



HAL
open science

Facial reactions to face representations in art: An electromyography study

Amel Achour-Benallegue, David Amarantini, Pierre-Vincent Paubel, Jérôme Pelletier, Gwenaël Kaminski

► **To cite this version:**

Amel Achour-Benallegue, David Amarantini, Pierre-Vincent Paubel, Jérôme Pelletier, Gwenaël Kaminski. Facial reactions to face representations in art: An electromyography study. *Psychology of Aesthetics, Creativity, and the Arts*, 2023, 17 (6), pp.793-805. 10.1037/aca0000423 . hal-03882090

HAL Id: hal-03882090

<https://hal.science/hal-03882090>

Submitted on 3 Feb 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Achour-Benallegue, A., Amarantini, D., Paubel, P.-V., Pelletier, J., & Kaminski, G. (2021). Facial reactions to face representations in art: An electromyography study. *Psychology of Aesthetics, Creativity, and the Arts*.

Facial Reactions to Face Representations in Art: An Electromyography Study

Amel Achour-Benallegue¹, David Amarantini², Pierre-Vincent Paubel³, Jérôme Pelletier¹,
and Gwenaël Kaminski^{3, 4}

¹ Institut Jean Nicod, Department of Cognitive Studies, French National Center for Scientific Research - École Normale Supérieure -

School for Advanced Studies in the Social Sciences, Paris Sciences et Lettres University
² Toulouse NeuroImaging Center, Inserm, Paul Sabatier University, Toulouse University

³ Cognition, Language, Ergonomy, Jean-Jaurés University, Toulouse University

⁴ Academic Institute of France, Paris, France

Abstract

Facial mimicry is a reaction to facial expressions. It plays a role in social interaction. Indeed, scholars associated facial mimicry with emotional contagion and understanding others' mental states such as intentions. This is the case for facial mimicry toward human facial expressions, but we know that facial expressions are widely depicted in art through face representations (visual creations that depict facial expressions). However, despite face representation involvement in social interactions, facial reactions toward face representations in art are still unknown. The reason could be that interaction with art objects is usually analyzed within anthropology and art theories, such as conveying social agencies (a desire of action, intentions). Here, we show that facial mimicry is also observed toward face representations. This could be a means that might facilitate social interaction including emotions. Using the electromyography technique, we could show that participants mimic involuntarily face representations when these depict mouth expressions. Participant's *zygomaticus* and *depressor* were significantly activated when the pictures depict an expression including *zygomaticus* or *depressor* representation respectively. This result led us to infer that when it comes to mouth expressions, face representations in art might trigger spontaneously emotional contagion (of the expressed emotion). It might also convey information about the expressed mental states, which might help to indicate social agencies. Mimicry could participate to explain partly the social agencies of art, that might be no more just abstract concepts, but could find a real correlate in cognitive processes.

Keywords: Facial mimicry, Faces in art, Face-like, Electromyography, Emotional contagion, Art agency.

Facial expressions are configurations of facial features through the motion of facial muscles. Facial expressions are relevant configurations for nonverbal communication and displaying emotion (Awasthi & Mandal, 2015; Reisenzein et al., 2013). They could induce a motor reaction in the observer's face, known as facial mimicry. Facial mimicry is a tendency to imitate the facial expressions of other people (Hess & Fischer, 2014). Previous research describes the process of facial mimicry as similar muscle patterns in both observer's face and observed facial expression. These muscle patterns could be measured by using the electromyography (EMG) technique, where muscle activity is recorded through facial electrodes. Facial mimicry occurs automatically and unconsciously (Bailey & Henry, 2009; Dimberg et al., 2000; Korb et al., 2010), but could also be modulated by social contexts, such as empathy, cooperation, and competition, or social membership (Hess & Fischer, 2014; Seibt et al., 2015). For example, mimicry of smiles and sad expressions are more observed among members of the same group compared with members of different groups, which is interpreted as affiliative signs (Seibt et al., 2015).

The matching pattern with an observed expression is part of the embodied emotion processes (Barrett & Lindquist, 2008; Niedenthal, 2007). In embodied emotion processes, perceiving an emotional stimulus and experiencing an emotion involve overlapping mental processes (Gallese, 2019; Niedenthal et al., 2013; Niedenthal & Maringer, 2009). This means that the matching pattern indicates also the presence of the emotion process, which can be noticed in the following two ways: first, muscle patterns in observers are congruent with the emotions displayed in stimuli (Dimberg et al., 2011; Künecke et al., 2014). Studies showed, for example, that expressions of happiness and anger enhance, in observers, the activity of the muscles responsible for happiness and anger expressions respectively (Rymarczyk et al., 2011). We know that specific muscles are more implicated in emotional expressions, such as *zygomaticus* for happiness, *corrugator* for anger, *frontalis* for fear or surprise, and *depressor anguli oris* for sadness (Soussignan et al., 2013). Second, observers do experience emotions that are similar to those displayed by the observed facial expressions (Niedenthal, 2007; Niedenthal & Brauer,

2012; Winkielman et al., 2015). Experiencing an observed emotion means that this emotion happens mentally and physiologically in the observer. This is known as "*emotional contagion*", which is feeling in oneself the mimicked emotion (Dimberg & Thunberg, 2012; Sato et al., 2013; Hess & Fischer, 2014). Indeed, experiments had shown that facial mimicry is accompanied by a self-report of the corresponding emotion (McIntosh, 2006). Furthermore, when mimicry is prevented, emotional experience and emotional information processing might be disturbed (Niedenthal et al., 2017). Experiments had shown that when preventing mimicry of *corrugator* muscle (that expresses sad and hopeless feelings), depression may be lifted (Finzi & Rosenthal, 2014; Wollmer et al., 2012).

The above studies (McIntosh, 2006; Finzi & Rosenthal, 2014; Wollmer et al., 2012) showed that facial mimicry might help (or at least be associated with) emotional contagion between individuals when interacting. Consequently, the facial mimicry process is not a mere motor reaction, but also contributes to emotional interactions (Beall et al., 2008; Hess & Fischer, 2013; Prochazkova & Kret, 2017). Moreover, the mimicry process could be associated with understanding others' mental states (Schilbach, 2016; Niedenthal et al., 2010). Indeed, among the neural correlates of facial mimicry, some studies observed the activation of the mentalizing network (Schilbach, 2016; Baetens et al., 2014). This network (also called the theory of mind network) is involved in the inference of mental states such as intentions (Blakemore & Decety, 2001; Gendron et al., 2014). At this point, facial mimicry could be associated with the metaphorical "*direct' access to other people's minds*" claimed by Schilbach (2016, p. 85). Emotions, as well as intentions, might be important clues in social interaction. In social interaction, expressing emotions is convenient to communicate to others clues about our own mental state and to orientate their interactions with us (Damasio, 1994). As put by Schilbach (2016), visible behavioral responses that are produced by facial mimicry help to sustain the process of interaction.

Studies on facial mimicry focus on facial expressions of human faces (known as "actual faces"). However, we know that facial expressions are largely depicted in art. In this article, we call these facial expressions which are depicted in art: *face representations*. Face representations are the category of

crafted objects such as drawings, paintings, sculptures, and other visual creations that depict facial expressions. Face representations include faces of different realism degrees due to the variety of styles, cultures, and periods. Realistic face representations involve pictures that resemble actual human faces such as classical portraits. Non-realistic ones are images that differ from actual human faces such as ethnographic masks or modern portraits. Some questions arise then: what are facial reactions to face representations? Do they fall into facial mimicry as reactions to actual facial expressions? This issue draws further attention since art has always represented faces with various expressions, all over the world and throughout history. For instance, those represented faces could be noticed in masks, portraits, animation, comics, and even in robots (Achour-Benallegue et al., 2016).

We notice that interacting with face representations has often played an important role in social interaction. These could be observed in idol worship, ritual ceremonies, aesthetic experience of classical portraits, and human-robot interaction (Tateyama, 2016; Guédron, 2011; Chen et al., 2018). As with any art object, an interaction with face representations or its aesthetic understanding is a complex relationship that involves social norms and cultural background, but also calls on the cognitive processes of the observers. For example, interpreting some will or intention (Gell, 1998) or experiencing an emotion (Schaeffer, 2015) at the view of a face representation could reflect those cognitive processes. We assume that facial reactions to face representations could also play a role in those interactions relying on embodied emotion processes. From the aesthetic experience point of view, Gallese (2019) and Freedberg (2009) insisted on the role of body engagement in the interaction with artistic images. Freedberg (2009) reported that, beyond context, aesthetic understanding of objects requires a sense of *“the neural substrate of human engagement with movement and embodiment, and the innate potential for recognition of the emotions that may ensue from them”* (Freedberg, 2009, p.6).

Observer's cognitive processes and their facial reactions, in art interaction context, have already been investigated (Gerger et al., 2011, 2014; Leder et al., 2014; Gernot et al., 2018). However, beholder's cognitive processes and their facial reactions when interacting with face representations in art has not

been the interest of research yet. Having a further understanding of the reaction towards face representations helps understanding, at some point, the social interaction with face representations and contributes to shedding light on a new facet of art and social analysis.

