



OPEN Restricting facial mimicry does not impair emotion recognition or influence the evaluation of human affect vocalizations and instrumental sounds

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The embodied simulation approach predicts that restricting facial movements disrupts emotion recognition. Such effects have been reported for facial and whole-body emotional expressions, but findings remain inconsistent, and it is unclear whether they generalize to emotional sounds. Previous work has also shown that restricting mimicry induces a positivity bias in valence ratings, consistent with the facial feedback hypothesis. Here, we tested whether restricting facial mimicry impairs recognition of emotional sounds across four emotion categories in a forced-choice task and whether it affects valence and arousal ratings. Drawing on previous findings indicating that vocal emotional expressions elicit facial mimicry, whereas instrumental emotional sounds do not, we expected to find an effect only for the former. Instrumental sounds were recognized less accurately and more slowly than vocalizations, particularly for negative and neutral expressions. Crucially, both frequentist and Bayesian analyses provided no evidence that the pen-in-mouth manipulation impaired emotion recognition or influenced valence or arousal ratings. Taken together, these findings underscore the need for further studies to systematically determine the conditions under which restricting emotional mimicry influences emotion processing, as well as the nature of such effects.

Human mimicry—namely, the tendency to spontaneously copy others' behavior, including facial expressions, gestures, and body postures—is a well-established phenomenon^{1,2}. But why do people mimic? This question remains a topic of ongoing debate, with at least three, though not mutually exclusive, positions. The first position considers mimicry to serve as a “social glue”—a factor that promotes social bonding by enabling individuals to align with others^{3–5}. This position is supported by findings showing that mimicry intensifies liking toward others⁶ and that people mimic more when they feel more positive feelings towards their partners^{7–9} or share pre-existing social bonds and affiliative goals⁴. The second position sees mimicry as a type of automatic imitation—where repeated pairing of a stimulus with a response leads to spontaneous triggering of associated motor patterns¹⁰. This view is supported by evidence that facial mimicry develops very early, as a consequence of frequent perception–action coupling¹¹. Note that in this view, the functional role of automatic mimicry is limited as it is mostly a by-product of associative learning. The third position considers mimicry as a manifestation of embodied simulation^{12,13}, a mechanism involved in the conceptual processing, or understanding, of emotional expressions^{14–17}. In line with this view, numerous studies found that restricting spontaneous facial activity disrupts the categorization^{18,19} and evaluation²⁰ of emotion-specific facial displays. However, the available evidence is not fully consistent^{21,22}, and it remains unclear whether the observed effects generalize to other forms of emotional expression and across modalities^{23,24}. More generally, the embodied cognition framework has faced criticisms for its theoretical commitments and its empirical basis^{25–28}.

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Embodied simulation and facial mimicry

Here, we focus on the role of facial mimicry, i.e., “the low-level spontaneous motor reaction commonly observed in perceivers of facial expressions (p. 228)”¹⁷, as it is understood within the embodied simulation account. In a nutshell, embodied simulations consist of subthreshold reenactments of sensory, motor, and somatosensory resources that are usually active during the production of an individual’s own actions, such as facial expressions^{12,13,17,29}. While originating in the brain, embodied simulations are systematically linked with specific bodily changes—in our case, facial mimicry. Such mimicry can be covert—that is, too subtle to be visible to the naked eye of the observer or even consciously experienced by the individual—yet it plays a functional role in facilitating stimulus processing. In line with the simulation account, emotions are patterns composed of intertwined behavioral, physiological, neural, and subjective components, in which activating one component triggers the activation of the others. Thus, when an observer perceives a facial expression of a smile—in which contraction of the *zygomaticus major* muscle is particularly involved—they automatically contract the corresponding muscle and, as a result, facilitate a quick and accurate inference about the expressed emotion^{14,16,17,30}. The main line of evidence in favor of the just-described account comes from studies on individuals with facial mimicry impaired due to Möbius syndrome-related congenital facial paralysis^{31,32}, lesions in sensorimotor areas³³, transient inactivation of somatosensory face-related regions by repetitive transcranial magnetic stimulation³⁴, Botox injections³⁵, or behavioral manipulations^{18,19,36–40}. Although facial movement impairments vary in their functional characteristics—for instance, Botox prevents any activity in the targeted facial region, while behavioral manipulations usually produce constant, non-specific muscle activity in a given part of the face¹⁹—taken together, these findings converge on a general conclusion: facial mimicry is causally involved in processing perceived emotional states³¹.

Among behavioral manipulations of facial mimicry, one of the simplest and most frequently used in research involves asking participants to hold a pen or chopsticks horizontally between their teeth, which restricts selective movements in the lower facial muscles, especially the *zygomaticus major*. For simplicity, we refer to this procedure as the “pen-in-mouth manipulation,” regardless of what participants actually hold between their teeth. Note also that while we use the term “restricting” facial movements, other authors prefer the term “blocking”²⁴. The term “inhibiting” is sometimes used, though technically some of these manipulations involve participants biting on a “pen”, which non-specifically engages relevant facial muscles in a tonic (continuous) fashion, preventing those muscles from having a phasic (strong and rapid) stimulus-dependent muscle response.

Niedenthal et al.¹⁸ found that such a manipulation impairs performance on a task requiring the detection of the precise moment of the transition from a displayed sad face to a happy one, and vice versa. Next, Oberman et al.¹⁹ found that restricting the activity of the *zygomaticus major* selectively impaired recognition of happy and disgusted emotional faces—emotions that typically strongly engage the muscles affected by the manipulation. This result has been corroborated, among others, by Ponari et al.³⁹, who additionally found poorer recognition of angry facial expressions when the brow area was activated by drawing together two small stickers placed near the inner edges of the participants’ eyebrows. Recognition of fear expressions was disrupted regardless of which area of the perceiver’s face was manipulated. More recently, Borgomaneri et al.²³ replicated the effect of restricting the *zygomaticus major* on the recognition of happiness portrayed in faces and found a similar effect of this manipulation on the recognition of whole-body expressions of the same emotion. All of the just summarized studies reveal a consistent pattern: restricting mimicry worsens recognition of visually portrayed emotions. Moreover, Borgomaneri et al.’s²³ finding on whole-body emotional expressions supports the claim that mimicry might be a part of the causal mechanism responsible for grasping the emotional meaning of a stimulus, rather than merely a by-product of stimulus–response associations. Nevertheless, the impact of manipulating mimicry may be task-dependent. In a study by Orłowska et al.²², participants were asked to assess the extent to which static or dynamic emotional displays expressed three types of smiles—reward, affiliation, and dominance. Restricting facial movements did not reduce accuracy. Moreover, in a study by Blairy et al.²¹, manipulating mimicry through explicit instruction likewise did not affect responses made on visual analog scales.

Facial mimicry and emotional sounds

If embodied simulation operates at the conceptual level of processing—namely, the level that concerns the emotional meaning of a stimulus—then the effects of restricting facial mimicry should be observable not only when seeing others’ faces, but should also generalize to other modalities. Yet, the influence of manipulating facial mimicry on the recognition of vocal emotional expressions—or, more broadly, auditory emotional patterns—has been studied much less frequently than effects involving facial displays.

