrugator supercilii activation as well. Alternatively, although less likely, it was possible that frontalis lateralis reactions might be observed in response to fear, and possibly also in response to anger (if a fear response is elicited by angry primes) if emotion-specific emotional reactions are triggered.

To provide more conclusive evidence for the involvement of facial muscle responses in the masked misattribution procedure, we applied linear mixed-model mediation analyses (Bauer, Preacher, & Gill, 2006; Preacher, Zyphur, & Zhang, 2010) to directly investigate whether facial muscle responses (partially) mediate the choice of behavioral responses to the neutral target faces (i.e., the indirect path from prime to facial muscle activity to behavioral response).

The misattribution phase was followed by two control measures: (a) The emotional facial expressions were presented in a clearly visible manner; participants categorized the expressions based on emotion. (b) After informing participants about the masked presentation in the first part and asking them about their subjective awareness of the prime faces, we obtained an objective measure of awareness. We report results with regard to these control measures in the online supporting information.

2 | METHOD

2.1 | Participants

Fifty-eight female students (aged 19–33 years, *Mdn* = 24 years) participated in the experiment for monetary compensation (€8/hr). We recruited only female participants, as women show more pronounced (but not qualitatively different) mimicry effects than men (Dimberg & Lundquist, 1990; Likowski, Mühlberger, Seibt, Pauli, & Weyers, 2011). All participants gave written informed consent. Data from two further participants were discarded due to extensive electromyography (EMG) artifacts (i.e., less than half of the trials remained after artifact rejection in the masked conditions; see below for details).

The focus of the study was on a priori defined contrasts (e.g., whether happy and negative conditions differ in behavioral and EMG measures); thus, effects can be indicated by d_Z. To detect an effect of size $d_Z = 0.5$ (i.e., a medium effect as defined by Cohen, 1988) with a probability of $1 - \beta = .95$, given an α value of .05, minimum sample size was $N = 54$. Actual power with $N = 58$ was $1 - \beta = .96$ (G. Power 3.1.3; Faul, Erdfelder, Lang, & Buchner, 2007).

2.2 | Design

The experiment had a 3 (Prime: joy, anger, fear) × 3 (Muscle: zygomaticus major, corrugator supercilii, frontalis lateralis) repeated measures design with EMG activity as the dependent variable. Behaviorally, we assessed target categorization as a function of prime emotion. Additionally, trials with neutral primes were added as a further control condition.

2.3 | Materials

As primes, we selected 60 images of different individuals (30 men, 30 women), depicting emotional (joy, anger, fear) and neutral facial expressions (15 images per category), half from the Radboud Faces Database (Langner et al., 2010) and half from the Karolinska Directed Emotional Faces database (Lundqvist, Flykt, & Öhman, 1998). Targets were images of the same individuals but with neutral facial expressions (i.e., neutral primes were identical to the corresponding targets). Each individual appeared only once in the misattribution task. The images were cropped using an oval mask (see Figure 1). All target and prime images were adjusted to a size of 302 × 345 pixels (11 × 13.5 cm) and presented on a gray background. The experiment was run in E-Prime (Version 2.0) on a standard PC with a 19″ LCD monitor with a refresh rate of 75 Hz.

2.4 | Procedure

Participants were tested individually. An experimental session lasted about 1.5–2 hr; the duration of the experiment