The review of literature about the facial process as a reaction to facial expressions leads us to expect that facial mimicry could be a potential process in reaction to face representations. Studies on face perception of some face representations offer support to this postulate. Indeed, some studies showed that face representations are recognized as face categories even if they depict only schematic faces, emoticons, or items with mere hints of a face (Hadjikhani et al., 2009; Wheatley et al., 2011; Liu et al., 2016; Churches et al., 2014). This is attested by the fact that an increase in brain wave associated with face perception was observed in EEG studies (Eimer, 2011; Sagiv & Bentin, 2001). If facial mimicry takes place when people observe face representations in art like facial mimicry of actual faces, then we may assume that perceiving facial representations might also rely on emotional contagion and probably understanding others' mental state processes. Facial mimicry is one of the many ways in which viewers precognitively grasp emotions that are shown or suggested in works of art (Freedberg & Gallese, 2007), and might be the most significant one to grasp emotions in face representations. As put by Freedberg (2009), part of the force of masks belonging to faraway cultures resides in our bodily responses, even if we may not be able to pinpoint the exact emotions involved.

Some anthropological theory has already put forward the hypothesis that beholders attribute a social agency to artistic objects (Gell, 1998). The social agency is the capacity of action of an agent in its environment. It could be the capacity of causing events by acts of will or intention. This anthropological hypothesis (Gell, 1998) claims that beholders infer mind qualities (will, intention) in the art objects. The focus of this theory extends beyond face representations, but we can suggest that toward art objects representing faces, mimicry could stand among the cognitive causes of art agency. This would give cognitive support to art agency theory. In the present study, we will investigate whether the mimicry process underlies facial reactions to face representations.

In the present work, we propose to examine facial mimicry of realistic and nonrealistic face representations. We hypothesize that mimicry would be observed in face reactions to face representations. To test this hypothesis, we performed electromyography (EMG) experiment that tests mimicry to static facial expressions in face representations. In this experiment, we focused EMG measures on the muscles of facial regions that are more strongly activated in the emotions depicted by stimuli. Here, the emotions are not identified, as such, but only the expression of the muscles related to them. The study focuses more on mimicry according to the muscular pattern than to specific emotions. *Zygomaticus major*, *corrugator supercilii*, *lateral frontalis*, and *depressor anguli oris* are the four recorded muscle-regions. Our hypothesis states that mimicry occurs in reaction to face representations whatever the stimuli are realistic or nonrealistic. We expect that observers might produce a facial reaction pattern that is similar to the pattern of facial expressions depicted in the observed face representations. In other words, we expect that EMG activity would be stronger when stimuli depict high muscle activity than when they depict low muscle activity. This expresses a similar muscle pattern between the observer and the stimulus. Following the analysis of the previous hypothesis, we also suggest more exploratory analyses to investigate realism degree and emotional dimension effect on mimicry and emotional contagion.

Materials and methods

Participants

Participants were 30 women and 17 men, belonging to western culture, between the ages of 18 and 62 ($M = 29.6$, $SD = 9.5$). All participants had normal or corrected to normal visual acuity. Twelve participants, among 47, were eliminated because of technical or continuous behavioral artifacts (e.g., sleeping or tic movements). Most of these discarded participants showed sleepiness and were not watching the screen. All participants have received explicit information about the experiment design and gave signed informed consent according to the Declaration of Helsinki. They also were paid at the

end of the experiment. The study protocol followed the local ethic guidelines from Jean Jaurès University in Toulouse, France.

Physiological data

After suitable skin preparation (Hermens et al., 2000) to reduce the electrode-site impedance, EMG from *zygomaticus major* (involved in smiling), *corrugator supercilii* (involved in frowning), *lateral frontalis* (involved in eyebrow raising), and *depressor anguli oris* (involved in lip lowering) of each participant was recorded at 1024 Hz using ActiveTwo system (BioSemi instrumentation, Amsterdam, the Netherlands). Electrode placement for these muscles followed the recommendations of Van Boxtel (2010) for measuring facial EMG activity (see the figure of electrode positioning in supplementary material). Eight BioSemi FLAT active electrodes (11 mm width, 17 mm length, 4.5 mm height) were placed on the skin in bipolar configuration with 10-mm interelectrode distance using electrode placement recommended by Dimberg and Petterson (2000). Two additional electrodes, the common mode sense active electrode, and the driven right leg passive electrode, were used as reference and ground electrodes, respectively. Participants were told that their skin conductance will be recorded when viewing the stimuli. They have been informed about the actual measurement at the end of the experiment.

Procedure

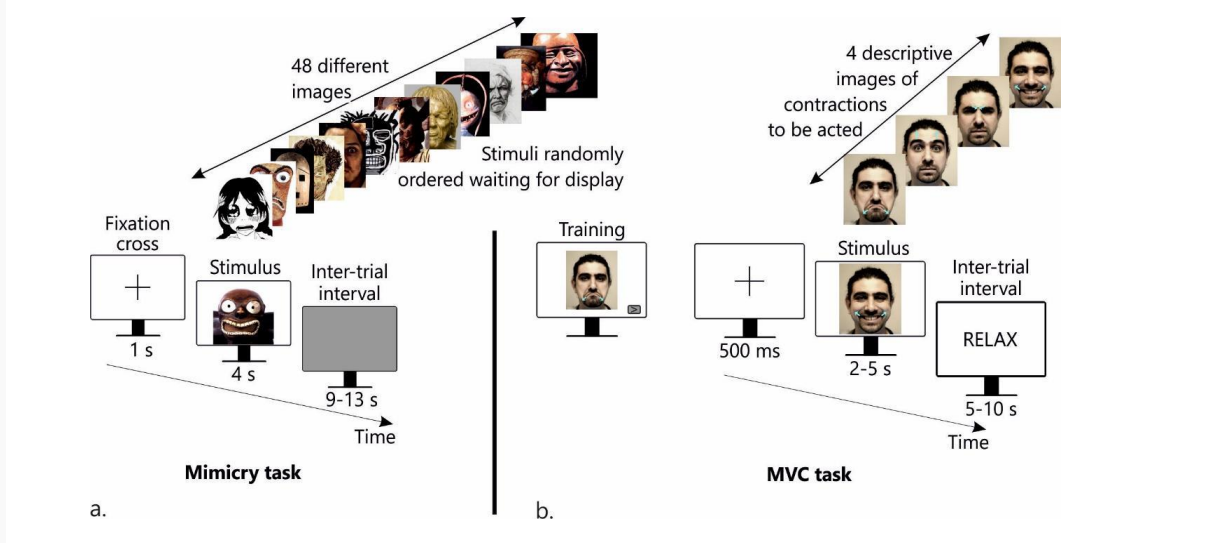
EMG task

The experiment was divided into four blocks, each one included 48 trials (Fig 1a). A 3- to 5- min break was taken between blocks. Each stimulus was displayed for four seconds preceded by 1-s fixation cross. A blank screen was displayed as an intertrial interval with a random duration from 9 s to 13 s to relax the muscles. The display was carried out on a 17-in. computer screen at a viewing distance of 60 cm. We asked participants to view displayed stimuli after focusing on the fixation cross. To ensure that

participants have understood the task, a pretest was performed at the beginning of each block. Thus, each stimulus was repeated four times in total, one per block. Stimuli were displayed randomly without repetition within blocks. To avoid boredom and loss of concentration for participants, we added cognitive tasks in the second, third, and fourth blocks: yes/no question about familiarity (did participants see the stimulus before), yes/no question about attractiveness (is the stimulus attractive), and memory task at the end of the block respectively.

After completing the four blocks, Maximum Voluntary Contractions (MVC) were measured (Fig 1b). This step corresponds to a physiological data standardization measure. Participants were asked to imitate the stimuli by contracting voluntary and strongly some muscles. Four actual human facial expressions were displayed as stimuli (smile, frown, eyebrow raising, and lip lowering). Each stimulus was preceded by 500 ms fixation cross and displayed three times during 2 s to 5 s. Stimuli were displayed randomly. Intertrial grey screen with "Relax" inscription was displayed during a random interval of 5 s to 10 s. To avoid muscle fatigue during the MVC task, the task was split into two parts. Each one includes a set of six-trial presentation. A 2-min break was taken between the two parts. During this break, participants filled up a personal data questionnaire.

Figure 1 Experimental Design of Facial Mimicry to Face Representations



Note. The picture depicts stimuli sequence and display time for (a) one block of mimicry task and (b) Maximum Voluntary Contraction (MVC) task. The individual shown gave explicit written consent for the publication of his face images.

SAM task

After the MVC task, participants assessed the 48 stimuli using the Self-Assessment Manikin scale (SAM), which assesses emotion in three independent affective spaces (pleasure, arousal, and dominance). Participants reported their pleasure, arousal, and dominance feelings when viewing stimuli. Each of the SAM emotion dimensions (pleasure, arousal, and dominance) was displayed on a nine-value graphical scale beneath the stimulus display (one dimension per screen).