To our knowledge, three studies have shown that nonverbal human vocalizations evoke emotion-congruent facial activity. First, Hawk et al.⁴¹ demonstrated that facial activity while listening to emotional sounds correlates with that observed during self-produced vocalizations, suggesting that the perception of emotional vocalizations involves the simulation of facial behavior associated with sound production. Lima et al.⁴² demonstrated selective activation of the *zygomaticus major* and *orbicularis oculi*—the “smiling muscles”—in response to laughter, with stronger responses to authentic than to posed laughs. In contrast, no reliable facial responses were observed for cries. Furthermore, the study by Wołoszyn et al.⁴³ demonstrated that happy emotional expressions triggered activity in the *zygomaticus major*. Importantly, this muscular response was observed in reaction to human affective vocalizations but not to comparably valenced emotional sounds produced by musical instruments. Because only vocalizations are produced by expression-like facial configurations, this suggests that the effect reflected emotional mimicry rather than a general emotional response to auditory stimuli. Additionally, in two studies on emotional prosody, Arias et al.^{44,45} demonstrated zygomatic responses to sentences transformed to include an acoustic cue characteristic of speech produced with a smile. They argued that this cue triggers corresponding muscular activity in the perceiver by matching the speaker’s orofacial configuration.

Emotional mimicry across different modalities (auditory, motor, and visual) may be based on learned sensorimotor associations. According to Viswanathan et al.'s⁴⁶ scenario of the ontogenetic development of facial imitation, auditory–motor associations might emerge prior to the formation of visuomotor links. Infants vocalize frequently, even in the absence of other people. While vocalizing, they learn to associate the spectrotemporal features of the sounds produced by specific orofacial gestures with their own facial motor actions and proprioceptive signals. The association between seeing someone's facial expression and one's own motor action is learned later, during dyadic interactions with a caregiver¹¹. At this point, the child learns to associate visually perceived facial expressions with motor movements already linked to familiar sounds. All this could simply reflect the process of perception–action learning¹⁰. Nevertheless, from the perspective of the embodied simulation account, mimicry is not merely the passive result of triggered auditory–motor associations, but a manifestation of sensorimotor reenactments that serve as the mechanism for processing emotion concepts. Therefore, interfering with mimicry should affect the process of emotion recognition.

To our knowledge, only three studies to date have demonstrated an influence of mimicry manipulation on the processing of emotional human vocalizations. The first, conducted by Hawk et al.⁴¹, reported an effect in the opposite direction to that observed in studies on emotional faces. Participants were presented with sounds that gradually transitioned from laughing to crying and vice versa, and their task was to detect the moment of emotional change while holding a pen either between their teeth or in their hands. The results were contrary to findings from studies using visual emotional expressions, particularly that of Niedenthal et al.¹⁸, which employed a face transition detection task and the same emotion categories. Specifically, Hawk et al.⁴¹ found that restricting mimicry facilitated the detection of emotional change compared to the control condition. The authors argued that, under unrestricted conditions, facial mimicry of vocal expressions heightens attentional focus and emotional engagement with the ongoing affective state—ultimately delaying the detection of a shift to an opposing emotion. The study by Vilaverde et al.⁴⁷ demonstrated that restricting facial movements impairs the ability to differentiate authentic from posed vocal expressions; specifically, accuracy for both laughs and cries was reduced when mimicry was inhibited.

The effect of manipulating facial mimicry on emotional vocalizations was also examined by Wołoszyn et al.²⁴, who included five emotion categories: anger, disgust, fear, happiness, and neutral. Participants were asked to evaluate the sound's emotional category, as well as its valence and arousal, using unmarked visual analog scales. The mimicry response of selective muscles was restricted by having some participants hold a chopstick between their teeth. As mentioned, this manipulation creates a tonic (continuous) input but prevents phasic, stimulus-specific responses. The study did not find any selective effects of the manipulation on either emotion categorization or arousal evaluation. However, it found a non-specific effect of the manipulation on valence ratings. Specifically, participants rated the valence of all sound categories, including neutral, more positively when lower facial muscle movements were restricted. The latter result can be explained by the facial feedback hypothesis⁴⁸ (but see^{49–51} for challenges to the evidence and interpretation of facial feedback studies), and is consistent with Hyniewska and Sato's²⁰ finding that participants rated emotional facial expressions as more positive when their lower facial muscles were non-specifically activated by the instruction to “raise the cheeks,” compared to when they were asked to lower their brows.

While mimicry may represent a specific response to human emotional expressions⁴³, facial feedback may exert an influence on a broader range of emotional stimuli, reflecting the impact of body changes on subjective emotional experience and the evaluation of affective material⁴⁸. Therefore, the positivity bias observed in response to human vocalizations in Wołoszyn et al.'s²⁴ study could potentially generalize to other types of emotional auditory stimuli, such as instrumental expressions of emotion. We discuss the methodological differences between the previous and current studies shortly.

Study background and preregistered hypotheses

As discussed in the previous sections, although the results are not entirely consistent^{21,22}, numerous studies have shown that manipulating facial mimicry influences the processing of perceived emotional facial expressions^{18–20,36–39}. These results suggest that mimicry manipulations affect the sensorimotor simulation underlying the conceptual processing of emotions^{14,17}. On the other hand, the generalization of this effect to the auditory modality has been investigated in only a handful of studies, yielding inconsistent results. As discussed, Hawk et al.⁴¹ found that restricting facial movements increases participants' performance in detecting the moment of transition in an emotional sound from laughing to crying, while studies using emotional faces as stimuli typically indicate that such manipulation decreases task performance. Next, Wołoszyn et al.²⁴ found that restricting facial movements introduces a non-specific valence positivity bias in the evaluation of emotional vocalizations, but without affecting emotion recognition accuracy. The authors proposed that the latter null result might be linked to the employed response format. Participants were asked, “To what extent did the sound express the following emotion?” and responded on a visual analog scale. However, this differs from studies on facial expressions, in which a forced-choice response format is typically used²³. Thus, the ineffectiveness of restricting facial movements in Wołoszyn et al.'s²⁴ study may have been linked to more deliberate processing allowed by the response format.

In sum, examining the potential role of embodied simulation in the processing of emotional sounds—stimuli we encounter in our daily lives—is theoretically important, as it distinguishes between major accounts of mimicry and emotional processing. It is also practically important because a considerable number of psychotherapeutic approaches draw inspiration from the embodied cognition account in general^{52–54}, and from research on mimicry in particular⁵⁵.

Our preregistered study (OSF, <https://doi.org/10.17605/OSF.IO/PKUDX>) investigated the causal role of the listener's mimicry in the processing of emotional sounds. Participants listened to two types of sounds: non-verbal vocalizations and instrumental sounds from four emotion categories: sadness, fear, happiness, and

neutral. Vocalization stimuli—such as laughing and crying—were selected from the Montreal Affective Voices (MAV) database⁵⁶, which was designed as an auditory analog of Ekman's emotional faces⁵⁷. Instrumental sounds—brief melodies played on either the violin or the clarinet—were selected from the Musical Emotional Bursts (MEB) database⁵⁸, which serves as a musical analog of the MAV. After listening to each sound, the participants categorized the emotion using a four-alternative forced-choice format. Next, they evaluated each sound on two scales measuring valence and arousal. Crucially, the participants performed the task under two conditions previously applied in Wołoszyn et al.²⁴. In the control condition, participants held the chopsticks horizontally between their lips, in front of their teeth, keeping the lower face relaxed and free to move. In the mimicry restriction condition, participants held chopsticks horizontally between their teeth with their mouths closed around them. This manipulation creates a constant muscular tension, and as such interferes with the dynamic response of the *zygomaticus major*, the facial muscle activated while smiling. This manipulation has been previously validated using facial electromyography^{15,19,59}.

