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No evidence for modulation of facial mimicry by attachment tendencies in adulthood: an EMG investigation

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ABSTRACT
Mimicking another individual functions as a social glue: it smoothens the interaction and fosters affiliation. Here, we investigated whether the intrinsic motivation to affiliate with others, stemming from attachment relationships, modulates individuals' engagement in facial mimicry (FM). Participants (N = 100; M_{Age} = 24.54 years, SD_{Age} = 3.90 years) observed faces with happy, sad, and neutral expressions, while their facial muscle activity was recorded with electromyography. Attachment was measured with the Attachment Styles Questionnaire, which provides a multidimensional profile for preoccupied and dismissing styles. It was proposed that the preoccupied and dismissing styles are characterized by high and low intrinsic affiliation motivation, respectively, and these were hypothesized to manifest in enhanced and diminished FM. Participants showed happy and sad FM, yet attachment styles did not significantly predict FM. Bayes Factor analyses lend evidence favoring the null hypothesis, suggesting that adult attachment do not contribute to FM.

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Facial mimicry; electromyography (EMG); attachment styles; affiliation motivation

From early in development, social interactions include the rapid mirroring of others' facial expressions (De Klerk et al., 2019; Seibt, Mühlberger, Likowski, & Weyers, 2015). This widely studied phenomenon, facial mimicry (Chartrand & Van Baaren, 2009; Dimberg, 1982; Hess & Fischer, 2016), entails that individuals display a facial expression congruent with that of their interaction partner within a few milliseconds upon its observation (Korb et al., 2010; Lundquist & Dimberg, 1995). As such, facial mimicry takes place outside of one's awareness (Dimberg et al., 2000; Mancini et al., 2013; Moody et al., 2007). In order to capture the subtlety and the rapidity with which facial mimicry occurs, often facial electromyography (EMG) is employed (Dimberg, 1988; Dimberg & Karlsson, 1997; Tassinary et al., 1989). Candidate muscles recruited during specific emotional expressions are selected and their activity is recorded with small surface electrodes. For instance, to assess mimicry of happy expressions, the muscle activation of the cheek's zygomaticus major (ZM; Dimberg et al., 2000) is recorded, whereas the response to a sad expression is detected in the activity of the corrugator supercilii muscle (CS; Bourgeois & Hess, 2008), responsible for frowning.

What is most remarkable about facial mimicry is its central role in social interactions. Findings suggests that interpersonal mimicry fosters affiliations (Bourgeois & Hess, 2008; Chartrand & Bargh, 1999; Lakin et al., 2008, 2003) and promotes closeness between interaction partners (Cheung et al., 2015; Stel & Vonk, 2010), and it is thought to be implicated in emotion sharing and empathic processes (Hess & Fischer, 2013, 2014; McIntosh, 2006; Sato et al., 2013). Furthermore, the extent to which individuals mimic one another is largely dependent on their motivation within a certain

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context. For instance, cooperative contexts promote higher empathy and facial mimicry than competitive contexts (Lanzetta & Englis, 1989), and general affiliative goals enhance mimicry responses (Kavanagh & Winkielman, 2016; Wang & Hamilton, 2012). Yet, despite the abundance of evidence for its social function in adults (for a comprehensive review of the literature see Hess & Fischer, 2016), surprisingly little is known about the mechanisms responsible for this social behavior.

In order to understand the mechanisms underlying social mimicry, we must investigate how one's experiences during early development contributes to its selective modulation. In contrast to the traditional view postulating neonates' inborn capacity to mimic (A. Meltzoff & Moore, 1977; A. N. Meltzoff & Moore, 1983), studies have failed to replicate earlier findings (Heyes, 2016; Oostenbroek et al., 2019, 2016; Ray & Heyes, 2011). It has thus been posited that the capacity to mirror others' facial expressions lies in the early parent-infant relationships (Catmur et al., 2009; Heyes & Ray, 2000; De Klerk et al., 2019; Rayson et al., 2017). From the first days of life, babies engage in face-to-face interactions with their caregivers, and it has been shown that these are largely characterized by parental imitation (Beebe et al., 2010; Bigelow et al., 2015; Gergely & Watson, 1996; Jones, 2006; Markova, 2018; Užgiris et al., 1989). It is thought that these early imitogenic experiences provide babies with the learning opportunity for associations between the observation of one action and its execution, and hence the basis of facial mimicry (Ray & Heyes, 2011). In support of this view, it has been shown that imitogenic experiences at age 2 months predict infants' motor system activation in observation of the same action at age 9 months by fostering the formation of sensory-motor couplings (Rayson et al., 2017). Accordingly, evidence for facial mimicry of emotions has been found from the age of 5 months on (Datyner et al., 2017; Geangu et al., 2016; Isomura & Nakano, 2016; Kaiser et al., 2017; Vacaru et al., 2019).