The two tasks of the experiment were implemented on Matlab R2009b using the Psychophysics Toolbox extensions (see the implementation script in supplementary material).

Stimuli

Stimuli consisted of 48 cross-cultural pictures of facial expression representations (25 from western art and 23 from nonwestern art). All belong to pictures of artworks and ethnographic objects crafted with different techniques (25 images in two-dimensions [2D; painting, drawing] and 23 images in three-dimensions [3D; sculpture]). They appear in different colors and textures due to their different styles and origins. Among these stimuli, 28 have open eyes (observer-toward gaze or a slightly averted gaze) and 20 have closed/occluded eyes due to their expressions. To preserve the cross-cultural diversity balance of the stimuli, we kept them as they are despite their differences in style, technique, and eye appearance. In all stimuli, pictures were cropped on faces and presented full-face. The stimuli displayed different expressions from neutrals to extreme smiling, frowning, lip lowering, or eye-opening/eyebrow-raising (24 images with intense expression and 24 images with neutral expression). These two controlled categories of expression intensity are relevant for testing emotional contagion in terms of arousal. The stimuli include two other controlled categories: 24 realistic images

and 24 nonrealistic images. These two categories are relevant for testing the realism degree effect on mimicry. Besides these categories, we fulfilled a classification according to the expressed muscular activity. This classification provides the muscular pattern of the represented facial expression (see the sorting figure in supplementary material), which is necessary for mimicry examination (comparison of classes). The classification ranges, for each muscle, the 48 images into three classes. The three classes are (a) images expressing the weakest muscle activity (weak), including the absence of activity (N = 16 for *zygomaticus* and *corrugator*, N = 17 for *frontalis*, and *depressor*); (b) images expressing medium muscle activity (medium; N = 16 for *zygomaticus*, N = 15 for *corrugator*, *frontalis*, and *depressor*); and (c) images expressing the strongest muscle activity (strong; N = 17 for *corrugator*, N = 16 for *zygomaticus*, *frontalis*, and *depressor*). In sum, we constructed two independent variables from stimuli to test mimicry: realism degree including two modalities (realistic vs. nonrealistic) and image classes counting three modalities (weak, medium, and strong). We also constructed a supplementary independent variable from stimuli to test emotional contagion: expression intensity including two modalities (intense vs. neutral).

Classification procedure

Realism and expression intensity categories

The 48 stimuli were selected from a database of 211 face representations previously online assessed (Achour-Benallegue et al., 2016). In this previous study, the realism degree and the intensity of expression of each image were assessed by other participants than the EMG study ones. The 211 face representations were ranged on two axes according to the assessment results: one axis for realism degree and one axis for expression intensity. Then four clusters from the intersection of the two axes extremes were highlighted. Forty-eight images were randomly chosen from the four clusters: 12 from the extreme realistic degree cluster, 12 from the extreme nonrealistic degree cluster, 12 from the extreme intensity cluster, and 12 from the extreme neutral cluster. Thus, among the 24 realistic

images, 12 represent an intense expression and 12 represent a neutral expression. Similarly, among the 24 nonrealistic images, 12 represent an intense expression and 12 represent a neutral expression.

Image classes

The classification according to muscle activity required a supplementary task. Stimuli classification was operated using an EMG based-criterion through the following protocol: (a) a voluntary imitation of the stimuli facial expressions, (b) a record of this imitation in terms of muscle activity (EMG activity), and (c) a classification of the stimuli according to the different values of the EMG activity. The supplementary task consisted of performing a voluntary mimicry task on 15 new participants (equipped with an EMG recording device) respecting the same conditions as in the present experiment (the same 48 stimuli, 1-s fixation cross, 4-s stimulus display, 9- to 13-s intertrial interval, four blocks, MVC task). More precisely, we asked the new participants to reproduce exactly on their faces the facial expression of each stimulus.

The classification was done by using three quantiles of EMG activity means (which were computed for each stimulus). These quantiles divide the data into three categories. Each category includes the same number of images. First, the images to which facial reaction (EMG activity expressed in Δ RMS relative to the baseline) is greater than the second quantile constitute the class of images expressing the strongest muscle activity (strong). Then, the images to which facial reaction is between the first and the second quantile constitute the class of images expressing the medium muscle activity (medium). Finally, the images to which facial reaction is below the first quantile constitute the class of images expressing the weakest muscle activity (weak). For example, among the realistic stimuli, the strong classes of *frontalis*, *corrugator*, *depressor*, and *zygomaticus* activation include, respectively: L'ébahi (painted by Boilly), the face of Boy Bitten by a Lizard (Caravaggio), the Humored Man (sculpted by Messerschmidt), and the Moche portrait vessel (Moche culture). Among the nonrealistic stimuli, the strong classes of *frontalis*, *corrugator*, *depressor*, and *zygomaticus* activation respectively include for

example: the Kavat mask (Baining ethnicity), Reversible Head with a Fruit Basket (painted by Arcimboldo), 'aumakua hulu manu (Hawaiian feathered god), and Tupilak figure (Ammassalik island).

Data preparation

To check behavioral artifacts, participants were videotaped all along the data acquisition using a digital video camera (Canon iVUS HF M31). As videotape analysis showed several kinds of motion artifacts (e.g., yawning or turning eyes away), artifacts-contaminated trials were removed from the analysis. Only 4% of the whole trials were removed, 96% among them were included in clean data.

EMG data

Raw EMG was first denoised by band-pass filtering at 20-400 Hz, then full-wave rectified by taking the absolute value, and finally smoothed at 9 Hz to obtain the linear envelopes (Lajante et al., 2017). For each muscle, facial EMG activity was then obtained by computing the root-mean-square (RMS) from the EMG envelope, which provides a relevant measure of the electrical activity of the muscle during contraction (Bouisset & Maton, 1995). As was done in numerous studies investigating facial EMG responses, in different fields, (Sato, 2008; Lajante et al., 2017; Kwon & Christou, 2018; Urgesi et al., 2016), the muscle activity during the last second before each stimulus onset was defined as the baseline to subsequently quantify EMG response associated to this stimulus presentation appropriately. Facial reactions were expressed as a change in the Root Mean Square (Δ RMS relative to the baseline) between the muscle activity during the 4 s picture presentation and the associated baseline. To obtain physiologically standardized data (Van Boxtel, 2010), this Δ RMS value was normalized to the corresponding muscle Δ RMS (relative to the baseline) measured during MVC test. That is, for each muscle, the measured Δ RMS during the mimicry task was divided by the Δ RMS of the same muscle measured during the MVC test. This enables facial EMG analysis to compare data between different participants. Signal processing was performed on Matlab R2009b (see the EMG

analysis script in supplementary material). Raw signals were extracted using the eeglab toolbox (Delorme & Makeig, 2004).

SAM data

From SAM data, we reconstructed three variables: valence (negative, average, positive), arousal (low, average, positive), and dominance (low, average, high). The negative/low modality includes data that is below the score 3, the average modality includes data that is between the score 4 and score 6, and the positive/high modality includes data that is higher than 6.

Statistical Analysis

To investigate the influence of facial expression representations on mimicry, we used a mixed-effect model, with facial reactions (Δ RMS relative to the baseline) being the dependent (continuous) variable, and image classes (weak, medium, strong), image realism degree (realistic vs. nonrealistic) being the independent variables. Four mixed effect models were performed, one model per muscle region: *zygomaticus*, *corrugator*, *frontalis*, and *depressor*. All variables were considered fixed-effect variables, except for participants ($N = 35$) and images ($N = 48$), which were considered random-effect variables. Inspection of the results made us refrain from doing any analysis involving the intermediate stimuli, and will follow the analysis method used in previous studies that used stimuli with high intensity of expressions (Dimberg & Thunberg, 2012; Likowski et al., 2012). Thus, we focused our comparison only on the two extreme classes (weak vs. strong). Planned contrast analysis was performed to test facial mimicry. This contrast tests whether the facial reaction (Δ RMS relative to the baseline) was greater in "strong" compared with "weak" classes.

Other post hoc contrasts were conducted to investigate: (a) the effect of the stimuli properties, which are noncontrolled variables, on EMG activity (technique: 2D, 3D; style: western, nonwestern; eyes: opened, closed/occluded), as well as the effect of the expression intensity of stimuli on EMG

activity; and (b) the effect of image realism degree and the effect of valence, arousal, and dominance on mimicry. The latter contrasts, first, compare the Δ RMS (relative to the baseline) of the two extreme classes ("weak" vs. "strong") for realistic images on one side, then for nonrealistic images on the other side. Secondly, these contrasts test whether the facial reaction (Δ RMS relative to the baseline) was different for the extreme modalities of valence (positive vs. negative), arousal (high vs. low), and dominance (high vs. low). The contrasts were included in the mixed-model procedure.