First, we were interested in emotion recognition performance. Relying on the embodied simulation approach, which considers facial mimicry as being causally involved in the processing of the emotional meaning of a stimulus, we hypothesize that restricting selective activation of lower facial muscles (in the area of the *zygomaticus major*) will impair the recognition of emotional sounds. That is, accuracy will be lower and reaction times longer compared to the control condition in which those muscle movements are not restricted. Second, considering that, in contrast to instrumental emotional sounds, human emotional vocalizations elicit prominent mimicry⁴³, we expected a more pronounced effect of restricting lower facial muscle movements on happy human vocalizations compared to instrumental sounds. Third, we revisit the previous finding on the impact of pen-in-mouth manipulation on the evaluation of emotional sounds²⁴. We hypothesize that the teeth (restriction) condition will introduce a non-specific, i.e., irrespective of emotion category, valence positivity bias.

Method

Participants

The a priori power analysis for repeated measures ANOVA was conducted using G*Power⁶⁰ based on Brysbaert's⁶¹ recommendations. Desired sample size was calculated with the probability of a Type I error set to $1-\alpha=0.05$, the desired power set to $1-\beta=0.80$, and small effect size ($f=0.15$), resulting in 64 participants. 70 Polish-speakers participated in the study. Three of them were initially excluded due to average accuracy below 50%. The remaining sample consisted of 47 females, 18 males, 1 reporting another gender, and 1 preferring not to answer. The sample's mean age was 23.2 years (range = 18–40, $SD=4.92$). Further exclusions from specific analyses are described in the *Analysis and data processing* subsection. Because 22 participants had empty data cells in the reaction time data, we conducted a sensitivity analysis, the results of which are reported in the final subsection of the *Results*. Each participant received a 50 PLN (approx. 12 USD) gift card to a media store for taking part in the experiment. The study was conducted in a group setting, with up to 4 participants in the lab at the same time. The study's design was approved by the Committee on Research Ethics at the University Ignatianum in Cracow (decision number 27/2025 issued on 25/01/2025).

Materials

The experimental procedure was preregistered at OSF: <https://doi.org/10.17605/OSF.IO/PKUDX>. It was run using the PsychoPy software⁶² on Dell OptiPlex 7090 PCs with AKG K52 headphones. We used 80 short sounds that were non-verbal expressions of three basic emotions: fear, sadness, and happiness, and 20 neutral sounds. Half of the stimuli (40) were selected from the Montreal Affective Voices (MAV)⁵⁶, consisting of brief human-made affect vocalizations (e.g., laughing, crying). Half of them were male and half female. The sounds lasted on average 1.33 s ($SD=0.81$). The other 40 sounds came from the Musical Emotional Bursts (MEB) database⁵⁸, which was created as a musical analog of the MAV. Instrumental sounds were brief melodies played on either the violin or the clarinet. They lasted, on average, $M=1.6$ s ($SD=0.64$). According to the validation conducted by the authors of the databases^{56,58}, the sounds we selected for our study were characterized by high recognizability, i.e., emotions expressed by those sounds were recognized in over 91% (happy sounds had the highest recognition accuracy at 98.25%, fear was the lowest at 87.25%).

Procedure

Data were collected from January 31 to February 20, 2025. Upon arrival at the laboratory, the experimenter presented participants with the general purpose of the study and explained the procedures. Then, participants provided written informed consent for study participation and anonymized data sharing. Next, participants underwent a brief training session to familiarize them with proper chopstick placement in the mouth and the required response procedure.

The experimental procedure consisted of two blocks. In the experimental block (mimicry restriction condition), participants were asked to hold the chopsticks horizontally between their teeth with their mouths closed around them. In the control block, participants were asked to gently hold the chopsticks horizontally between their lips in front of their teeth, keeping the lower face relaxed. This method was modeled on the study by Davis et al.⁵⁹. Each block contained 40 sounds, including five stimuli from each emotion category and sound type, which were randomly assigned to the blocks. The order of the blocks was assigned pseudo-randomly so that half of the participants began with the experimental block and the other half with the control block.

Participants were first asked to identify the emotion conveyed by each sound using a four-alternative forced-choice task. During the sound presentation, a picture appeared on the screen indicating which keyboard key (one of the arrow keys) corresponded to each emotion. The key–emotion mapping remained constant throughout the entire procedure and was counterbalanced across participants. After selecting the emotion by pressing the appropriate key, participants then evaluated each sound on two scales. The first concerned valence (*To what*

extent were the emotions expressed by the sound negative or positive?), and the second concerned arousal (To what extent were the emotions expressed by the sound arousing?). These two scales were always presented in the same order.

Responses concerning valence and arousal were given using a mouse on an unmarked visual analog scale ranging from 0 to 1. Verbal labels were placed at the endpoints: “very negative” and “not at all” on the left, and “very positive” and “extremely” on the right, for the valence and arousal scales, respectively. Each scale was displayed on a separate screen. The sounds were played through headphones, and the volume remained constant throughout the experiment. In total, the task lasted up to 30 min.

Analysis and data processing

Raw data were initially processed in RStudio⁶³ using the *dplyr* package⁶⁴. Prior to analysis, the normality of the distributions were assessed using visual inspection of Q–Q plots of standardized residuals. Accuracy data were logit-transformed due to pronounced deviations from normality; one participant was excluded based on residual diagnostics, with no change in the pattern of results. For the reaction times data, first, we excluded participants whose error and timeout rates exceeded 3 *SD* relative to the sample mean. Second, we excluded trials with incorrect responses. Third, we filtered RT data: RTs < 200 ms were treated as anticipations and not further analysed. Subsequently, we applied a sequential trimming method to exclude outlier RTs. After calculating RTs and *SD*s for each participant separately, we removed RTs outside ± 3 *SD* from the participant mean. Subsequent data inspection revealed that the residuals deviated from normality. While a log transformation can be used to address this issue, we chose not to apply it, as log transformation of reaction times is not always recommended and did not alter the pattern of results in the present data. Minor deviations in valence ratings were driven by a small number of outlying observations, which were excluded without affecting results. No substantial deviations from normality were observed for arousal ratings. Inferential statistics were computed on transformed data where applicable, while descriptive statistics and figures are reported in the original scales.

Using JASP⁶⁵, we conducted repeated measures ANOVA with restriction condition (restriction, control), sound type (vocal, instrumental), and emotion (fear, sad, happy, neutral) as within-subject factors. The Huynh–Feldt correction was applied when the assumption of sphericity was violated, and the Bonferroni correction was used for multiple comparisons.