Not only do imitogenic experiences during early interactions foster learning of sensory-motor associations, but the quality of these early interactions shapes individuals' intrinsic motivation for affiliation with others (Bohlin et al., 2000; Groh et al., 2017; Schwartz et al., 2007). Based on the quality of infant-caregiver interactions, individuals form secure or insecure attachments (Ainsworth, 1979; Ainsworth et al., 1978; Bowlby et al., 1989), which are thought to remain stable throughout the lifespan (Cassibba et al., 2017; Verhage et al., 2016). The attachment theory posits that parents' promptness to responding to their infants' cues and needs is a signature of secure relationships, while inconsistent or lacking responsiveness is characteristic of insecure attachment relationships (Ainsworth et al., 1978). Insecure attachment relationships can be divided into dismissing (avoidant in childhood) and preoccupied (resistant in childhood) styles, that are characterized by different strategies to adapt to the early social environment with their primary caregivers. Individuals with a dismissing attachment style show avoidant behaviors and tend to distance themselves from others. Instead, individuals with an anxious/preoccupied style are characterized by preoccupation in relationships and fear of abandonment, and, hence, tend to show a strong desire for proximity with others (Mikulincer et al., 2003). Accordingly, dismissing and preoccupied individuals have been shown to score low and high on intrinsic motivation for affiliation, respectively (Schwartz et al., 2007). Individuals thus may recruit different behavioral strategies in social encounters, depending on their motivation for affiliation.

Developmental research has revealed that 3-year-old children's facial mimicry is predicted by their attachment patterns with primary caregivers. In particular, children characterized by anxious/preoccupied attachment showed enhanced facial mimicry to sad facial expressions, suggesting that individuals characterized by a high desire for affiliation recruit more affiliative behaviors (Vacaru et al., 2019). Likewise, secure but not insecure 5-year-olds were found to display more facial mimicry toward a peer whom they wanted to affiliate with (Vacaru et al., 2020). Given the long lasting effects of early attachment on affiliation motivations into adulthood (Cassibba et al., 2017), we hypothesized that attachment patterns would also predict adults' facial mimicry, as means of affiliation in interpersonal relationships. This is because the way adults perceive themselves in close attachment relationships also manifest in their social and coping behaviors (Alexander et al., 2001). Indeed, there is some evidence that adults with a dismissing attachment style display atypical mimicry by showing a smile-like response to angry faces, interpreted as a possible attempt to suppress negative emotion processing (Sonnby-Borgstrom & Jonsson, 2004). However, the scope of these findings was limited to dismissing attachment style within a small sample of only twelve participants. Furthermore, dismissing individuals' facial reactions only differed from non-dismissing individuals after a prolonged exposure to the emotional stimuli (>2000 ms). To address these shortcomings, our study aimed to examine the contribution of preoccupied-anxious and dismissing attachment to facial mimicry during adulthood with a considerably larger sample size. Additionally, we used continuous measures of attachment styles to best capture non-categorical individual differences within the general population.