To investigate the emotional contagion of face representations, we used a Kruskal-Wallis test, with arousal responses (scored on 9 value-scale) being the dependent (continuous) variable, and expression intensity of images (intense vs. neutral) being the independent variable. This ANOVA tests the effect of the expression intensity on the affective response of arousal. Not to be confused with the independent variable arousal (low, high), the arousal responses scored on nine-value-scale is designated as arousal_affect.

The threshold of significance (alpha) is .05. The models were adjusted using Bonferroni corrections pairwise comparisons. Statistical analyses were conducted using SAS Version 9.2. All scripts (procedure, data preparation, and statistical analysis) are available in supplementary data (see the statistics analysis script in supplementary material).

Results

Mimicry

As depicted in Figure 2, findings on mimicry show different facial reactions to the different muscles. For three muscles (*zygomaticus*, *depressor* and *frontalis*), the facial reaction was significantly influenced by image classes (weak vs. strong; $t(1,6395) = -2.57$, $p = .03$ for *zygomaticus*, $t(1,6395) = -2.89$, $p = .01$ for *depressor*, and $t(1,6395) = 2.70$, $p = .02$ for *frontalis*). *Zygomaticus* and *depressor* results did respect our predictions, that is, the Δ RMS relative to baseline for *zygomaticus* and

depressor activation in the weakest activity class was lower than the Δ RMS relative to baseline for these muscles activation in the strongest activity class ($.82 (\pm .93) < 3.15 (\pm .92)$; and $-.39 (\pm .93) < 3.09 (\pm .88)$ respectively). However, *frontalis* results were opposite to our predictions: the Δ RMS relative to baseline for *frontalis* activation in the weakest activity class was higher than the Δ RMS relative to baseline for *frontalis* activation in the strongest activity class ($.42 (\pm 1.07) > -1.61 (\pm 1.06)$). The image classes (weak vs. strong) seem to not influence the Δ RMS relative to baseline for the *corrugator* muscle ($t(1,3695) = -1.09, p = .83$).

Exploratory analyses

In an exploratory way, we performed several other statistical analyses that shed light on the category of stimuli and bring some explanations of the previous results. These exploratory analyses also give an insight to emotional contagion.

Category of stimuli

None of the noncontrolled properties (technique, style, and eyes) significantly influenced the EMG activity of each muscle. Similarly, the EMG activity of each muscle was not affected by the expression intensity nor the realism degree. No differences were observed in the Δ RMS for *zygomaticus*, *corrugator*, *frontalis*, and *depressor* activation between the following pairwise-tests: 2D versus 3 D images, western-belonged versus non-western-belonged images, opened-eye versus closed/occluded-eye images, intense versus neutral images.

Realism degree effect on mimicry

As the stimuli include as well realistic as nonrealistic face representations, we looked closer into the data to investigate whether the realism degree affects mimicry. Does mimicry occur in the category of realistic stimuli and the category of nonrealistic stimuli separately? If so, for each category of realism

degree (realistic and nonrealistic) EMG activity would still be stronger for stimuli depicting high muscle activity than for stimuli depicting low muscle activity. In realistic stimuli, no differences were observed in the Δ RMS relative to baseline for *zygomaticus*, *corrugator*, and *depressor* activation between image classes (see Table 1). However, the effect of realistic image classes on the Δ RMS relative to baseline for *frontalis* activation was significant ($t(1,6395) = 3.18, p = .02$). Conversely to our predictions, the Δ RMS for *frontalis* activation in the weakest activity class was higher than the Δ RMS for *frontalis* activation in the strongest activity class ($.79 (\pm 1.06) > -2.41 (\pm 1.26)$). In nonrealistic stimuli, for all muscles, no effect of image classes on the Δ RMS relative to baseline was observed.

Valence effect on mimicry

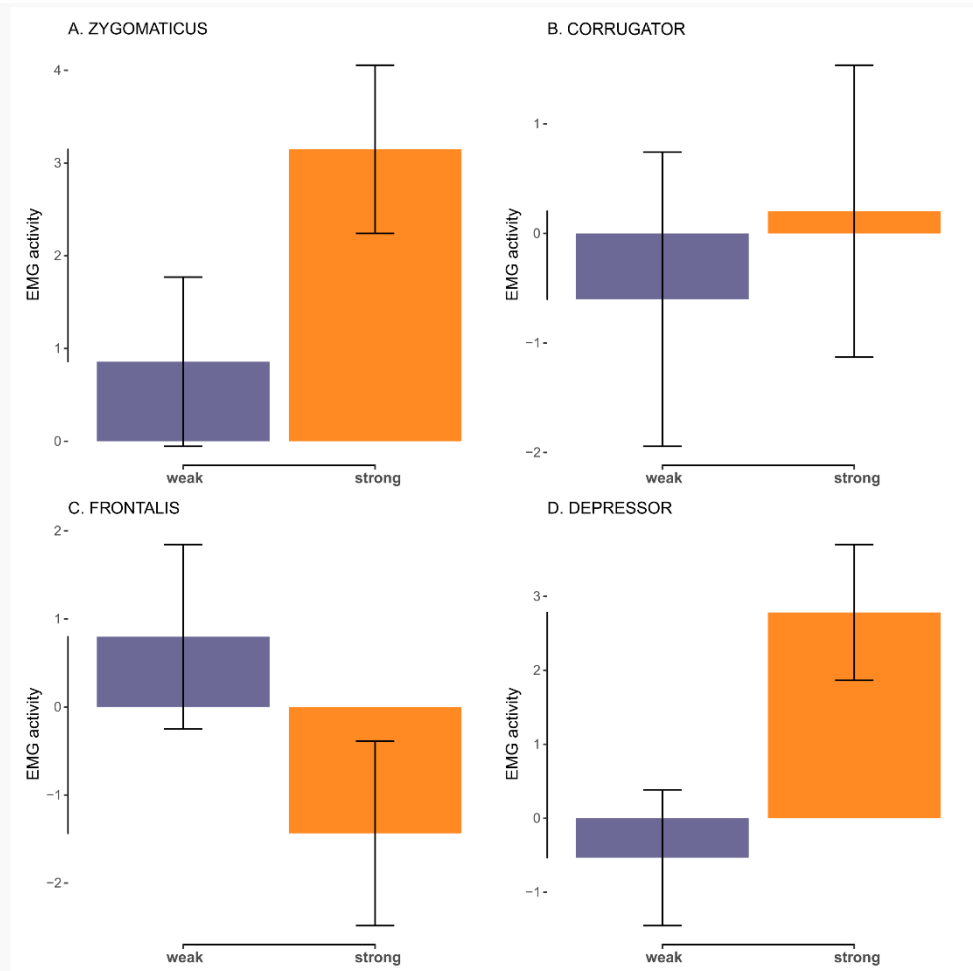
To investigate previous results for *corrugator* and *frontalis*, we tested the effect of emotional dimensions (valence, arousal, dominance) on facial reaction (Δ RMS relative to baseline). Findings show a significant effect of valence on *corrugator* and *frontalis* reactions, as well as on *zygomaticus* (Table 2). Arousal and dominance did not have any significant effect on the *corrugator* and *frontalis*. Besides, findings show a significant effect of valence on *corrugator* only in the strong *corrugator* activity class of stimuli ($t(1,6385) = -3.59, p = .0003$). Negative valence was associated with a significant *corrugator* activity response (Δ RMS relative to baseline = 2.50), whereas, positive valence was associated with a significant decrease of *corrugator* activity response (Δ RMS relative to baseline = -1.81; Figure 3).

For *zygomaticus*, findings show a significant influence of valence on *zygomaticus* activation ($t(1,6385) = 3.01, p = .003$). Positive valence enhanced stronger *zygomaticus* activity (Δ RMS relative to baseline = 3.85) compared to negative valence (Δ RMS relative to baseline = .88). Moreover, the valence that has been attributed to stimuli associated with strong *corrugator* activity was not significantly associated with changes in *zygomaticus* activity ($t(1,6385) = 0.98, p = .33$).

On *frontalis*, a significant effect of valence was observed only in the weak *frontalis* activity class of stimuli ($t(1, 6385) = -2.29, p = .02$). The negative valence was associated with a significant *frontalis* activity response (Δ RMS relative to baseline = 1.71) whereas, the positive valence was associated with a significant decrease of *frontalis* activity response (Δ RMS relative to baseline = -1.21; Figure 3).

Figure 2

EMG activity of the four measured muscles in the two extreme image classes (weak vs. strong).



Note. EMG = electromyography; RMS = root-mean-square. The EMG activity of zygomaticus (A), corrugator (B), frontalis (C), and depressor (D) is represented by the estimation of Δ RMS relative to baseline. This represents EMG facial reactions as a response to stimulus presentation. The figure depicts, for each muscle, the measured estimation of Δ RMS relative to baseline for the two extreme classes of images: the weakest activity class 'weak' (blue bars), and the strongest activity class 'strong' (orange bars). The estimation values were multiplied by 1000 (‰). Error bars indicate the standard deviation of the estimation.