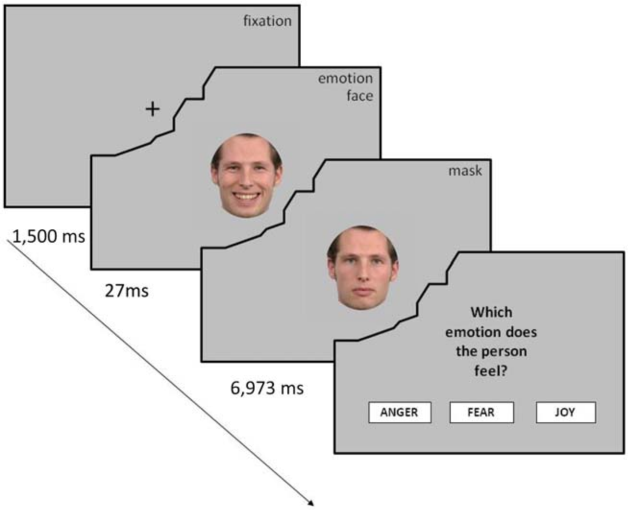

FIGURE 1 Schematic depiction of a trial from the misattribution task

proper was approximately 75 min. Participants received the instructions on the screen, including the cover story that the study was concerned with the recognition of subtle emotional expressions and that skin conductance would be measured during the experiment.

After electrode application, the experiment started with a voluntary muscle contraction task in order to make sure that electrodes were placed correctly to the corresponding muscle. Then, the main experiment started. Each trial started with the presentation of a black fixation cross for 1,500 ms as a baseline measure for EMG activity. Briefly (i.e., 27 ms) presented prime expressions preceded the neutral and clearly visible target faces (presented for 6,973 ms). Participants categorized the supposedly subtle emotional state of the target person as either joy, anger, or fear without explicit knowledge of the briefly presented primes. Four practice trials were followed by five experimental blocks of 12 trials each. Prime emotion was randomized within blocks (i.e., each emotion, including the neutral expression, was presented three times). Furthermore, a filler task (an intensity rating task) was included subsequent to the actual task response[1] in order to fill the long intertrial intervals required for EMG (e.g., Fridlund & Cacioppo, 1986). The duration of the intertrial interval was randomly jittered and ranged from 17–23 s. At the end of each trial, there was an "Attention, next trial!" display followed by a countdown from five to one (total duration 6 s) to mark the start of the subsequent trial. Figure 1 depicts an example of the exact trial structure.

2.5 | EMG recording and analysis

EMG was recorded from three muscles using bipolar placements of 13/4 mm Ag/AgCl surface electrodes: zygomaticus major, corrugator supercilii, and frontalis lateralis. All electrodes were placed on the left facial hemisphere (see Fridlund & Cacioppo, 1986), with a common reference electrode placed on the middle of the forehead directly below the headline. Before electrode placement, participants' skin was cleaned and skin resistance decreased by applying abrasive skin preparation gel (SkinPure, Nihon Kohden, Tokyo, Japan) and then cotton pads drenched with 70% alcohol, so that the impedance of all electrodes was reduced to about 10 kOhm.[2] Super-Visc (EasyCap GmbH, Germany) electrode electrolyte gel was used as conducting medium. Continuous EMG was recorded with a V-Amp 16 amplifier (Brain Products Inc.) at a sampling rate of 2,000 Hz. Difference signals of the bipolar recording channels were combined into single channels offline. The continuous signal was band-pass filtered offline (20–500 Hz with 24 dB/oct roll-off; see van Boxtel, 2001). Additionally, a 50-Hz notch filter was applied, and data were rectified and smoothed with a 125.5-ms moving average filter. Event-related EMG responses elicited by the relevant face pictures were calculated in an offline analysis: The continuous signal was segmented into epochs of 4,000 ms and an additional 1,000-ms baseline period before prime onset. Epochs were baseline corrected using this prestimulus interval (i.e., EMG responses are expressed as the change in activity from the prestimulus level). We chose 4,000-ms epochs for analysis as a compromise between the sometimes used short periods in masked presentation studies ($\leq$ 2,000 ms; Bornemann, Winkielman, & van der Meer, 2012; Dimberg, Thunberg, & Elmehed, 2000; Neumann et al., 2014) and the relatively long time intervals typically used in EMG studies with visible presentation conditions (about 6,000–7,000 ms; e.g., Likowski et al., 2011). Epochs contaminated with severe artifacts were rejected if activity exceeded $\pm$ 30 μV during an epoch, or if it exceeded $\pm$ 8 μV during the prestimulus baseline (i.e., 2.61% of frontalis lateralis responses, 2.53% of corrugator supercilii responses, 3.39% of zygomaticus major responses). In a further step, we screened the EMG responses for statistical outliers, based on Tukey's (1977) "far out" criterion (i.e., values three times the interquartile difference above the third quartile or below the second quartile with regard to the individual distribution, separately for the three muscles; 3.52% of all trials). After outlier rejection, the EMG responses were individually z standardized, and the epochs were averaged for each participant, per emotion condition.