Taken together, affiliation goals affect adults' facial mimicry, but the mechanisms underlying this ubiquitous behavior are poorly understood. Attachment styles affect an individual's intrinsic motivation for affiliation (Schwartz et al., 2007), and may drive individual differences in affiliative behaviors. To investigate these potential effects of adult attachment on facial mimicry, this study assessed facial mimicry of happy, sad, and neutral facial expressions using EMG. Participants' attachment styles were assessed via self-report, a method, which has been shown to reflect implicit attachment-related attitudes (Shaver & Mikulincer, 2002a, b). We hypothesized that attachment-related attitudes in close relationships would influence implicit social behaviors, such as mimicry, in line with prior adult evidence that showed that adult attachment styles influence mimicry. Particularly, we expected that adults would mimic happy and sad facial expressions by recruiting the corresponding muscles (i.e. an increase in the ZM activation and a decrease in the CS activation for happy and the opposite pattern for sad), while no differences in muscle activation were expected for neutral expressions. Furthermore, we hypothesized that individuals characterized by preoccupied attachment styles would show enhanced facial mimicry, in accordance with a strong desire for proximity (Lavy et al., 2010). Likewise, dismissing attachment styles were hypothesized to lead to diminished facial mimicry, in line with these individuals' tendency to disengage from social interactions (Dewitte et al., 2008).

Method

Participants

A total of 100 participants (68 females; M_{Age} = 24.54 years, SD_{Age} = 3.90 years, range 18 to 35 years, primarily White European) took part in the current study. Participants were recruited through the Radboud University online research registration system. An a priori power analysis conducted with G* Power software (Faul et al., 2007) revealed a minimum sample size of 100 given an expected small to moderate effect (based on Vacaru et al., 2019) and a statistical power of 95%. Participants were compensated with €10 or one study credit. The study was approved by the ethics committee of the Faculty of Social Sciences at the BLIND (ECSW2016-0905-396) and was conducted according to the ethical standards of the Declaration of Helsinki. Written informed consent was obtained from all participants before the start of the experimental procedure.

Attachment

Attachment was assessed with the Attachment Styles Questionnaires (ASQ; Van Oudenhoven et al., 2003). The AQS is a self-report questionnaire assessing adults' attachment styles on four continuous dimensions, namely secure (7 items), preoccupied (7 items), dismissing (5 items) and fearful (5 items). These 24 items are answered on a 5-point Likert scale (−1 = *strongly disagree*, −0.5 = *disagree*, 0 = *neutral*, 0.5 = *agree*, 1 = *strongly agree*; Hofstee & Ten Berge, 2004; Mosterman & Elf, 2015). The choice for the ASQ was guided by its strong psychometric properties and validation with several samples, including a Dutch one (Bakker, van Oudenhoven, & van der Zee, 2004; Hofstra, 2009; Polek et al., 2008). Furthermore, the ASQ instrument was developed based on the Relationships Scale Questionnaire (RSQ; Griffin & Bartholomew, 1994) with the aim to improve its psychometric properties. It is a psychometrically sound instrument to assess general attachment styles in close relationships. However, it is important to note that it is not a clinical assessment of early parent-caregiving experiences (Ravitz et al., 2010; Roisman et al., 2007). The ASQ has shown acceptable test-retest reliability and good construct validity (Hofstra, van Oudenhoven, & Buunk, 2005). The preoccupied and dismissing subscales were used in the analyses. In our sample, the dismissing and the preoccupied subscales yielded Cronbach's alpha coefficients of .74 and .85 respectively, suggesting moderate to high internal consistency.

EMG paradigm and stimulus material

To test facial responses, images of facial expressions of happy, sad and neutral emotions of nineteen White female models were selected from the Radboud Faces Database (Langner et al., 2010). From each model one example of a happy, sad, and neutral expression was selected. Each stimulus was presented four times, resulting in a total of 228 trials. Pictures were presented in a pseudo-randomized manner. The presentation lists were prepared with MIX (Van Casteren & Davis, 2006) with the following constraints: each model could not be presented more than once consecutively, and each emotion could not be presented more than twice in a row.

Each trial lasted 4000 ms and unfolded as follows: 1000 ms fixation cross, 2000 ms stimulus presentation and a 1000 ms inter-stimulus interval (see Figure 1). With the onset of the fixation cross a brief, a short beep was played as an attention getter. Pictures were displayed on a 17" monitor (1280 x 1024 pixels) and watched from 60 cm distance. The experiment was programmed with Presentation software (Version 17.1, Neurobehavioral Systems, Inc., Berkeley, CA).