Emotional contagion

Our exploratory analyses show a significant effect of expression intensity of stimuli on arousal_affect ($\chi^2 = 19.48$; $p < 0.0001$). The means of arousal_affect toward intense images was greater than the means of arousal_affect toward neutral images ($5.8 > 4.6$).

Discussion

This study investigates whether facial expressions in face representations are mimicked. We tested the hypothesis stating that observers would mimic face representations regardless of realism categories. A reaction could be labeled as mimicry if it met the following two conditions (Fujimura et al., 2010; Lajante et al., 2017): (a) image classes have a significant effect on facial reactions, and (b) the strongest activity class has a greater Δ RMS relative to baseline for muscle activation compared with the weakest activity class.

Mimicry of face representations

To test our assumptions, we conducted analyses for the four muscles independently (see Table 3).

Table 1 Effect of the Interaction of Image Classes with Realism Degree on Mimicry

Muscles	Realistic images		Nonrealistic images	
	<i>t</i>	<i>p</i>	<i>t</i>	<i>p</i>
<i>Zygomaticus</i>	-1.76	1.00	-1.87	.92
<i>Corrugator</i>	.76	1.00	-2.14	.48
<i>Frontalis</i>	3.18	.02	.76	1.00
<i>Depressor</i>	-2.82	.07	-1.35	1.00

Note. The effect is represented in t test and Bonferroni corrected probabilities. The first column displays the effects of contrast between the extreme classes (weak vs. strong) in realistic images, and the second column in nonrealistic images.

Zygomaticus* and *Depressor

The two conditions for mimicry were satisfied in two muscles: *zygomaticus* and *depressor*. That means that participants' faces reacted similarly to image expressions in terms of *zygomaticus* and *depressor* muscle patterns. Consequently, face representations depicting mouth expressions might be mimicked by observers. When it comes to mouth expressions, observers' facial reactions to face representations might be quite similar to the reactions toward actual (human) faces. This brings experimental support to Freedberg's suggestion on Inuit masks from Point Hope (Copenhagen; Freedberg, 2009). Freedberg (2009) reported that we can be sure that the force of these masks resides perhaps in our felt buccal responses to them. Mimicry in *zygomaticus* and *depressor* is consistent with previous studies on human faces stimuli showing mimicry in *zygomaticus* (Seibt et al., 2015) and *depressor* (Soussignan et al., 2013; Philip et al., 2018). Philip et al.'s (2018) study tested also facial reactions toward virtual faces (not human faces), which are very realistic according to our definition of realism. This study reported that sad virtual faces also enhanced facial reactions that are congruent with the expression they display, but only when displayed in the dynamic condition and not in the static one. In our study, even though

all stimuli were static and regardless of their realism category, *depressor* activity in observers was congruent with the facial expressions of these stimuli. This means that face representations depict strongly facial expressions that might convey salient social events.

None of the mimicry studies have been conducted on cross-cultural face representations (realistic and nonrealistic), consequently, our results are the first to show this effect in observer's reactions to face representations. And compared with previous studies on human or virtual faces, our stimuli include nonrealistic images in which the representation of *zygomaticus* and *depressor* muscle activity could refer to more complex emotions than just happy or sad emotions. Thus, our result on *zygomaticus* and *depressor* muscle mimicry reactions to face representations might widen the possibility of mimicry to more complex emotions (not only basic emotions; Ekman & Cordaro, 2011) compared with the literature on human faces (such as happy and angry faces).

The fact that mimicry was observed only in *zygomaticus* and *depressor* could be due to a bias caused by cultural background. Participants belonging to Western culture may have a bias that makes them focus on mouth representations that involve *zygomaticus* and *depressor*. Indeed, it has been shown that in recognizing the facial expressions of emotions, Westerners focus on the position of the mouth more than the eyes, compared to Easterners (Yuki et al., 2007; Caldara, 2017). A cross-culturally bigger sample of participants may bring more answers on this issue.

Reactions of *zygomaticus* and *depressor* muscles to realistic and nonrealistic images separately did not satisfy the mimicry conditions. This contrasts with the result of the global mimicry hypothesis showing mimicry in *zygomaticus* and *depressor*. This led us to think that our experiment did not include enough data in each of the two categories (realistic and nonrealistic) to draw conclusions on the issue. A larger sample of stimuli in both categories should bring more conclusions on the effect of realism degree on facial reactions to face representations.

Frontalis

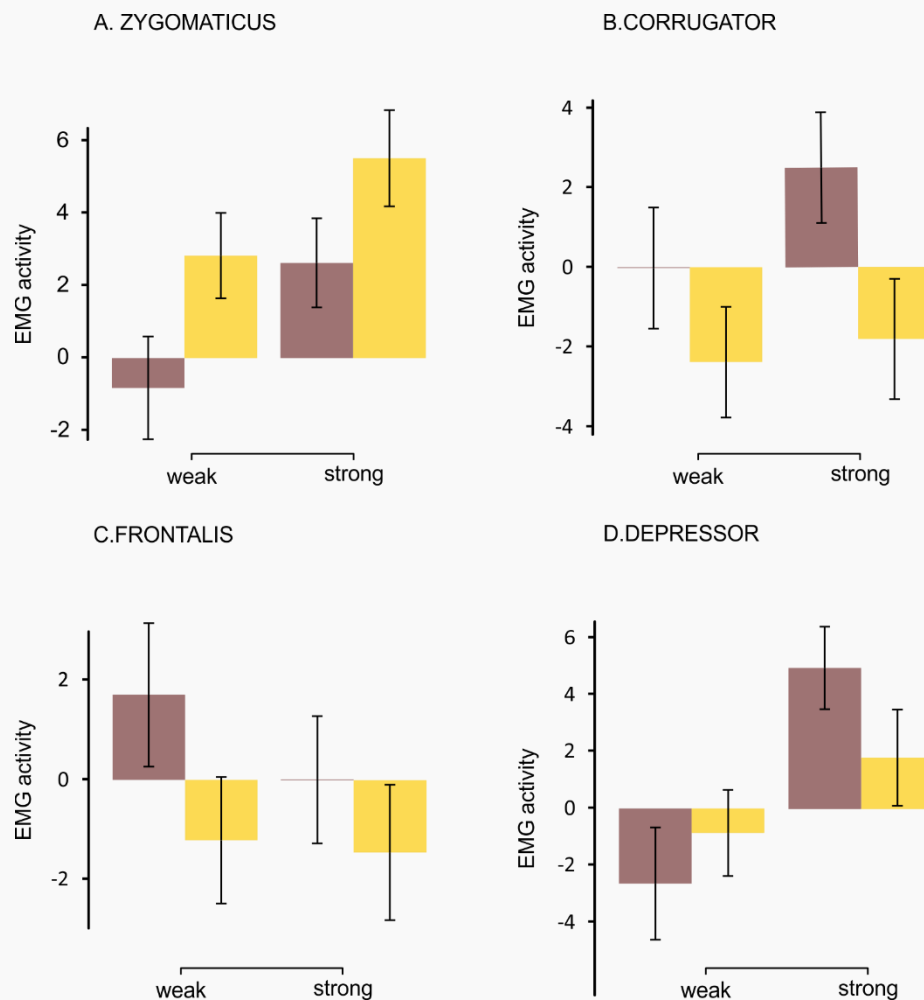
In the *frontalis* muscle, the first mimicry condition was satisfied, but not the second one. Contrary to expectation, the Δ RMS relative to baseline for *frontalis* activation in the "weak" class was higher than in the "strong" class. This means that the muscle pattern of facial reactions does not fit the displayed expressions in stimuli, but it is inverted compared to the displayed expressions. i.e., *Frontalis* activity pattern is produced in reaction to images without *frontalis* activity representation, and conversely, images with *frontalis* activity representation do not elicit *frontalis* activity pattern. To explain this result, we may suppose that this *frontalis* reaction could be the result of an emotion stemming from self-relevant appraisal processing (Soussignan et al., 2013; Grèzes et al., 2013), such as surprise. In other words, participants could have displayed *frontalis* reactions as a function of social meaning of some image properties, here the images belonging to the weak *frontalis*-activity class. This result is to be compared with studies, in which participants displayed congruent facial reactions to perceived facial expressions as a function of the social meaning of perceived gaze direction (Soussignan et al., 2013). In that case, gaze direction in stimuli affected facial reactions (higher *zygomaticus* and *corrugator* activity to happy and angry faces, respectively, with direct than averted gaze, higher *frontalis* activity to fear faces with averted than direct gaze). Gaze direction was interpreted as a self-relevant clue to account for responses to salient events (Soussignan et al., 2013). In our study, we may suppose that a common property among those "weak" images could have enhanced *frontalis*-related emotion, similarly to the gaze direction. When looking deeply in the two extreme *frontalis* classes we note, *a posteriori*, that most of "weak" class stimuli are realistic and most of "strong" class stimuli are nonrealistic. This realism distribution over stimuli might have an influence on facial reaction and mimicry. Participants might have activated more their *frontalis* when the stimuli were realistic than when stimuli were nonrealistic despite the strength of the expressions of *frontalis* activation. Nevertheless, this does not seem appropriate for all stimuli belonging to all classes. Indeed, in our statistical model the effect of realism variable alone on *frontalis* reaction was not significant as

reported in the exploratory analyses. Then, the realism degree over all stimuli (whatever the expression is) does not seem to influence *frontalis* reactions. However, our results showed an influence on *frontalis* reactions by realism degree in the subset of stimuli belong to the extreme *frontalis* activity classes (expressions related to *frontalis* only).