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[1] These tasks were included only as filler tasks and thus not analyzed.

[2] We aimed at 10 kOhm impedance or less, which was achieved in 94.3% of electrode placements. In the remaining 5.7%, impedances ranged from 11 to 19 kOhm despite extensive cleaning.

TABLE 1 Mean response frequencies (standard errors) for all cells in the misattribution phase

	Prime emotion					
Response	Happy	Anger	Fear	Expected frequency	Neutral	Σ
Happy	6.02 (.38)	2.72 (.22)	2.90 (.23)	3.88 (.20)	5.64 (.29)	17.28 (.76)
Anger	4.31 (.27)	7.50 (.29)	7.16 (.30)	6.32 (.18)	3.76 (.20)	22.72 (.61)
Fear	4.67 (.26)	4.78 (.26)	4.95 (.28)	4.80 (.17)	5.60 (.29)	20.00 (.63)
Σ	15	15	15		15	60

Note. Expected frequencies for each response are calculated by multiplying the row totals with the column totals divided by the grand total (excluding the neutral condition). Depicted at the right are the row totals including the neutral condition. The Neutral column refers to the condition without emotional prime.

3 | RESULTS

A significance level of alpha = .05 (two-tailed, unless otherwise noted) was adopted for all analyses. For results of the control measures (see above), see supporting information.

3.1 | Behavioral results

Table 1 shows the raw mean response frequencies. Individual priming scores served as the dependent variable for further analyses (see Rohr et al., 2015). These scores were calculated for each cell of the 3 (Prime Emotion) × 3 (Response Category) design by subtracting the expected frequency of the given cell from its observed frequency. In prime-response congruent cells, a positive score on this measure indicates positive priming, interpretable as a misattribution of the prime emotion to the target. We were also interested in the incongruent prime-response cells of angry/fear primes, as we expected a specific pattern of misattribution scores for these categories (i.e., misattribution of fear from anger primes and vice versa; see Rohr et al., 2015). Positive scores in these cells indicate that participants responded with anger (fear) after a fearful (angry) prime. Furthermore, we calculated difference scores for the neutral prime control condition as well.

The difference scores are depicted in Figure 2. Happy and angry primes were associated with concordant responses, while fearful primes were primarily associated with anger responses. We conducted a multivariate analysis of variance (MANOVA) for repeated measures (i.e., see O'Brien & Kaiser, 1985) on the scores from the three prime-response congruent cells, with emotion as a three-level factor. The intercept test yielded a significant result, $F(1, 57) = 29.40$, $p < .001$, $\eta_p^2 = .340$, indicating a significant misattribution effect overall. The main effect of emotion was significant as well, $F(2, 56) = 43.02$, $p = .001$, $\eta_p^2 = .606$, indicating significant differences in misattribution across emotions. Follow-up t tests (with Bonferroni-Holm adjustment) revealed that happy and angry primes led to concordant misattribution effects, $M_{joy} = 2.14$, $SD = 2.00$, $t(57) = 8.14$, $p < .001$, $d = 1.07$; $M_{anger} = 1.18$, $SD = 1.79$, $t(57) = 5.02$, $p < .001$, $d = .66$, respectively. Fearful primes, however, were not associated with concordant misattribution, $M_{fear} = .15$, $SD = 1.80$, $t(57) < 1$, $p = .53$, $d = .08$.

To investigate discordant effects, we analyzed misattribution scores in the prime-response incongruent cells, specifically those involving anger responses to fear primes (fear-anger) and fear responses to anger primes (anger-fear), respectively. As suggested by Figure 2, the mean of the misattribution score for the fear-anger cell was significantly greater than zero, $M_{fear/anger} = .83$, $SD = 1.60$, $t(57) = 3.98$, $p < .001$, $d = .52$, indicating that participants interpreted the neutral target as angry after a fearful prime. No discordant misattribution occurred after angry primes, $M_{anger/fear} = -.02$, $SD = 1.19$, $|t|(57) < 1$, $p = .88$, $d = .02$.