Procedure

Participants were welcomed in the lab and explained the procedure of experiment. The experimenter then cleaned the facial areas of the muscle sites of interest (CS, ZM; see Figure 1) and two additional areas for the ground electrodes on the forehead and the reference electrode on the mastoid bone behind the ear. The skin was cleaned using a scrubbing gel (Nuprep Skin Prep Gel), medical alcohol, and cleansing wipes. Moreover, a conductive OneStep clear gel was added to the already pre-gelled electrodes to improve impedances. Thereafter, the EMG electrodes were placed on the left side of the

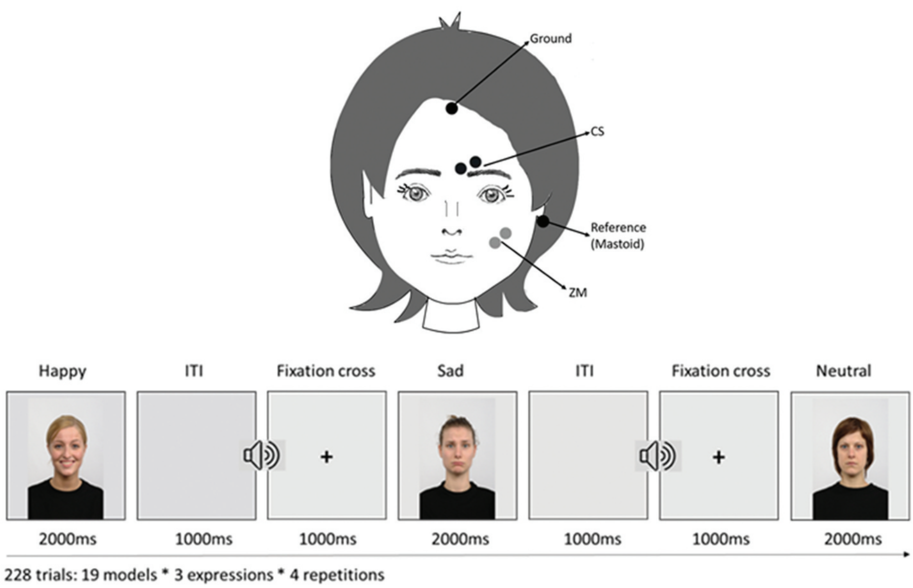

Figure 1. Schematic illustration of the study design and the positions of the electrodes assessing the activation over the ZM and CS facial muscles.

cheek, based on facial EMG guidelines by Fridlund and Cacioppo (1986). Once the electrodes were applied, the experimenter checked the impedances and the signal quality. When the signal quality was not within the 100 Hz range or impedances were too high (>10 ohm), more gel was added to the electrodes and the skin was further cleaned. Participants were instructed to simply look at the pictures on the screen. The experiment lasted approximately 15 minutes. After the stimulus presentation, the electrodes were removed, and the participants were invited to fill in the attachment questionnaire. Finally, participants were debriefed, compensated, and thanked for their participation.

EMG recordings and data reduction

EMG responses were measured with Brain Vision Recorder (GmbH, 2009). Disposable 4 mm Ambu-Neuroline 700 Ag/AgCl surface electrodes were used to record muscle activation with a bipolar configuration and 10 mm inter-electrode distance between their centers (Cacioppo et al., 1986, 2000). A sampling rate of 2500 Hz was used, and a low cutoff of 10 Hz and a high cutoff of 1000 Hz were applied.

EMG data were pre-processed with Matlab (MathWorks, 2015). Trials were filtered using a band rejection filter of 50 Hz, 0.2 bandwidth and order 4. Next, an infinite impulse response (IIR) zero phase shift Butterworth filter with a low cutoff frequency of 20 Hz and high cutoff frequency of 500 Hz, order 8 was applied (De Luca, 2003). After the data pre-processing, the signal was rectified and artifact rejection on individual trials was conducted and trials with amplitudes ± 3 SD from the mean amplitude of the trials of each subject were rejected. The mean number of trials for the happy condition was 54.95, for the sad condition 55.37, and for the neutral condition 56.39. Thereafter, EMG data were standardized within participants and within muscle sites to reduce the impact of high values and allow comparisons across muscle sites (Dawson et al., 2007). Next, we performed the baseline correction by subtracting the baseline (1000 ms) mean activation from each data point of the window of interest (0–2000 ms).