Next, we conducted the Bayesian analysis to directly quantify the evidence for positive and null effects. To this end, we used the *Bayesian Repeated Measures ANOVA* module of JASP, which is based on the *BayesFactor* R package^{66,67}. Our crucial methodological choices were as follows. Bayesian repeated-measures ANOVA with model averaging was conducted using zero-centered Cauchy priors (i.e., Student-*t* distributions with 1 degree of freedom) on standardized coefficients, following the Jeffreys–Zellner–Siow (JZS) framework. Fixed effects were assigned a scale parameter of 0.5, reflecting an a priori expectation of small effects. Subject-level random effects were assigned a wider prior (scale = 1) to allow substantial individual variability. Since we could not safely assume universal effect sizes for every individual, and in line with Van den Bergh et al.’s⁶⁸ recommendations, we used the maximal set of random effects (MRE) model specification. In line with Rouder et al.⁶⁹, we enforced the principle of marginality for fixed effects. In JASP, we set both the number of steps used to approximate the integral for the Bayes factor and the number of Markov chain Monte Carlo samples used to calculate the posterior to 20 000. We interpreted the resulting Bayes Factor values using categories proposed by Jeffreys⁷⁰, with labels updated by Wetzels et al.⁷¹, i.e., 1–3 as anecdotal evidence, 3–10 as substantial evidence, 10–30 as strong evidence, 30–100 as very strong evidence, and > 100 as decisive evidence.

Results

Accuracy of emotion recognition

Descriptive statistics for accuracy data are reported in Table 1. Figure 1 (panel A) shows the mean accuracy as a function of emotion, restriction condition, and sound type. No effect of the restriction condition was observed for raw accuracy data ($F(1, 65) = 1.48, p = 0.227, \eta^2_p = 0.022$). The mean difference in accuracy between the restriction and control conditions was 0.013 (95% CI [-0.008, 0.034]). After applying a logit transformation to address non-normality of the residuals, the effect of the restriction condition reached significance ($F(1, 65) = 4.09, p = 0.047, \eta^2_p = 0.059$) indicating slightly higher accuracy in the restriction condition. Bayesian analyses provided strong evidence ($BF_{\text{excl}} = 10.93$) and anecdotal evidence ($BF_{\text{excl}} = 2.17$) against an effect of the restriction condition on the untransformed and transformed data, respectively.

The analysis yielded a significant effect of emotion ($F(3, 195) = 35.81, p < 0.001, \eta^2_p = 0.35$) with a decisive Bayesian support, $BF_{\text{incl}} > 100$. Happy sounds were recognized most accurately, and this accuracy was significantly higher than for all other emotions: fear ($t_{65} = 13.35, p < 0.001, d = 1.04$), sadness ($t_{65} = 8.23, p < 0.001, d = 0.64$), and neutral sounds ($t_{65} = 6.34, p < 0.001, d = 0.65$). On the other hand, fear was recognized the least accurately, with significantly lower accuracy than happy, sad ($t_{65} = -4.21, p < 0.001, d = -0.39$), and neutral sounds ($t_{65} = -3.47, p = 0.006, d = -0.39$). Notably, the emotion \times restriction condition interaction was not significant ($F(3, 195) = 0.46, p = 0.708, \eta^2_p = 0.007$), with very strong Bayesian evidence against its inclusion ($BF_{\text{excl}} = 55.66$).

The accuracy differed across sound types both overall, yielding a significant effect of sound type ($F(1, 65) = 200.54, p < 0.001, \eta^2_p = 0.75$), and in interaction with emotion ($F(3, 195) = 9.78, p < 0.001, \eta^2_p = 0.13$), with decisive Bayesian evidence in both cases (both $BF_{\text{incl}} > 100$). Emotional vocalizations were recognized with higher accuracy than instrumental emotional displays (0.92 vs. 0.71). This was the case for the displays of fear ($t_{65} = 8.96, p < 0.001, d = 1.32$), sadness ($t_{65} = 5.65, p < 0.001, d = 0.86$), and neutral sounds ($t_{65} = 7.74, p < 0.001, d = 1.19$). Notably, happy instrumental sounds were recognized as accurately as happy vocalizations, with accuracy over 90% ($t_{65} = 2.56, p = 0.362, d = 0.29$).

Additionally, the following differences were observed among instrumental sounds: the accuracy rate for happy sounds was significantly higher than for all other emotion categories (fear: $t_{65} = 11.26, p < 0.001, d = 1.55$;

	<i>M</i>	<i>SE</i>		<i>M</i>	<i>SE</i>		<i>M</i>	<i>SE</i>		<i>M</i>	<i>SE</i>		<i>M</i>	<i>SE</i>
Accuracy														
Fear	0.74	0.02	Sadness	0.81	0.02	Happiness	0.94	0.01	Neutral	0.78	0.02	Across emotions		
Vocal	0.89	0.01	Vocal	0.90	0.02	Vocal	0.96	0.02	Vocal	0.92	0.02	Vocal	0.92	0.01
Instrumental	0.58	0.03	Instrumental	0.72	0.03	Instrumental	0.91	0.02	Instrumental	0.64	0.04	Instrumental	0.71	0.01
Reaction times														
Fear	2.05 s	0.90	Sadness	2.82 s	0.08	Happiness	2.1 s	0.07	Neutral	2.3 s	0.1	Across emotions		
Vocal	1.77 s	0.08	Vocal	2.59 s	0.1	Vocal	2.05 s	0.1	Vocal	2.07 s	0.01	Vocal	2.12	0.08
Instrumental	2.33 s	0.12	Instrumental	3.05 s	0.08	Instrumental	2.14 s	0.05	Instrumental	2.54 s	0.11	Instrumental	2.52	0.08
Valence														
Fear	0.28	0.01	Sadness	0.29	0.01	Happiness	0.74	0.01	Neutral	0.47	0.01	Across emotions		
Vocal	0.25	0.01	Vocal	0.22	0.01	Vocal	0.74	0.01	Vocal	0.49	0.01	Vocal	0.43	0.005
Instrumental	0.32	0.01	Instrumental	0.37	0.01	Instrumental	0.74	0.01	Instrumental	0.45	0.01	Instrumental	0.47	0.007
Arousal														
Fear	0.66	0.01	Sadness	0.56	0.01	Happiness	0.66	0.01	Neutral	0.42	0.01	Across emotions		
Vocal	0.65	0.01	Vocal	0.58	0.02	Vocal	0.65	0.01	Vocal	0.38	0.02	Vocal	0.57	0.01
Instrumental	0.66	0.01	Instrumental	0.53	0.02	Instrumental	0.68	0.01	Instrumental	0.46	0.02	Instrumental	0.58	0.01

Table 1. Descriptive statistics for reaction times and accuracy of emotion recognition, as well as valence and arousal ratings.