Note that the misattribution of anger following fearful and angry primes was not due to a general response tendency, as the response pattern in the neutral condition revealed that neutral faces tended to be interpreted as joyful or fearful, but not angry, $M_{neutral/anger} = -1.92$, $SD = 1.41$, $t(57) = -10.35$, $p < .001$, $d = 1.36$, for the deviation of observed anger responses from the expected value (we refrain from reporting the corresponding tests for joy and fear because the three tests are not independent).

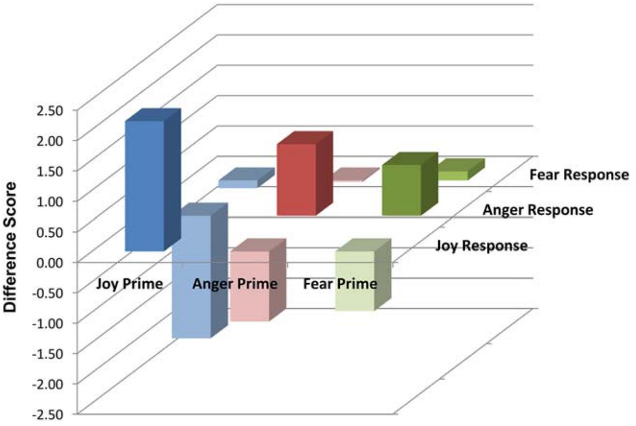

FIGURE 2 Difference scores (i.e., observed response frequency minus expected frequency) from the misattribution phase; see text for details

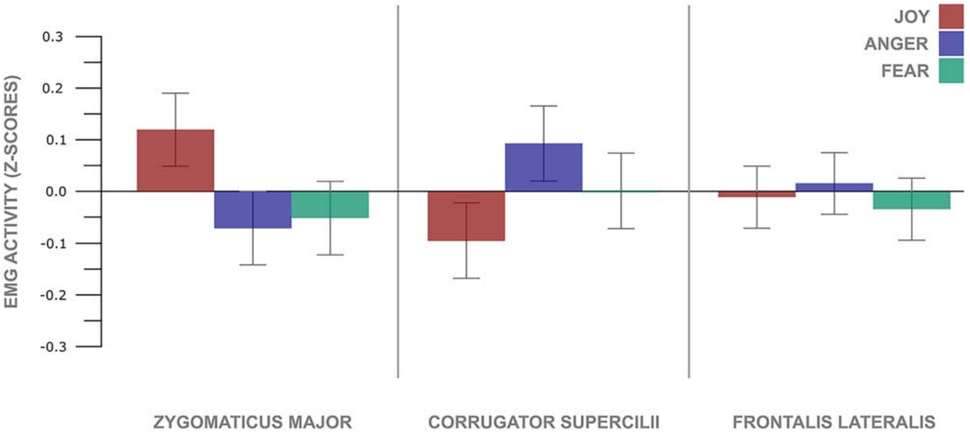

FIGURE 3 *Z*-standardized EMG responses for joy, anger, and fear expressions in the misattribution phase from the zygomaticus major, corrugator supercilii, and frontalis lateralis muscles. Error bars are 95% within-subject confidence intervals for the main effect of emotion, specific to each muscle (Jarmasz & Hollands, 2009)