Reactions of *frontalis* to realistic and nonrealistic images separately were as follow: (a) for nonrealistic images none of the mimicry conditions were satisfied, and (b) for realistic images, the first condition of mimicry was satisfied (with inverted pattern) but not the second condition. These results show that only realistic images lead to an inverted muscular pattern in the *frontalis*. Thus, this self-relevant appraisal processing might be specific to realistic images (and not to nonrealistic ones). Realism might be interpreted as a self-relevant clue that contributes to *frontalis* reaction. Further studies should be conducted with more balanced realism degree in each class (weak and strong) to shed light on this result. This alternative hypothesis supposes that mimicry does not occur when it comes to *frontalis* expressions.

Another result on *frontalis* activation depending on stimuli property (valence) brings more explanation to *frontalis* reactions. The test of valence effect on *frontalis* reaction showed a significant effect of stimuli valence on *frontalis* activity that was stronger in negative compared to positive valence. This suggests that participants' *frontalis* reacted when they felt negative valence emotion toward face representations, and not specifically when face representations were expressing strong *frontalis* activity. *Frontalis* reaction might be the result of a negative emotion stemming from self-relevant appraisal processing that is related to the realism of face representations in art. A more detailed observation of the valence effect on *frontalis* reaction indicated a significant effect of valence on *frontalis* reactions only in the weak activity class. This reflects the inverted pattern of *frontalis* mimicry.

Figure 3 Stimuli valence effect on *zygomaticus*, *corrugator*, *frontalis*, and *depressor* reactions.



Note. EMG = electromyography; RMS = root-mean-square. The EMG activity of *zygomaticus* (A), *corrugator* (B), *frontalis* (C), and *depressor* (D) is represented by the estimation of Δ RMS relative to baseline. The figure depicts, for each muscle, the measured Δ RMS relative to baseline for the two valence conditions (negative vs. positive) in each stimuli class (weak vs. strong). The EMG activity in the negative valence condition is depicted by purple bars, and the EMG activity in the positive valence condition is depicted by yellow bars. The estimation values were multiplied by 1000 (%). Error bars indicate the standard deviation of the estimation.

In the weak activity class, the negative valence was associated with a significant *frontalis* activity response (activated *frontalis*), whereas, positive valence was associated with a significant decrease of *frontalis* activity response (relaxed *frontalis*). This result suggests that, beyond stimuli realism, the property related to the self-relevant appraisal hypothesis is related to the negative affect conveyed by the stimuli. Further research is needed to understand better how negative valence and realism play a role in *frontalis* reactions toward face representations.

We may also consider other alternative hypotheses: (a) *frontalis* reaction could have been disturbed by a lack of information related to the full actual expression which highlights *frontalis* activation; (b) *frontalis* reaction could have been disturbed by a combination of contradictory activations which is depicted in the stimuli of the “strong” class. This could be tested, in further studies, by comparing *frontalis* reaction to the current stimuli with its reaction to face representations which respects the combination of actual activations.

Corrugator

For *corrugator*, none of the mimicry conditions were satisfied, neither in general nor in realism categories separately. One explanation might be the influence of pleasure felt by participants due to their interaction with artworks. *Corrugator* activity has been shown as a good indicator of negative valence (Gerger et al., 2011). The hedonistic experience of art (experience of pleasure) might have attenuated the *corrugator* activation by enhancing positive valence in participants. This hedonistic influence could be a consequence of social context influence on mimicry (Seibt et al., 2015).

Our explanation is endorsed by the results on the valence effect on *corrugator* reaction. *Corrugator* reaction was significantly affected by stimuli valence. The negative valence was associated with a significant *corrugator* activity response (activated *corrugator*), whereas, positive valence was associated with a significant decrease of *corrugator* activity response (relaxed *corrugator*). This result endorses previous studies on *corrugator* reaction to negative valence (Gerger et al., 2011).

Given the mimicry hypothesis, the *corrugator* strong-activity class of stimuli is supposed to enhance *corrugator* activity (and this activity should be higher than the one toward stimuli from the weak activity class). However, when we tested the effect of valence in this strong activity class, we found a significant influence of valence on *corrugator* reaction (enhanced activation in the negative condition and decreased activation in the positive condition). This effect could be explained by the influence of the hedonistic context on *corrugator* activity in terms of the felt pleasure when viewing highly expressive art representations.

As *zygomaticus* and *corrugator* activities are negatively correlated when observing positive and negative stimuli (Gerger et al., 2014, Fujimura et al., 2010), a better understanding of the *corrugator* reaction should take into account the *zygomaticus* one. Indeed, it has been shown that positive stimuli enhance *zygomaticus* activity and decrease *corrugator* activity, and negative stimuli enhance *corrugator* activity and decrease *zygomaticus* activity (Gerger et al., 2014, Fujimura et al., 2010). We observed a significant effect of valence on *zygomaticus* activity (stronger *zygomaticus* activity in the positive compared to the negative valence condition). This result supports previous studies on *zygomaticus* reaction to positive valence (Gerger et al., 2011, 2014). However, the felt valence that has been attributed to stimuli associated with strong *corrugator* activity was not significantly associated with changes in *zygomaticus* activity. This means that the positive valence attributed to face representations expressing strong *corrugator* activity did not show a significant effect on *zygomaticus*. This result suggests that stimuli, representing a strong activation of the *corrugator*, might have prevented *zygomaticus* activation despite the positive valence. This prevention of *zygomaticus* activation toward positive-assessed stimuli, associated with strong *corrugator* activity, might reflect a trace of a tendency of mimicry reaction. Taken together, our findings lead us to consider the hypothesis of hedonistic context influence on *corrugator* activity as the most relevant one.

Table 2 Valence effect on *corrugator*, *frontalis*, and *zygomaticus* reactions.

Muscle	<i>Corrugator</i>	<i>Frontalis</i>	<i>Zygomaticus</i>
Valence	P < .0001 RMS (+) < RMS (-)	P = .001 RMS (+) < RMS (-)	P = .003 RMS (+) > RMS (-)

Note. RMS = root-mean-square; EMG = electromyography. Δ RMS (+) refers to the Δ RMS, relative to baseline, of EMG reaction in the positive valence condition, and Δ RMS (-) refers to the Δ RMS, relative to baseline, of EMG reaction in the negative valence condition.

Table 3 Mimicry's Conditions per Muscle.

Muscles	Condition 1	Condition 2	Mimicry
<i>Zygomaticus</i>	Satisfied	Satisfied	Satisfied
<i>Corrugator</i>	Not satisfied	Not satisfied	Not Satisfied
<i>Frontalis</i>	Satisfied	Not satisfied	Not Satisfied
<i>Depressor</i>	Satisfied	Satisfied	Satisfied

Note. RMS = root-mean-square; Condition 1 refers to a significant effect of image classes on facial reactions; Condition 2 refers to a greater RMS for muscle activation in the strongest activity class compared to the weakest activity class.

An interdisciplinary study

Mimicry might contribute to a new approach for studying face representations and their relationship with observers. Indeed, experimental psychology in general and, facial expressions and mimicry, in particular, are not that much appealed in anthropology and art studies to understand the human behavior toward face representations. Yet a lot of knowledge has been collected on facial expressions in experimental psychology. Our study offers an interdisciplinary view that associates art issues (social interaction with face representations) with a specific cognitive process (facial mimicry).

Consequently, our hypothesis and result interpretations might extend the anthropological and artistic discussions to findings on mimicry and facial expressions.

Moreover, our findings on the expression intensity on arousal responses (arousal_affect) lead us to assume that face representations might trigger an emotional contagion regardless of upper-face or lower-face muscles. Indeed, the expression intensity of face representations is related to the intensity of the expressed emotion. Thus, a higher arousal_affect response to intense images compared to neutral ones reflect an emotional contagion process in terms of arousal affect. Given the mimicry result and by relying on the emotional contagion one, we can suggest, as mentioned in the literature, that the observed mimicry might be related to emotional contagion (Dimberg & Thunberg, 2012; Hess & Fischer, 2014), and understanding others' mental states such as intentions (Schilbach, 2016; Niedenthal et al., 2010; Blakemore & Decety, 2001). Thus, it might be possible to convey spontaneously emotions (such as happiness, satisfaction, sadness, or contempt) or intentions (such as caring or benevolence) through face representations expressing *zygomaticus* or *depressor* activation. This does not mean that the felt emotion in front of face representations is limited to this kind of spontaneous emotional contagion or is forced to stay at this level. The felt emotion could also stem from more complex processes which include regulatory strategies that depend on participants mood (Stamatopoulou, 2018), or mental representations related to the context of the interaction (Niedenthal, 2007) or which include memory (Adolphs, 2002). Nevertheless, the early emotional contagion that we suggest to be induced by face representations might apply as a priming bias for further more complex emotional experience (Niedenthal, 1990).