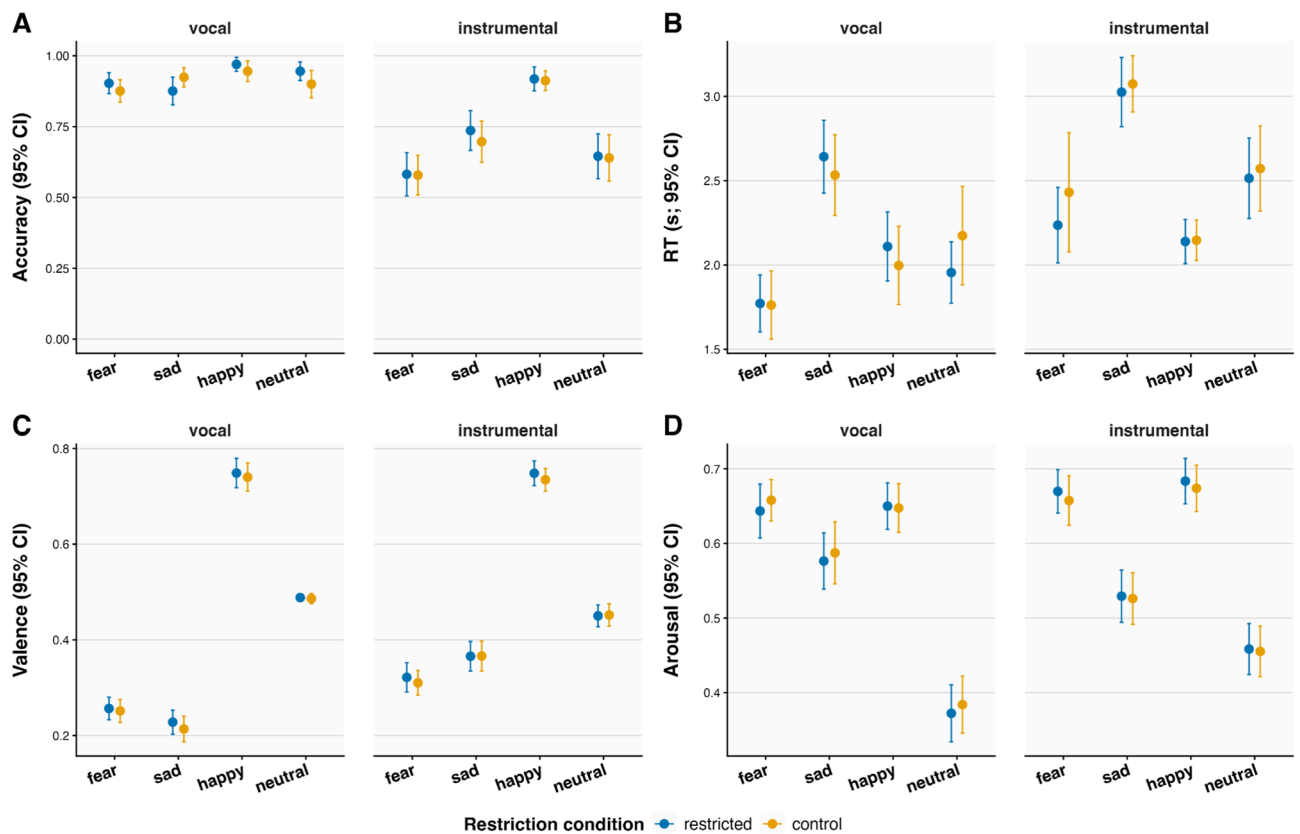


Fig. 1. Mean performance and ratings as a function of emotion, restriction condition, and sound type. Panels show **A** accuracy, **B** reaction times (RTs, in seconds), **C** valence ratings, and **D** arousal ratings. Results are plotted separately for vocal and instrumental sounds. Points represent condition means; error bars indicate 95% confidence intervals.

sad: $t_{65} = 6.40, p < 0.001, d = 0.93$; neutral: $t_{65} = 6.38, p < 0.001, d = 1.09$). Furthermore, fearful instrumental sounds were recognized with lower accuracy than sad instrumental sounds ($t_{65} = 3.71, p = 0.012, d = 0.62$). Among vocal sounds, the accuracy for happy vocalizations was higher than for fearful ($t_{65} = 5.27, p < 0.001, d = 0.52$) and sad vocalizations ($t_{65} = 4.02, p = 0.004, d = 0.36$).

The sound type \times restriction condition interaction ($F(1, 65) = 0.96, p = 0.330, \eta_p^2 = 0.015$), as well as the three-way interaction between emotion, sound type, and restriction condition ($F(3, 195) = 1.75, p = 0.157, \eta_p^2 = 0.026$) were not significant, with substantial ($BF_{\text{excl}} = 6.60$) and anecdotal ($BF_{\text{excl}} = 3.02$) Bayesian evidence against their inclusion, respectively.

Reaction times of emotion recognition

Descriptive statistics for reaction time data are available in Table 1. Since repeated measures ANOVA requires all data cells representing conditions to contain a value, only 45 of the 67 participants were included in the analysis of reaction times. Thus, the outcomes of the sensitivity analysis are provided in the final subsection of the *Results*. Figure 1 (panel B) shows mean RT as a function of emotion, restriction condition, and sound type.

The restriction condition did not significantly affect reaction times ($F(1, 44) = 0.35, p = 0.556, \eta_p^2 = 0.01$). Bayesian analysis yielded substantial evidence against the inclusion of this effect ($BF_{\text{excl}} = 5.36$). The mean difference in RT between the restriction and control conditions was 37 ms (95% CI [-163, 89]). The analysis yielded a significant effect of emotion ($F(3, 132) = 59.41, p < 0.001, \eta_p^2 = 0.58$), with decisive Bayesian evidence ($BF_{\text{incl}} > 100$). Apart from the non-significant difference between reaction times to fear and happy sounds ($p = 0.416$), all other differences were significant. The reaction times were longest for sad sounds, and significantly differed from those to fear ($t_{44} = 11.08, p < 0.001, d = 1.04$), happy ($t_{44} = 13.15, p < 0.001, d = 0.98$), and neutral sounds ($t_{44} = 6.68, p < 0.001, d = 0.7$). Reaction times to neutral sounds were longer than those to happy ($t_{44} = -3.27, p = 0.004, d = 0.28$) and fear displays ($t_{44} = 4.08, p < 0.001, d = 0.34$).

There was a significant effect of sound type ($F(1, 44) = 112.76, p < 0.001, \eta_p^2 = 0.72$) with longer reaction times to instrumental than to vocal sounds. Bayesian analysis yielded decisive evidence for the effect of sound type ($BF_{\text{incl}} > 100$). Moreover, the interaction of emotion and sound type was significant ($F(3, 132) = 5.15, p = 0.004, \eta_p^2 = 0.11$) with very strong Bayesian support ($BF_{\text{incl}} = 33.42$). Reaction times to happy sounds did not differ between sound types ($p = 0.981$). In the case of other emotions, reaction times to vocalizations were shorter than to instrumental sounds (fear: $t_{44} = -5.6, p < 0.001, d = -0.77$; sad: $t_{44} = -5.17, p < 0.001, d = -0.63$; neutral: $t_{44} = -5.44, p < 0.001, d = -0.65$).

Importantly, the interactions involving the restriction condition, namely, restriction condition \times emotion ($F(3, 132) = 1.78, p = 0.155, \eta_p^2 = 0.039; BF_{\text{excl}} = 6.28$), restriction condition \times sound type ($F(1, 44) = 1.48, p = 0.230, \eta_p^2 = 0.033; BF_{\text{excl}} = 4.04$), and restriction condition \times emotion \times sound type ($F(3, 132) = 1.56, p = 0.207, \eta_p^2 = 0.034; BF_{\text{excl}} = 3.14$) were non-significant with substantial Bayesian evidence against their inclusion.