3.2 | EMG results

Group-averaged EMG responses for each muscle are presented in Figure 3a (see Appendix Figure A1 for the time profiles). A 3 (Emotion: joy, anger, fear) × 3 (Muscle: zygomaticus major, corrugator supercilii, frontalis lateralis) repeated measures MANOVA yielded only a significant interaction, $F(4,\ 54) = 5.45$, $p = .001$, $\eta_p^2 = .287$ [$F(2,\ 56) = 1.25$, $p = .294$, $\eta_p^2 = .043$, for the main effect of emotion]. We ran further one-factorial within-subject MANOVAs on the data from each muscle with a priori specified orthogonal Helmert contrasts. For the zygomaticus major, a significant main effect of emotion emerged, $F(2,\ 56) = 7.62$, $p = .001$, $\eta_p^2 = .214$. The a priori contrast of joy versus anger/fear (i.e., the valence contrast) was significant, $F(1,\ 57) = 15.51$, $p < .001$, $\eta_p^2 = .214$, indicating higher zygomaticus major activity after a masked joy face compared to masked negative faces. As expected, zygomaticus major activity did not differ between angry and fearful primes, $F < 1$. For the corrugator supercilii, there was also a significant main effect of emotion, $F(2,\ 56) = 5.96$, $p = .005$, $\eta_p^2 = .176$. The a priori contrast of joy versus anger/fear (i.e., again, the valence contrast) was significant, $F(1,\ 57) = 8.25$, $p = .006$, $\eta_p^2 = .126$. Furthermore, the two negative emotions (anger vs. fear) showed a marginally significant difference, $F(1,\ 57) = 3.95$, $p = .05$, $\eta_p^2 = .065$. As Figure 3a indicates, corrugator supercilii activity was highest in the anger condition, followed by the fear condition and the joy condition, which indeed showed relaxation. By contrast, responses of the frontalis lateralis muscle were not influenced by the masked emotional faces, $F(2,\ 56) = 0.57$, $p = .569$, $\eta_p^2 = .020$. Here, we a priori specified the first contrast as fear versus anger/joy, because of the assumed fear-specificity of the frontalis lateralis; it was not significant, $F(1,\ 57) = 0.90$, $p = .347$, $\eta_p^2 = .016$, and neither was the contrast of anger and joy, $F < 1$. Thus, the masked face primes elicited facial muscle responses in line with our hypotheses: The zygomaticus major as well as the corrugator supercilii differentiated between joy and the two negative prime conditions in the expected direction. No significant frontalis lateralis activation was observed in response to the masked primes.

3.3 | Mediation analyses

We ran hierarchical linear mediation models (Preacher et al., 2010) using Mplus software (Muthén & Muthén, 1998–2015) to test if the prime effects on the behavioral choices were mediated by the corresponding muscle responses. That is, the mediation analyses focus on the level of trials within participants. Thus, they test the assumption that within participants, but across trials, part of the priming influence on the behavioral response is mediated by muscle activity. We focused on the three cases where the simple analyses indicated significant differences.

Figure 4 shows the fixed factor parameters. For Mediation 1 (i.e., $\text{prime}_{\text{joy vs. negative emotions}} \rightarrow$ corrugator supercilii $\rightarrow \text{response}_{\text{joy vs. negative emotions}}$; Figure 4a), Path a (i.e., prime → corrugator supercilii) and Path b were negative and significant, with critical ratio (i.e., parameter estimate divided by its standard error) $CR = 2.86$, $p = .004$ for Path a, and $CR = 7.67$, $p < .001$ for Path b. Correspondingly, the indirect path overall was significant as well, $CR = 2.83$, $p = .005$. Finally, the direct path was also significant, $CR = 7.44$, $p < .001$, indicating partial mediation.

For Mediation 2 (i.e., $\text{prime}_{\text{joy vs. negative}} \rightarrow$ zygomaticus major$\rightarrow \text{response}_{\text{joy vs. negative}}$; Figure 4b), Path a and b were both positive and significant, $CR = 4.01$, $p < .001$ for Path a, and $CR = 6.17$, $p < .001$ for Path b, and the indirect path was significant as well, $CR = 2.17$, $p = .030$. The direct path was also significant, $CR = 7.12$, $p < .001$. Thus, zygomaticus major activity also partially mediated the link between prime emotion and behavioral response.