Statistical analyses

Visual inspection of the data suggested a peak in amplitude between 100 ms and 400 ms across all conditions and muscles. This peak might represent a startle response, unrelated to the experimental conditions, as it has also been found in other previous studies (Dimberg & Peterson, 2000; Moody et al., 2007). Hence, data were analyzed for the time window between 400 ms and 2000 ms after stimulus onset.

To address the first hypothesis, namely that participants mimicked the facial expressions, the mean amplitude (400 ms – 2000 ms) for each muscle in each condition was calculated and further analyzed in a 3 (Emotion: happy, sad, neutral) * 2 (Muscle: CS, ZM) repeated measures ANOVA with EMG activation as dependent variable. Planned paired samples t-tests were performed to test the hypothesis that the ZM activation is significantly higher than the CS in the happy condition and that the CS activation is significantly higher than the ZM in the sad condition. No significant difference between the two muscles were expected in the neutral condition.

To test the second hypothesis, namely that dismissing and preoccupied attachment styles differently predict facial mimicry, we ran two hierarchical regression models, one with sad and one with happy mimicry as the dependent variable. In the first step, we tested the main effects of preoccupied and dismissing attachment, while in the second step we tested the interaction effect between preoccupied and dismissing attachment on facial mimicry. For these analyses, we computed a mimicry score by subtracting the CS mean activation from the ZM mean activation as an index for happy mimicry, and by subtracting the ZM mean activation from the CS mean activation as an index for sad mimicry. A positive score indicates happy and sad mimicry, respectively. Furthermore, we computed an interaction term between preoccupied and dismissing attachment styles (P X D), to test whether attachment styles interactively predict facial mimicry. First, the predictors were centralized and then multiplied with each other. Analyses were performed with SPSS IBM 25 (IBM Corp, 2017). Additional analyses were performed with JASP 0.9.2 using a Bayesian approach to quantify evidence supporting our hypotheses. The Bayesian approach to hypothesis testing verifies the likelihood of the data under each hypothesis (i.e. both the null hypothesis and the alternative hypothesis). The Bayes Factor (BF) is the statistic that compares the probability of a set of observed data under two models. BF_{10} represents the odds for the alternative hypothesis, whereas $1/BF_{10}$ (i.e. BF_{01}) represents the odds for the null hypothesis. Guidelines suggest that $BF_{10} < 0.33$ provides strong or 'substantial' evidence for the null hypothesis, $BF_{10} > 3$ provides strong evidence for the alternative hypothesis, and a BF between 0.33 and 3 provides only anecdotal support either way (Rouder & Morey, 2012).

Results

Facial mimicry

Figure 2 illustrates the EMG signal of the CS and the ZM muscles in the happy, sad, and neutral conditions, respectively. The repeated measures ANOVA yielded a significant interaction between condition (happy, sad, neutral) and muscle (ZM, CS), $F(2, 98) = 9.19$, $p < .001$, $\eta_p^2 = .16$. The $BF_{10} = 646.66$ with $P(M|Data) = 488.00$ represents decisive evidence for the alternative hypothesis (Jarosz & Wiley, 2014), suggesting that the statistical model including the condition per muscle interaction is 647 more likely than the null model, and the posterior probability of the model given our data compared to the null model is 488 higher. Together, this result indicates muscle activation differs

Figure 2. Time course of standardized EMG activation of the CS (orange) and ZM (blue) muscles, in response to happy, sad and neutral facial (2000 ms). The shadings around each line represent the standard error of the mean.

across conditions. Further, a significant main effect of condition ($F(2, 98) = 6.59$, $p = .002$, $\eta p^2 = .12$; $BF_{10} = 2.41$, P(M|Data) = 0.02) emerged, indicating differences in activation amongst the different emotions, whereas the main effect of muscle was not significant, $F(2, 98) = 0.04$, $p = .841$; $BF_{10} = 0.09$, P (M|Data) = 0.00.