Valence

Descriptive statistics for valence ratings data are available in Table 1. Figure 1 (panel C) shows mean valence ratings as a function of emotion, restriction condition, and sound type. Importantly, we did not find a significant influence of the restriction condition on valence ratings ($F(1, 61) = 1.52, p = 0.222, \eta_p^2 = 0.024$). The mean difference in valence ratings between the restriction and control conditions was 0.007 (95% CI [-0.004, 0.017]). Bayesian analysis yielded substantial evidence against the inclusion of the effect of the restriction condition ($BF_{\text{excl}} = 4.14$). The analysis of valence ratings yielded a significant effect of emotion ($F(3, 183) = 562.75, p < 0.001, \eta_p^2 = 0.902$), with decisive Bayesian support ($BF_{\text{incl}} > 100$), showing a predictable pattern: happy sounds were rated as the most positive, fear and sad sounds as the most negative, with neutral sounds falling in between. Post-hoc tests showed that the valence ratings of happy sounds significantly differed from the ratings of the auditory displays of fear ($t_{61} = 27.94, p < 0.001, d = 4.59$), sadness ($t_{61} = 26.23, p < 0.001, d = 4.51$), and neutral sounds ($t_{61} = 21.77, p < 0.001, d = 2.74$). Additionally, neutral sounds were rated significantly higher than sadness ($t_{61} = 20.55, p < 0.001, d = 1.76$) and fear expressions ($t_{61} = 18.45, p < 0.001, d = 1.85$). The expressions of sadness and fear were rated as equally negative ($p = 0.368$).

Valence ratings were also significantly influenced by the sound type, with instrumental sounds rated as slightly more positive than human vocalizations ($F(1, 61) = 33.15, p < 0.001, \eta_p^2 = 0.35$). In the same vein, Bayesian analysis yielded decisive evidence for the effect of sound type ($BF_{\text{incl}} > 100$). Also, the emotion \times sound type interaction was significant ($F(3, 183) = 45.47, p < 0.001, \eta_p^2 = 0.43$) and decisively supported by Bayesian evidence ($BF_{\text{incl}} > 100$). Post-hoc tests showed that the two types of sounds differed significantly in the case of fear, sadness, and neutral displays (fear: $t_{61} = 4.9, p < 0.001, d = 0.62$; sadness: $t_{61} = 9.94, p < 0.001, d = 1.46$; neutral: $t_{61} = 0.04, p = 0.004, d = 0.36$). Happy vocal and instrumental expressions were rated as equally positive ($p = 0.811$).

We did not find significant interactions between the restriction condition and emotion ($F(3, 183) = 0.23, p = 0.874, \eta_p^2 = 0.04$), the restriction condition and sound type ($F(1, 61) = 0.06, p = 0.806, \eta_p^2 < 0.001$), and the three-way interaction among restriction condition, sound type, and emotion ($F(3, 183) = 0.55, p = 0.646, \eta_p^2 = 0.009$). Bayesian analyses yielded, respectively, strong ($BF_{\text{excl}} = 24.48$) and substantial ($BF_{\text{excl}} = 7.87$) evidence against the two-way interactions, and strong evidence ($BF_{\text{excl}} = 21.11$) against the three-way interaction.

Arousal

Descriptive statistics for arousal ratings data are available in Table 1. Figure 1 (panel D) shows mean arousal ratings as a function of emotion, restriction condition, and sound type. The restriction condition did not significantly affect the arousal ratings ($F(1, 66) = 0.01, p = 0.917, \eta_p^2 < 0.01$). The mean difference between the restriction and control conditions was 7.42×10^{-4} (95% CI [-0.014, 0.016]). The frequentist result is supported by strong Bayesian evidence against the effect of the restriction condition ($BF_{\text{excl}} = 14.32$). As in the case of emotion-recognition accuracy, reaction times, and valence ratings, arousal ratings also differed significantly depending on the emotion conveyed by the sound ($F(3, 198) = 122.98, p < 0.001, \eta_p^2 = 0.65$), with decisive Bayesian support ($BF_{\text{incl}} > 100$). Fear and happy sounds were rated as the most arousing and did not significantly differ from one another ($t_{66} = -0.49, p = 1.000, d = -0.05$). Neutral sounds were rated as the least arousing, and their ratings significantly differed from those of fear ($t_{66} = -14.72, p < 0.001, d = -1.71$), happiness ($t_{66} = -17.72,$

$p < 0.001$, $d = -1.76$), and sadness displays ($t_{66} = -8.47$, $p < 0.001$, $d = -0.98$). Sad sounds were rated as moderately arousing and significantly differed from each of the other emotion categories (fear: $t_{66} = -8.19$, $p < 0.001$, $d = -0.73$; happiness: $t_{66} = -7.07$, $p < 0.001$, $d = -0.78$; neutral: $t_{66} = 8.47$, $p < 0.001$, $d = 0.98$).

No significant difference was observed in arousal ratings between vocal and instrumental sounds ($F(1, 66) = 2.33$, $p = 0.132$, $\eta_p^2 = 0.034$), with anecdotal Bayesian evidence against the effect of sound type ($BF_{\text{excl}} = 2.08$). A significant interaction between emotion and sound type ($F(3, 198) = 14.92$, $p < 0.001$, $\eta_p^2 = 0.18$), with a decisive Bayesian support ($BF_{\text{incl}} > 100$), indicated that the two sound types differed only in the case of neutral sounds, with instrumental neutral sounds being rated as more arousing than neutral vocalizations ($t_{66} = 4.712$, $p < 0.001$, $d = 0.56$).

Also, none of the interactions involving the restriction condition factor were significant with substantial to very strong Bayesian evidence against their inclusion: restriction \times emotion ($F(3, 198) = 0.19$, $p = 0.863$, $\eta_p^2 < 0.01$; $BF_{\text{excl}} = 58.85$), restriction \times sound type ($F(1, 66) = 3.27$, $p = 0.075$, $\eta_p^2 = 0.05$; $BF_{\text{excl}} = 3.00$), restriction \times emotion \times sound type ($F(3, 198) = 0.19$, $p = 0.902$, $\eta_p^2 < 0.01$; $BF_{\text{excl}} = 54.34$).

Sensitivity analysis

An alternative approach to power analysis, rather than attempting to estimate power for an inherently complex three-way interaction model that is relevant to one of our hypotheses, was to assess power for our most theoretically relevant comparisons. Taking into account that the repeated-measures ANOVA of accuracy included 66 participants, while the reaction time analysis included only 45 participants (due to empty cells), we conducted separate sensitivity analyses. Specifically, in both cases, we tested whether (i) there was a main effect of the restriction condition, which can be assessed using a paired t -test; (ii) the interaction between sound type and restriction condition could be examined in terms of a difference between restriction conditions for human vocalizations, but not for instrumental sounds. Accordingly, this effect of interest can be expressed as a simple effect, assessed using a paired t -test, of the restriction condition for human vocalizations; (iii) for human vocalizations expressing happy emotion, we expected a difference between the two restriction conditions. Again, this comparison can be assessed using a paired t -test.

These three tests were treated as multiple comparisons; therefore, a Bonferroni correction was applied, and α was set to 0.016. Desired power was set to 0.80. For a sample size of 66 participants (accuracy), the study was powered to detect effect sizes of $d \geq 0.37$, and for a sample size of 45 participants (reaction times), effect sizes of $d \geq 0.46$.

Discussion

We examined whether restricting mimicry influences the processing of emotions conveyed by human affect vocalizations and brief emotional instrumental sounds. Our focus was on the accuracy and speed of categorical emotion recognition, as well as the evaluation of the sounds in terms of their valence and arousal. Our hypotheses were as follows: (1) Restricting lower facial muscle movements will impair emotion recognition, i.e., the accuracy of emotion recognition will be lower and reaction times will be longer compared to the control condition, in which muscle movements are not restricted; (2) The restriction effect will be present especially for happy human vocalizations; (3) Restricting lower facial muscle movements will introduce a valence positivity bias irrespective of emotion category.