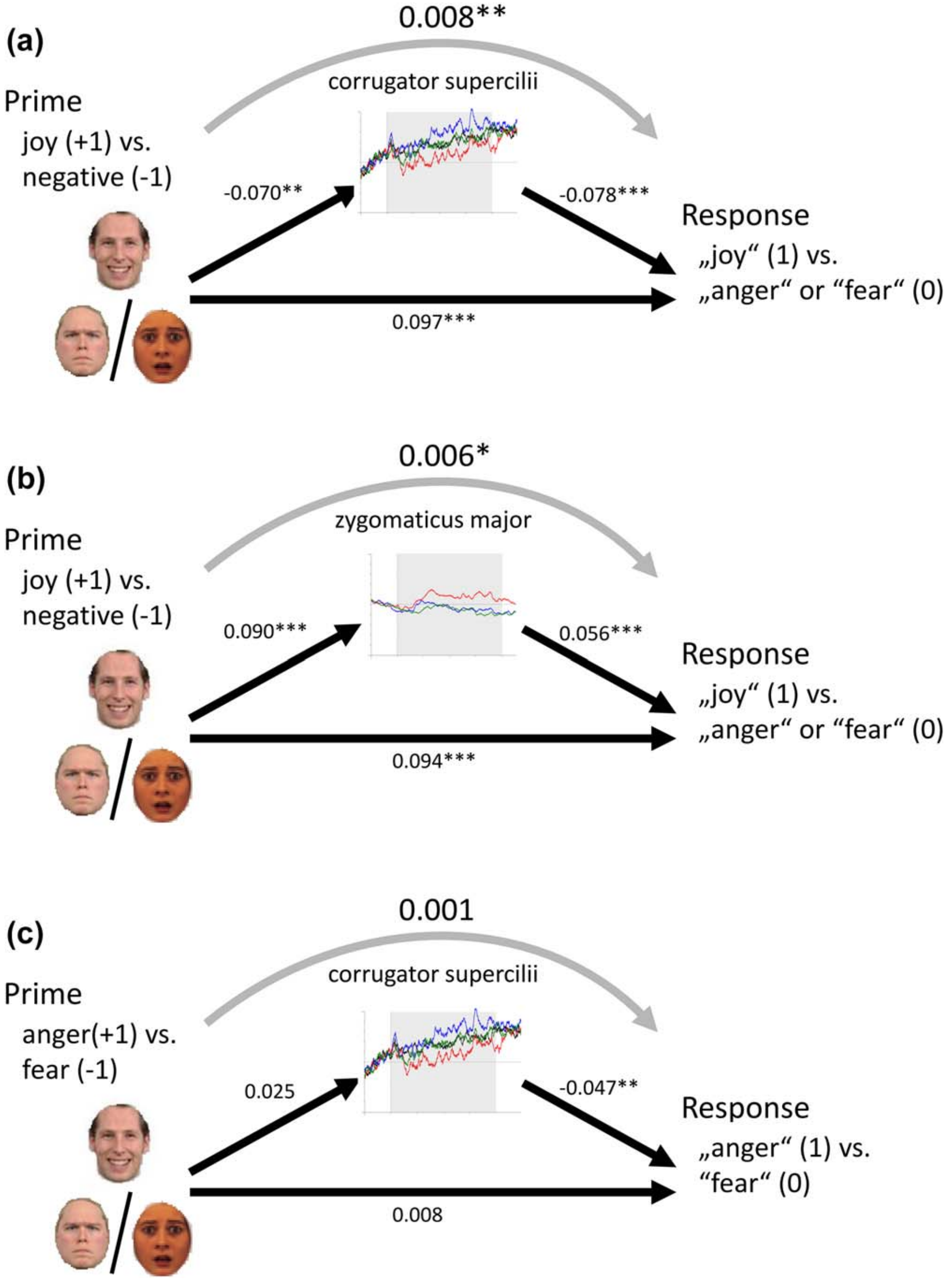

FIGURE 4 Results of the mediation analyses (see text for details)