Planned comparisons were conducted with paired samples t-tests to investigate which muscle showed higher activation for each emotion. The results for the happy stimulus showed a significantly higher ZM mean activation ($M = 0.01$, $SD = 0.05$) compared to the CS mean activation ($M = -0.06$, $SD = 0.31$; $t(99) = 2.18$, $p = .031$; $BF_{10} = 2.09$), suggesting that the alternative hypothesis for happy mimicry is twice more likely than the null hypothesis. The posterior distribution of the standardized effect size yielded a median effect of 0.21 with a central 95% credible interval (CI) ranging between 0.03–0.41. For sad expressions, the CS mean activation ($M = -0.02$, $SD = 0.15$) was higher ($t(99) = 1.95$, $p = .054$; $BF_{10} = 1.33$) than the ZM ($M = -0.01$, $SD = 0.05$), with a posterior median standardized effect size of 0.19 (CI: 0.03–0.38), suggesting positive, although weak, evidence for the alternative hypothesis for sad facial mimicry. Unexpectedly, the neutral condition revealed a significantly higher ($t(99) = 3.19$, $p = .002$; $BF_{10} = 12.52$) CS mean activation ($M = 0.04$, $SD = 0.01$) than the ZM mean activation ($M = -0.01$, $SD = 0.03$), with a posterior median standardized effect size of 0.31 (CI: 0.12–0.51), lending substantial support to the alternative hypothesis that neutral expressions elicit a distinct profile of muscle activation resembling sad expressions. A sensitivity analysis with repeated measures ANOVA with emotion (happy, sad, neutral) * muscle (zygomaticus, corrugator) * participant gender (females, males) was performed to exclude an effect of participant gender on facial mimicry. Results did not reveal a significant three-way interaction $F(2, 97) = .41$, $p = .668$, suggesting no effect of gender.

The relation between attachment styles and facial mimicry

Two separate hierarchical regression analyses were conducted to investigate whether attachment styles (dismissing and preoccupied) predict facial mimicry responses to sad and happy expressions, respectively. Before performing the regression analyses, the predictors were standardized to avoid multicollinearity (Knight, 2018), and an interaction term was computed between preoccupied and dismissing attachment styles (P X D). In the first step, the main effects of preoccupied and dismissing attachment styles were tested, whereas in the second step, their interaction effect on facial mimicry was examined. The results revealed no significant main or interaction effects of attachment on happy nor sad facial mimicry. Frequentist and Bayesian results of the hierarchical regression analyses are summarized in Table 1. Altogether, these findings suggest moderate to strong evidence for the null hypothesis positing no relation between adult attachment styles and mimicry.

Discussion

In the current study, we investigated the relation between adult attachment styles and affiliative behaviors through means of facial mimicry of emotional expressions. We found evidence for happy and sad facial mimicry. Moreover, Bayesian analyses yielded evidence in favor of the null hypothesis, that is, that there is no relation between mimicry and attachment styles.

Mimicry of happy and sad expressions

We examined the EMG responses of the ZM and CS muscles in response to happy, sad, and neutral facial expressions. Consistent with our hypothesis, the inferential and frequentist analyses provided decisive evidence for differential muscle activation in response to different emotions. Evidence emerged that participants reacted with stronger ZM activation and lower CS activation in response to happy facial expressions and with the opposite muscle pattern to sad facial expressions, suggesting happy and sad facial mimicry. Although these specific effects were statistically significant, the evidence

Table 1. Hierarchical regression analysis examining the effects of preoccupied (P) and dismissing (D) attachment styles and their interaction on facial mimicry of sad or happy facial expressions (N = 100).

	Sad facial mimicry									Happy facial mimicry								
	b	SE	β	t	p	$(\Delta)R^2$	BF_{10}	BF_{01}	P(M|Data) (CI)	b	SE	β	t	p	$(\Delta)R^2$	BF_{10}	BF_{01}	P(M|Data) (CI)
Model 1 (main effects)					.976	.000								.589	.011			
(Constant)	0.03	0.02		1.54	.126					0.03	0.01		3.12	.023				
Preoccupied (P)	0.00	0.01	0.02	0.19	.848					−0.00	0.01	−0.01	−0.12	.902				
Dismissing (D)	0.00	0.01	0.02	0.17	.864					−0.02	0.02	−0.101	−0.99	.324				
Model 2 (2-way interaction)					.631	.017								.094	.029			
(Constant)	0.04	0.02		1.92	.06					0.07	0.04		1.56	.123				
Preoccupied (P)	0.00	0.01	0.00	0.00	.99		0.21	4.71	0.87 (−0.00–0.00)	0.00	0.01	0.01	0.12	.902		0.34	2.97	0.83 (−0.00–0.00)
Dismissing (D)	0.00	0.01	0.01	0.75	.91		0.21	4.73	0.84 (−0.00–0.00)	−0.02	0.02	−0.10	−0.92	.358		0.22	4.59	0.78 (−0.00–0.00)
P X D	0.02	0.02	0.13	1.30	.20		0.46	2.18	0.80 (0.00–0.037)	−0.06	0.04	−0.17	−1.69	.094		0.74	1.36	0.68 (0.00–0.00)