First, we found no evidence that mimicry restriction impairs emotion recognition, either by reducing accuracy or slowing response times. Null effects were observed both overall and across emotion categories and sound types. Although a significant main effect of the restriction condition, indicating higher accuracy under facial movement restriction, emerged in the transformed data, this effect was not observed in analyses of the raw data. Moreover, Bayesian analyses provided support for the null effect of the restriction condition, with anecdotal evidence for the transformed data and strong evidence for the raw data. Therefore, the frequentist result contrary to our expectations should be interpreted with caution. Second, the restriction condition did not affect the evaluation of emotional sounds in terms of valence and arousal, regardless of the emotion displayed or the sound type.

Accuracy and reaction times of emotion recognition, as well as valence and arousal ratings differed across emotion categories. Happy sounds were recognized most accurately, and reaction times were shortest. In this case, the results did not differ depending on whether the emotion was conveyed by human vocalizations or music. This is important to establish because we hypothesized that the manipulation of lower facial muscle movements has a stronger influence on the recognition of happy vocalizations than instrumental sounds. Differences between the two types of sounds could obscure potential discrepancies in the effects of mimicry restriction across sound types. Conversely, negative and neutral vocalizations were recognized more accurately than instrumental portrayals of those emotions.

In the study, we used stimuli from the MAV and MEB sound sets^{56,58}. Our results resembled those obtained in the validation of those sets, though we observed some discrepancies. In both studies, happy sounds were recognized most accurately, and there were no differences between sound types in this regard. The main difference between our study and the validation studies lies in the accuracy of emotion recognition for negative and neutral sounds. Whereas in Paquette et al.⁵⁸ the accuracy exceeded 80% for each emotion category, in our study recognition rates for instrumental sounds were considerably lower: 58% for fear, 71% for sadness, and 64% for neutral sounds.

We found no detrimental effects of the pen-in-mouth manipulation on emotion recognition accuracy or reaction times for either type of emotional auditory stimulus. This contrasts with most published studies on face recognition, which have shown that restricting spontaneous facial activity disrupts the recognition of facial expressions of emotion^{18,19,36,37,39}, as well as with a study on the recognition of whole-body expressions suggesting that the detrimental effect of facial restriction may extend beyond face processing²³. Furthermore,

two studies examining the impact of restricting mimicry on the processing of emotional vocalizations reported some effects of the pen-in-mouth procedure^{41,47}, however, neither specifically addressed emotion categorization. Hawk et al.⁴¹ conducted a study on emotional vocalizations in which participants were asked to detect the shift between two emotional expressions—laughter and crying. Facial manipulation appeared to affect the speed of shift detection. Specifically, shift detection was faster in the mimicry-restriction condition. Hawk et al. (2012) interpreted this finding as evidence that mimicry enhances attentional engagement with the initial expression, thereby making the detection of a subsequent shift to a different emotion more difficult, as compared to when mimicry is restricted. Given the dynamic nature of the task used in Hawk et al.⁴¹, it is difficult to directly compare these findings with studies in which participants are asked to recognize a single emotional expression. One might hypothesize that unrestricted mimicry could enhance attention and thereby improve emotion recognition in terms of speed or accuracy. However, neither the results of Wołoszyn et al.²⁴ nor those of the present study provide evidence for this interpretation. In the study by Vilaverde et al.⁴⁷, participants were asked to judge whether a presented vocalization was authentic or posed, and restricting facial movements impaired these judgments. Notably, the findings of both studies appeared to be emotion-nonspecific: Vilaverde et al.⁴⁷ reported that restricting lower facial muscle movements impaired authenticity judgments for both laughs and cries, whereas Hawk et al.⁴¹ found facilitated detection of expression shifts regardless of their direction (cries–laughs).

Studies on the relationship between mimicry and emotion recognition are not entirely consistent. A meta-analysis concerning mimicry, empathy, and emotion recognition did not provide evidence for a link between mimicry and emotion recognition⁷². Similarly, the study by Blairy et al.²¹ found no correlation between mimicry and emotion recognition. In that experiment, participants evaluated the extent to which facial expressions conveyed each of seven basic emotions on continuous scales, analogously to our previous study²⁴, in which we did not find the impact of mimicry on emotion recognition. Another study⁷³ on this topic examined responses to non-prototypical, ambiguous expressions using the same continuous scales, again finding no relationship between mimicry and emotion recognition.

Furthermore, two studies did not find the effect of mimicry manipulation on facial emotion recognition. In the second experiment described in Blairy et al.²¹, one group of participants was instructed to mimic the presented facial expression, while another group was asked to mimic the expression shown immediately prior to each trial, which was incompatible with the target expression. The authors did not find differences between the groups in terms of facial emotion recognition. In another experiment, the authors used the pen-in-mouth procedure to manipulate facial movements²². Participants were asked to assess the extent to which static or dynamic emotion displays expressed three types of smiles: reward, affiliation, and dominance. Again, the study did not find the influence of mimicry restriction on emotion recognition.

On the one hand, it is noteworthy that in studies that did not find a significant effect of facial movement manipulation, participants rated emotional stimuli on continuous scales—as in the study by Wołoszyn et al.²⁴, which also did not observe an effect of facial movement restriction on emotion recognition accuracy. However, the results of the present study using a forced-choice categorical recognition task suggest that the lack of an effect is not solely due to task-driven processing of emotional expressions.

Our results does not appear to stem from the absence of mimicry in response to emotional auditory expressions, as such mimicry has been demonstrated in Hawk et al.⁴¹, Lima et al.⁴², and Wołoszyn et al.⁴³, where human affective vocalizations elicited congruent facial responses. Moreover, our manipulation of facial mimicry, where participants were asked to hold chopsticks horizontally between their teeth, is frequently used in studies on the processing of emotional faces⁵⁹ and emotional language¹⁵.

Taken together, these findings raise questions about the contexts in which restricting emotional mimicry influences the processing of emotional expressions, as well as about the nature of this influence. Considering the emotion-nonspecific effects reported in research on human auditory expressions, one possible explanation is the lack of specificity in lower facial muscle engagement during vocal production: all vocalizations involve activation of these muscles. This absence of clear distinctiveness of the muscles involved in vocalization may help explain why facial movements might not be causally involved in the processing of auditory expressions. Because lower facial muscles are broadly engaged across vocalizations, information about oro-facial configuration may provide little discriminative value for auditory emotion processing. It is also possible that mimicry serves a supportive role in enhancing the accuracy and speed of recognition for human vocalizations that are more ambiguous and characterized by lower recognition rates, while playing a minimal role in simpler tasks, such as the one we used. This possibility calls for further investigation. As such, authenticity judgments⁴⁷ and shift detection⁴¹ may involve situations with higher levels of ambiguity. Finally, the associative links between hearing emotional sounds and facial movement might be created very early in development, even earlier than the links between seeing the face and facial movement¹¹. Consequently, it is possible that these links have a more low-level, associative nature, thus making facial mimicry less relevant for auditory emotion processing.

Due to the limited evidence, future research employing diverse methods of mimicry manipulation (e.g., pen-in-mouth, Botox, voluntary expression manipulation; direct somato-motor intervention) and varied measures of emotion recognition (e.g., categorical, continuous) would make a valuable contribution to our understanding of the conditions under which restricting facial movements impacts emotion recognition—and in which direction.