Finally, for Mediation 3 (i.e., $\text{prime}_{\text{anger vs. fear}} \rightarrow$ corrugator supercilii $\rightarrow \text{response}_{\text{anger vs. fear}}$; Figure 4c), Path a was positive but nonsignificant, $CR = 0.93$, $p < .355$; Path b was negative and significant, $CR = 2.89$, $p = .004$. The indirect path, however, was not significant, $CR = 0.24$, $p = .809$, and neither was the direct path, $CR = 0.53$, $p = .595$. Thus, the linear mixed-model mediation analysis could not corroborate the anger versus fear differentiation observed with conventional analyses, and it also did not provide support for an indirect path. Thus, prime-elicited corrugator supercilii activity does not seem useful in differentiating between anger and fear. Of note, corrugator supercilii activity tended to be elevated after anger (compared to fear) primes (see the standard EMG analyses above). However, Mediation 3 revealed that increased corrugator supercilii activity was associated with an increased number of fear responses (Path b). Thus, variation in corrugator supercilii activity might still be used as a cue to infer which emotional information was presented. However, the underlying processes seem to be more complex.

4 | DISCUSSION

By and large, the results confirmed our hypotheses. First, we were able to replicate the behavioral effects found in Rohr et al. (2015): Participants showed specific behavioral misattribution effects after a masked joy prime, but confusion of anger and fear. Second, facial muscle activations mirrored the behavioral results: Joy primes were associated with higher zygomaticus major activity compared to anger/fear, and negative primes were associated with higher corrugator supercilii activity. Most importantly, the linear mixed-model mediation analyses found significant indirect paths from prime emotion via facial muscle activations to behavioral response, suggesting that the process underlying the generation of facial muscle responses is involved in the choice of a behavioral response. Third, we found no significant frontalis lateralis activation in misattribution (despite frontalis lateralis activity in our overt categorization task, see supporting information), in line with the assumption that, given masked presentation conditions, differentiation is not up to the specific emotion (Neumann et al., 2014; Rohr et al., 2015). Fourth, the results of the prime discrimination phase showed that the confusion of anger/fear primes was specific to the masked misattribution phase, and did not occur when discrimination was explicitly required (see supporting information).

The results provide clear evidence for a contribution of more than one process to the choice of the behavioral response. Based on recent models of facial emotion recognition (Wood et al., 2016) and evidence regarding the affect misattribution procedure (Payne & Lundberg, 2014), we suggest that the prime emotion prompts several cognitive-semantic, physiological, and sensorimotor processes (see also Barrett, 2017; Uithol & Gallese, 2015). Depending on the presentation conditions and task instructions, these processes can feed into the behavioral response to a varying degree. Thus, participants' behavioral responses might be selectively affected by one or more of these processes. The processes are thought to run in parallel, but their outcomes contribute to an integrated information that ultimately shapes the behavioral response (Winkielman, Ziembowicz, & Nowak, 2015; see also Gallese & Caruana, 2016; Wood et al., 2016). Thus, the present study helps to settle the discussion about the involvement of affect-related versus semantic processes in misattribution procedures. Depending on the specific task parameters employed (and perhaps also participants' habitual processing styles, such as introspective awareness or need for cognition), reported effects might be based to a greater or lesser degree on affect-related versus semantic processes.