Facial mimicry and its correlated processes (emotional contagion and understanding expressed intentions) might contribute to the social interaction with face representations. They might be an index of face representation agencies. This could reflect Gell's anthropological theory of art (Gell, 1998), where art objects are means that convey social agencies. In other words, art objects might transmit the emotions and the intentions of those who created them (artiste) or of the spiritual entities they depict (human in portraits, gods in idols, spirits in masks). This is not to say that mimicry, emotional

contagion and understanding expressed intentions alone are a way to impute a particular agency of the face representation, but they would be a good way to experimentally verify the abduction (inference) of agency in these images. Mimicry should, above all, indicate a potential for agency in the face representation. If we mimic and share emotions with face representations, this means that we attribute a certain mental state to them, and this mental state participate, among other things, to their agency. This does not exclude the fact that other processes, such as imaginative thoughts, could foster the abduction of agency in face representation.

Our study provides a new track to the issue of social interaction with face representations. It is the first to link mimicry and its correlated processes (emotional contagion and understanding other's mental states) to the theory of art agency. It brings some support to the art agency in the case of face representations. Social agencies, such as intentions, might be no more just abstract concepts, but could find a real correlate in cognitive processes. Consequently, our findings open the door to reveal abstract concepts by processes that are familiar to experimental psychology such as embodied emotion processes.

Conclusion

In summary, our study showed that facial expressions in actual human faces are not the only ones that cause facial mimicry. Face representations in art might also stimulate facial mimicry, at least in *zygomaticus* and *depressor* muscles (mouth surrounding muscles). The observation of mimicry only in the lower part of the face might be related to the participants' culture. A cross-culturally bigger sample of participants would make it possible to examine the effect of culture on mimicry. Besides, we also have shown that facial expressions might trigger emotional contagion, at least as arousal affect. Based on this finding and on the literature, we have postulated that emotional contagion and understanding others' mental states processes might be induced by mouth expression representations through mimicry. As put by Stamatopoulou (2018) about any expressive dynamic stimulus, face representations

in art might function as an affective primer that could elicit embodied sense-impressions in the perceiver. This hypothesis might be, among others such as imaginative thoughts, a support to Gell's anthropological theory of art (Gell, 1998), and this, from a cognitive psychology perspective. Further studies are needed to test these hypotheses on emotional contagion and understanding others' mental states. Our analyses did not allow us to bring to light mimicry in *corrugator* or *frontalis*. However, our results reflected an attenuated tendency to mimic stimuli depicting expressions associated with a strong *corrugator* activity, due to a hedonistic property of highly expressive face representations. Our results also reflected a possible appraisal-based reaction in *frontalis* that could be explained by the realism of stimuli and the valence they convey. Our analyses did not highlight mimicry toward realistic and nonrealistic images separately, in particular in *zygomaticus* and *depressor*. A larger sample of stimuli in both categories of realism would allow us to further examine the mimicry of these muscles in the two categories separately. In conclusion, mimicry, in the lower part of the face, may play a role in the interaction with a wide range of face representations in art. Thus, this study could serve to enrich the facial expression and mimicry research field such as contributing to the brain-machine interface project using emotional agents (Pillette et al., 2017). More specifically, as an interdisciplinary study, this work could also contribute to understanding art interactions with face representations usually explained by anthropological and art theories.

References

- Achour-Benallegue, A., Pelletier, J., & Kaminski, G. (2016). Aesthetic impact of anthropomorphic figures in art: The case of facial expressions. In Z. Kapoula & M. Vernet (Eds.), *Aesthetics and neuroscience* (pp. 55–80). Springer.

Adolphs, R. (2002). Recognizing emotion from facial expressions: psychological and neurological mechanisms. *Behavioral and cognitive neuroscience reviews*, 1(1), 21-62.

Awasthi, A., & Mandal, M. K. (2015). Facial expressions of emotions: Research perspectives. In M. K. Mandal & A. Awasthi (Eds.), *Understanding facial expressions in communication* (pp. 1–18). Springer.

Baetens, K., Ma, N., Steen, J., & Van Overwalle, F. (2014). Involvement of the mentalizing network in social and non-social high construal. *Social Cognitive and Affective Neuroscience*, 9 (6), 817–824.

Bailey, P. E., & Henry, J. D. (2009). Subconscious facial expression mimicry is preserved in older adulthood. *Psychology and Aging*, 24 (4), 995.

Barrett, L. F., & Lindquist, K. A. (2008). The embodiment of emotion. In G. R. Semin & E. R. Smith (Eds.), *Embodied grounding: social, cognitive, affective, and neuroscientific approaches* (pp. 237–262). Cambridge University Press.

Beall, P. M., Moody, E. J., McIntosh, D. N., Hepburn, S. L., & Reed, C. L. (2008). Rapid facial reactions to emotional facial expressions in typically developing children and children with autism spectrum disorder. *Journal of Experimental Child Psychology*, 101 (3), 206–223.

Blakemore, S.-J., & Decety, J. (2001). From the perception of action to the understanding of intention. *Nature Reviews Neuroscience*, 2 (8), 561.

Bouisset, S., & Maton, B. (1995). *Muscles, posture et mouvement. Bases et applications de la méthode Électromyographique*. (Vol. 26). Paris: Hermann.

Caldara, R. (2017). Culture reveals a flexible system for face processing. *Current Directions in Psychological Science*, 26 (3), 249–255.

Chen, C., Garrod, O. G., Zhan, J., Beskow, J., Schyns, P. G., & Jack, R. E. (2018). Reverse engineering psychologically valid facial expressions of emotion into social robots. In *2018 13th IEEE International Conference on Automatic Face & Gesture Recognition (FG 2018)* (pp. 448–452).

Churches, O., Nicholls, M., Thiessen, M., Kohler, M., & Keage, H. (2014). Emoticons in mind: An event-related potential study. *Social Neuroscience*, 9 (2), 196–202.

Damasio, A. R. (1994). *Descartes' error: Emotion, reason and the human brain*. Grosset/Putnam.

Delorme, A., & Makeig, S. (2004). EEGLAB: An open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *Journal of Neuroscience Methods*, 134 (1), 9–21.

Dimberg, U., Andréasson, P., & Thunberg, M. (2011). Emotional empathy and facial reactions to facial expressions. *Journal of Psychophysiology*, 25 (1), 26-31.

Dimberg, U., & Petterson, M. (2000). Facial reactions to happy and angry facial expressions: Evidence for right hemisphere dominance. *Psychophysiology*, 37 (5),

693–696.

Dimberg, U., & Thunberg, M. (2012). Empathy, emotional contagion, and rapid facial reactions to angry and happy facial expressions. *PsyCh Journal*, 1 (2), 118–127.

Dimberg, U., Thunberg, M., & Elmehed, K. (2000). Unconscious facial reactions to emotional facial expressions. *Psychological Science*, 11 (1), 86 - 89.

Eimer, M. (2011). The face-sensitive N170 component of the event-related brain potential. In A. Calder, G. Rhodes, M. Johnson, & J. Haxby (Eds.), *The oxford handbook of face perception* (Vol. 28, pp. 329–344). Oxford University Press Oxford.

Ekman, P., & Cordaro, D. (2011). What is meant by calling emotions basic. *Emotion Review*, 3 (4), 364–370.

Finzi, E., & Rosenthal, N. E. (2014). Treatment of depression with onabotulinumtoxin: a randomized, double-blind, placebo controlled trial. *Journal of Psychiatric Research*, 52, 1–6.

Freedberg, D., & Gallese, V. (2007). Motion, emotion and empathy in esthetic experience. *Trends in cognitive sciences*, 11(5), 197-203.

Freedberg, D. (2009). Movement, embodiment, emotion. *Les actes de colloques du musée du quai Branly Jacques Chirac*, (1).

Fujimura, T., Sato, W., & Suzuki, N. (2010). Facial expression arousal level modulates facial mimicry. *International Journal of Psychophysiology*, 76 (2), 88–92.

Gallese, V. (2019). Embodied simulation. Its bearing on aesthetic experience and the dialogue between neuroscience and the humanities. *Gestalt Theory*, 41(2), 113-127.

Gell, A. (1998). *Art and agency: An anthropological theory*. Oxford University Press.

Gendron, M., Roberson, D., van der Vyver, J. M., & Barrett, L. F. (2014). Perceptions of emotion from facial expressions are not culturally universal: evidence from a remote culture. *Emotion*, 14 (2), 251.

Gerger, G., Leder, H., & Kremer, A. (2014). Context effects on emotional and aesthetic evaluations of artworks and IAPS pictures. *Acta Psychologica*, 151, 174–183.