Regarding valence ratings, Wołoszyn et al.²⁴ observed that restricting lower facial muscle movements using the pen-in-mouth procedure led to more positive evaluations of sounds, in a category-nonspecific manner. This finding is consistent with the effect observed in Hyniewska and Sato's²⁰ study, in which participants were instructed to either raise their cheeks or lower their brows before rating facial expressions on valence and arousal scales. The study found that contracting the *zygomaticus major* by raising the cheeks was associated with higher valence ratings for both happy and angry expressions, with no effect observed on arousal. Hyniewska and Sato²⁰ interpreted this effect as evidence of a facial feedback effect. We might analogously explain the positive bias

observed in our previous study, as the pen-in-mouth procedure results in the contraction of the muscles of the lower face, particularly the *zygomaticus major*.

In the current study, we expected that, as in the study by Wołoszyn et al.²⁴, restricting mimicry would induce a positive bias in the valence evaluation of auditory emotional expressions. However, we did not find any influence of restricting mimicry on valence ratings, regardless of whether emotional vocalizations or instrumental sounds were evaluated. Substantial doubts about the facial feedback hypothesis emerged following a multi-lab replication by Wagenmakers et al.⁵¹, which found no effect of the pen-in-mouth manipulation on cartoon ratings. A meta-analysis by Coles et al.⁴⁹ showed that the effect of cheek muscle activation on subjective emotional experience is small and variable and provided no evidence for effects on affective judgments, which is more closely aligned with the present task. Moreover, a subsequent multi-lab replication by Coles et al.⁵⁰ demonstrated that although facial feedback effects on emotional experience exist, the pen-in-mouth manipulation is not an effective method for inducing them.

However, a definitive conclusion that the valence positivity bias observed by Wołoszyn et al.²⁴ was merely a false positive seems premature. The current study repeated several methodological choices from Wołoszyn et al.²⁴, namely, examining three of the five emotion categories used previously, including neutral sounds, and employing the same valence rating procedure. On the other hand, it is possible that in the current study the need to categorize emotions conveyed by various types of emotional auditory stimuli in a forced-choice format, and evaluating arousal on visual analog scales within a single task, influences the processing strategy and reduces reliance on facial signals in valence ratings. Thus, we speculate that facial feedback is not a universal, context-independent phenomenon and that its detection may depend on subtle aspects of the testing procedure.

The trajectory of the facial feedback hypothesis highlights the critical importance of both large-scale direct and conceptual replications⁷⁴. Null effects in terms of both the influence of facial manipulations on affective judgments and the effect of the pen-in-mouth manipulation on emotional experience do not necessarily imply that manipulating facial mimicry using this method would not affect emotion recognition, since there is a number of studies showing such an effect^{18,19,23}. Nevertheless, to date, no large-scale study has been conducted as a direct replication of any of these investigations. The replication crisis in psychology^{74,75}, in particular in embodied cognition research²⁶, highlights the need for such efforts. This is especially important given the criticisms of theoretical commitments of the embodied cognition framework^{27,28}. As such, it can also address a more general theoretical crisis in psychology^{76–78}.

As already noted, the current evidence base is limited for drawing firm conclusions about the effects of restricting mimicry through facial manipulations on the perception of non-facial expressions. To date, only a few studies—including the present one—have addressed this issue^{23,24,41,47}, and their methodologies vary while their findings remain inconsistent. The most effective way to determine the conditions and methodological choices under which mimicry plays a causal role in the recognition of emotional expressions would be to conduct multi-laboratory studies incorporating various types of emotional expressions (facial, bodily, and auditory) and diverse methods of facial muscle manipulation (e.g., voluntary facial movements, the pen-in-mouth procedure, Botox injections), including a novel method of selective muscle manipulation—facial neuromuscular electrical stimulation⁷⁹.

Establishing the scope of the influence of facial mimicry on emotion processing across modalities is particularly important not only for theoretical reasons, but also because there is a growing number of psychotherapeutic approaches grounded in the assumption of mind–body coupling that draw upon the embodied cognition framework. These approaches include, for example, Sensorimotor Psychotherapy⁵², Somatic Experiencing⁵³, and Integral Somatic Psychology⁵⁴. Nonverbal social signalling through facial expressions, gestures, and body postures and the mimicry process, is one of the main foci of Radically Open Dialectical Behavior Therapy⁵⁵, which is designed for individuals characterized by excessive self-control, emotional inhibition, perfectionism, and social withdrawal. These practical implications render thorough research on mimicry in particular and embodied processes more broadly especially important, particularly in light of concerns regarding the robustness of some findings within this field²⁶, to list only the Macbeth effect^{80,81} or the action-sentence compatibility effect^{82,83}.

The following limitations of the present study should be acknowledged. First, although the sample size was sufficient to detect the predicted two-way interactions relevant to Hypothesis 1 (i.e., effects of facial mimicry blocking on emotion recognition accuracy and reaction times), as well as the effects of facial mimicry blocking on valence ratings (Hypothesis 3), due to the presence of many empty cells the study may have been underpowered to detect more fine-grained three-way interactions in reaction times (Hypothesis 2). Nevertheless, the sample size was sufficient to detect small-to-moderate emotion-specific influences of facial mimicry blocking on recognition accuracy for particular emotional categories (e.g., happy human vocalizations; Hypothesis 2).

Second, the study used prototypical, posed vocal expressions, which were generally easy to recognize—especially happy expressions, for which accuracy exceeded 90%. Some studies showing the effects of mimicry blocking deliberately used stimuli with a weaker signal (around 65% for happy expressions)¹⁹. This allows for a potential greater contribution of bodily processes to a harder recognition task. The use of posed stimuli may also have limited our ability to discover effects of mimicry manipulation. In fact, prior work suggests that facial muscle engagement tends to be stronger in response to authentic than posed expressions; this applies to facial reactions to facial expressions^{84–86} as well as facial reactions to vocal expressions⁴². The strength of mimicry may potentially increase its relevance in such contexts.

Conclusions

In this preregistered study, we found no evidence that restricting lower facial movements via the pen-in-mouth manipulation impairs the recognition or affects the evaluation of emotional auditory stimuli, whether conveyed through human affect vocalizations or instrumental sounds. Our results suggest that, even though affective

vocalizations can elicit congruent facial activity, this mimicry may not play a causal role in recognizing or evaluating such stimuli—or, at the very least, that its role is limited and highly context-dependent. This contrasts with the robust effects observed in most studies using facial emotional expressions and adds to a growing body of mixed findings regarding the functional relevance of mimicry and facial feedback.

The inconsistency of existing findings, their limitations as well as their practical value underscore the need for rigorous, multi-laboratory replications that test the effects of facial manipulation across sensory modalities, emotional categories, and mimicry techniques—including the pen-in-mouth procedure. Such efforts are not only critical for theoretical debates surrounding embodied cognition, but also for psychotherapeutic approaches that draw on embodiment-based models. Clarifying when and how facial activity influences emotional perception will be crucial for evaluating the psychological and clinical relevance of embodied processes.

Data availability

Data and analyses for this study are publicly available from the Open Science Framework (<https://doi.org/10.17605/OSF.IO/FXN9S>).

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Author contributions

All authors conceptualized and designed the study; K.W. and P.W. developed the methodology; K.W. collected the data; K.W. and M.H. analyzed the data; All authors substantially contributed to the interpretation of data; K.W. and M.H. wrote the manuscript. All authors reviewed and accepted the manuscript. M.H. acquired the funding for the study.

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Declarations

Competing interests

The authors declare no competing interests.

Additional information

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