In this regard, our results indicate that masked presentation and implicit processing (compared to direct or unmasked presentation conditions, see supporting information) conditions lead to greater reliance on physiological or sensorimotor processes, beyond cognitive-semantic ones. In the prime discrimination phase, all emotions were discriminated above chance and there was no indication for confusion of anger and fear; in the misattribution phase, we found confusion of anger and fear. Thus, different processes seem to underlie the choice of behavioral response in the prime discrimination versus the misattribution phase, that is, an attempt to decode the prime percept, requiring an attentional focus on the briefly presented prime, and a more implicit process, relying to a greater degree on physiological processes, respectively. Thus, misattribution studies with clearly visible presentation conditions, and perhaps more direct or intentional responding, might be based to a greater degree on cognitive, semantic processes. Of course, the exact contribution of physiological or sensorimotor responses to a specific misattribution procedure with specific task parameters can only be determined empirically. Apart from masked presentation conditions, we used emotional facial expressions as primes, which might be especially susceptible to the involvement of sensorimotor processes. However, we think that facial muscle responses or other sensorimotor processes are triggered in misattribution procedures with different types of primes as well, if affect-related processing takes place. The existing evidence points already in that direction. For example, Weinreich and Funcke (2014) showed that corrugator supercilii responses are elicited in the misattribution of music album covers. De Houwer and Smith (2013) provided evidence for stronger misattribution effects with emotional pictures if participants are instructed to rely on their gut feelings. We hope that our study encourages researchers to test the involvement of sensorimotor processes in misattribution procedures more directly, that is, with a trial-by-trial design as in the present study. Such an approach seems highly interesting when prejudiced tendencies,[3] voting, or other preferences are assessed. It could help to disentangle whether sensorimotor or semantic aspects are considered for implicit or explicit liking, and which aspects predict behavior to a greater degree. Furthermore, the lack of frontalis lateralis activity suggests that the underlying sensorimotor process is not emotion specific. Either the facial muscle response reflects only valence differentiation (Neumann et al., 2014) or it is valence and arousal based (Cacioppo, Petty, Losch, & Kim, 1986). Given our former evidence (Rohr et al., 2015) and the different patterns for neutral versus angry and fear primes in the present study as well, a differentiation of valence and arousal, as postulated by the "core affect" hypothesis, seems likely. Further studies (e.g., including sadness as a low-arousal emotion) are, however, necessary to corroborate this assumption.

Of note, the mediation was only partial; that is, the direct path from prime to response was significant in all cases. There are two explanations for this pattern: First, as delineated above, part of the misattribution pattern is likely due to a semantic categorization process. That is, the prime

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[3] In this regard, it should be mentioned that mimicry to out-group members is typically found to be less pronounced compared to in-group members (Bourgeois & Hess, 2008; van der Schalk et al., 2011). Thus, facial muscle responses to facial expressions might necessitate affiliation and the motivation to understand the other (Wood et al., 2016).

activates corresponding semantic concepts that are subsequently used to categorize the target face. These activated concepts need not be emotion-specific; one could assume that the prime can also activate superordinate categories of "positive emotion" or "negative emotion." Second, facial muscle activity is, of course, only an indirect (and more or less reliable) index of the underlying process (Wood et al., 2016). Thus, if sensorimotor stimulation is the latent process, the mediation path might not be (fully) captured by the facial muscle response. Hence, the direct path may be overestimated.

Of course, mediation results do not provide clear evidence for causal links between prime emotion, facial muscle responses, and behavioral choices. From an "embodied" or simulation perspective, one might also state that the facial muscle responses reflect one aspect of a multimodal simulation triggered by the prime. In that sense, the facial muscle responses would not really be a mediator, but part of the triggered multimodal processing. Nevertheless, our results show that the different contributing processes can be (partly) separated, elucidating that more than one process contributes to misattribution effects.

While our study has elucidated several important aspects regarding the processes underlying masked misattribution, some limitations should be mentioned: First, we did not achieve objective unawareness, as the above-chance prime discrimination rate indicates (see supporting information). Thus, processing of the masked primes in the misattribution phase cannot be considered truly "nonconscious." Nevertheless, differences in behavioral response patterns across phases suggest that the masking was sufficient to induce differences in processing, indicated by the confusion of anger versus fear in the misattribution but not in the prime discrimination phase. Second, we cannot provide direct evidence for our assumption that both valence and arousal, rather than valence alone, were extracted from the emotional primes in the misattribution phase. While the pattern of results obtained with neutral faces points in that direction, this evidence is only indirect (see also Fugate, Gendron, Nakashima, & Barrett, 2017). Future studies should include, for example, sadness as a negative, low-arousal emotion to corroborate our interpretation.

To conclude, our study provides direct evidence for the contribution of several underlying processes, presumably (at least) a cognitive-semantic and a physiologically based embodied one. Based on the obtained pattern of results, we suggest that valence and arousal are extracted from masked emotional faces and that this information is used (via cognitive as well as sensorimotor processes) to prepare a behavioral response.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

Appendix S1
Table S1
Table S2
Figure S1
Figure S2

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