Gerger, G., Leder, H., Tinio, P. P., & Schacht, A. (2011). Faces versus patterns: Exploring aesthetic reactions using facial EMG. *Psychology of Aesthetics, Creativity, and the Arts*, 5 (3), 241.

Gernot, G., Pelowski, M., & Leder, H. (2018). Empathy, einführung, and aesthetic experience: The effect of emotion contagion on appreciation of representational and abstract art using femg and scr. *Cognitive Processing*, 19 (2), 147–165.

Grèzes, J., Philip, L., Chadwick, M., Dezeache, G., Soussignan, R., & Conty, L. (2013). Self-relevance appraisal influences facial reactions to emotional body expressions. *PloS One*, 8 (2), e55885.

Guédron, M. (2011). *L'art de la grimace : Cinq siècles d'excès de visage*. Paris: Hazan.

Hadjikhani, N., Kveraga, K., Naik, P., & Ahlfors, S. P. (2009). Early (N170) activation of face-specific cortex by face-like objects. *NeuroReport*, *20* (4), 403.

Hermens, H. J., Freriks, B., Disselhorst-Klug, C., & Rau, G. (2000). Development of recommendations for SEMG sensors and sensor placement procedures. *Journal of Electromyography and Kinesiology*, *10* (5), 361–374.

Hess, U., & Fischer, A. (2013). Emotional mimicry as social regulation. *Personality and Social Psychology Review*, *17* (2), 142–157.

Hess, U., & Fischer, A. (2014). Emotional mimicry: Why and when we mimic emotions. *Social and Personality Psychology Compass*, *8* (2), 45–57.

Korb, S., Grandjean, D., & Scherer, K. R. (2010). Timing and voluntary suppression of facial mimicry to smiling faces in a go/nogo task—an emg study. *Biological Psychology*, *85* (2), 347–349.

Künecke, J., Hildebrandt, A., Recio, G., Sommer, W., & Wilhelm, O. (2014). Facial EMG responses to emotional expressions are related to emotion perception ability. *PloS One*, *9* (1).

Kwon, M., & Christou, E. A. (2018). Visual information processing in older adults: reaction time and motor unit pool modulation. *Journal of neurophysiology*, *120*(5), 2630-2639.

Lajante, M. M., Droulers, O., & Amarantini, D. (2017). How reliable are “state-of-the-art”

facial EMG processing methods?: Guidelines for improving the assessment of emotional valence in advertising research. *Journal of Advertising Research*, 57 (1), 28–37.

Leder, H., Gerger, G., Brieber, D., & Schwarz, N. (2014). What makes an art expert? emotion and evaluation in art appreciation. *Cognition and Emotion*, 28 (6), 1137–1147.

Likowski, K. U., Mühlberger, A., Gerdes, A. B. M., Wieser, M. J., Pauli, P., & Weyers, P. (2012). Facial mimicry and the mirror neuron system: Simultaneous acquisition of facial electromyography and functional magnetic resonance imaging. *Frontiers in Human Neuroscience*, 6.

Liu, T., Mu, S., He, H., Zhang, L., Fan, C., Ren, J., Zhang, J., He, M., Luo, W. (2016). The N170 component is sensitive to face-like stimuli: A study of Chinese Peking opera makeup. *Cognitive Neurodynamics*, 10 (6), 535–541.

McIntosh, D. N. (2006). Spontaneous facial mimicry, liking and emotional contagion. *Polish Psychological Bulletin*, 37, 31-42.

Niedenthal, P. M. (1990). Implicit perception of affective information. *Journal of Experimental Social Psychology*, 26(6), 505-527.

Niedenthal, P., Wood, A., Rychlowska, M., & Korb, S. (2017). Embodied simulation in decoding facial expression. In J. M. Fernández-Dols & J. A. Russell (Eds.), *The science of facial expression* (pp. 397–414). Oxford University Press.

Niedenthal, P. M. (2007). Embodying emotion. *Science*, 316 (5827), 1002–1005.

Niedenthal, P. M., & Brauer, M. (2012). Social functionality of human emotion. *Annual Review of Psychology, 63*, 259–285.

Niedenthal, P. M., & Maringer, M. (2009). Embodied emotion considered. *Emotion Review, 1* (2), 122–128.

Niedenthal, P. M., Mermillod, M., Maringer, M., & Hess, U. (2010). The simulation of smiles (SIMS) model: Embodied simulation and the meaning of facial expression. *Behavioral and Brain Sciences, 33* (06), 417–433.

Niedenthal, P. M., Rychlowska, M., & Szarota, P. (2013). Embodied simulation and the human smile: Processing similarities to cultural differences. *Personality Dynamics: Embodiment, Meaning Construction, and the Social World*, 143–160.

Philip, L., Martin, J.-C., & Clavel, C. (2018). Rapid facial reactions in response to facial expressions of emotion displayed by real versus virtual faces. *I-Perception, 9* (4), 2041669518786527.

Pillette, L., Jeunet, C., Mansencal, B., N’Kambou, R., N’Kaoua, B., & Lotte, F. (2017). Peanut: Personalised emotional agent for neurotechnology user-training. *7th International BCI Conference, Sep 2017, Graz, Austria*.

Prochazkova, E., & Kret, M. E. (2017). Connecting minds and sharing emotions through mimicry: A neurocognitive model of emotional contagion. *Neuroscience & Biobehavioral Reviews, 80*, 99–114.

Reisenzein, R., Studtmann, M., & Horstmann, G. (2013). Coherence between emotion and facial expression: Evidence from laboratory experiments. *Emotion Review*, 5 (1), 16–23.

Rymarczyk, K., Biele, C., Grabowska, A., & Majczynski, H. (2011). EMG activity in response to static and dynamic facial expressions. *International Journal of Psychophysiology*, 79 (2), 330–333.

Sagiv, N., & Bentin, S. (2001). Structural encoding of human and schematic faces: Holistic and part-based processes. *Journal of Cognitive Neuroscience*, 13 (7), 937–951.

Sato, W., Fujimura, T., Kochiyama, T., & Suzuki, N. (2013). Relationships among facial mimicry, emotional experience, and emotion recognition. *PloS One*, 8 (3), e57889.

Schaeffer, J.-M. (2015). *L'expérience esthétique*. Editions Gallimard.

Schilbach, L. (2016). The neuroscience of mimicry during social interactions. In U. Hess & A. H. Fischer (Eds.), *Emotional mimicry in social context* (Vol. 72, pp. 72–89). Cambridge University Press.

Seibt, B., Mühlberger, A., Likowski, K. U., & Weyers, P. (2015). Facial mimicry in its social setting. *Frontiers in Psychology*, 6.

Soussignan, R., Chadwick, M., Philip, L., Conty, L., Dezechache, G., & Grèzes, J. (2013). Self-relevance appraisal of gaze direction and dynamic facial expressions: Effects on facial electromyographic and autonomic reactions. *Emotion*, 13 (2), 330.

Stamatopoulou, D. (2018). Empathy and the aesthetic: Why does art still move us?. *Cognitive processing*, 19(2), 169-186.

Tateyama, H. (2016). Ritual of superiority: Tolai Tubuan performance at the national mask festival in Papua New Guinea. *Journal de la Société des Océanistes* (1), 21–36.

Urgesi, C., Mattiassi, A. D., Buiatti, T., & Marini, A. (2016). Tell it to a child! A brain stimulation study of the role of left inferior frontal gyrus in emotion regulation during storytelling. *NeuroImage*, 136, 26-36.

Van Boxtel, A. (2010). Facial EMG as a tool for inferring affective states. In *Proceedings of measuring behavior* (pp. 104–108).

Wheatley, T., Weinberg, A., Looser, C., Moran, T., & Hajcak, G. (2011). Mind perception: Real but not artificial faces sustain neural activity beyond the N170/VPP. *PloS One*, 6 (3), e17960.

Winkielman, P., Niedenthal, P., Wielgosz, J., Eelen, J., & Kavanagh, L. C. (2015). Embodiment of cognition and emotion. In M. E. Mikulincer, P. R. Shaver, E. E. Borgida, & J. A. Bargh (Eds.), *Apa handbook of personality and social psychology* (Vol. 1, pp. 151–175).

Wollmer, M. A., de Boer, C., Kalak, N., Beck, J., Götz, T., Schmidt, T., . . . others (2012). Facing depression with botulinum toxin: a randomized controlled trial. *Journal of Psychiatric Research*, 46 (5), 574–581.

Yuki, M., Maddux, W. W., & Masuda, T. (2007). Are the windows to the soul the same in the East and West? Cultural differences in using the eyes and mouth as cues to

recognize emotions in Japan and the United States. *Journal of Experimental Social Psychology*, 43 (2), 303–311.

Supplementary material

The OSF repository includes:

1. experimental protocol script,
2. raw data and EMG analysis script,
3. analysis script.
4. Electrode positioning figure
5. Frontalis class sorting figures

The OSF repository URL:
https://osf.io/yk7hz/?view_only=972e5179b5904fcba5b1df70416b934