Note. b = unstandardized regression coefficient; SE = standard error; β = standardized regression coefficient; t = t-value; p = significance level; $(\Delta)R^2$ = additional variance explained by the second model compared to the first. Significance level was set at $p < .05$ (two-tailed); BF_{10} = the odds for the alternative hypothesis; (BF_{01}) = the odds for the null hypothesis; P(M|Data) = Posterior probability of our model given the data compared to the null model; CI = 95% credible interval.

for happy and sad facial mimicry was weak, yet comparable to previous findings using similar methods (e.g., Lundquist & Dimberg, 1995; Vacaru et al., 2019), warranting some caution in the interpretation of these findings.

Facial EMG studies differ in the type of stimuli used to elicit mimicry. In this study, we used prototypical standardized stills of emotional facial expressions (Radboud Faces Database, Langner et al., 2010). The face carries a wealth of social information, for instance, through head orientation, gaze direction, or intensity of an expressed emotion. These different aspects have implications for emotion perception and attention to specific facial cues (e.g., Loomis et al., 2008). This is why we chose a standardized stimulus set from an established database. It is thus possible that the stimuli look less genuine and are less ecologically valid. Some studies suggest that dynamic facial expressions induce more mimicry than static stimuli (e.g., Rymarczyk et al., 2016; Sato et al., 2008). Likewise, the genuineness of an expression influences the extent to which this is mimicked (Krumhuber et al., 2014; Maringer et al., 2011). Our findings regarding happy and sad facial mimicry are nevertheless comparable to previous findings (e.g., Likowski et al., 2008; Lundquist & Dimberg, 1995; Vacaru et al., 2019) and provide evidence for mimicry in standardized circumstances.

Different studies employed different methods to standardize the EMG signal to allow for meaningful comparisons across muscles and conditions. A comprehensive overview of EMG methodologies exceeds the scope of this paper, but the two most commonly used methods are the standardization within muscle and condition to z-scores and percentage change scores. In this study, we chose to use z-score transformations that have the advantage of bringing the muscle activation from different sites (CS, ZM) on the same scale and as such allow direct comparisons across muscles (e.g., Hess & Blairy, 2001; Oberman et al., 2009; Vacaru et al., 2019). Another advantage of this method is that it can control for individual differences in EMG amplitudes (caused by e.g., muscle morphology, gender). However, one disadvantage is that it may also lead to a reduction of experimental effects of individual differences (i.e. attachment) and group differences (Bush et al., 1993). Here, the decision for Z-scores to compare muscles and account for muscle morphology differences yielded a conservative measure of facial muscle activation.

Mimicry of neutral expressions

Unexpectedly, we found an EMG activation profile for neutral expressions resembling the response for sad, suggesting thus that neutral facial expressions might have been evaluated as having a negative valence, potentially due to their ambiguity (Phillips & Allen, 2004). The increased CS activation to neutral faces thus might have been a frown due to the cognitive load when interpreting the stimulus (Lishner et al., 2008; Van Boxtel et al., 1996). Past evidence has revealed CS activity for neutral faces similar to other negative expressions (i.e. disgust, anger; Künecke et al., 2014; Vrana & Gross, 2004).

Modulation of mimicry by attachment tendency

Next, we examined whether preoccupied and dismissing attachment styles predicted mimicry responses to happy and sad faces. The analyses revealed no significant associations between preoccupied and dismissing attachment and facial mimicry of happy and sad expressions. On the contrary, the results of our Bayesian analyses lend substantial evidence in favor of the null hypothesis, indicating that participants' attachment was not related to their facial mimicry of others' facial emotional expressions.

Attachment styles can be seen as a proxy for affiliation motivation that can lead to differences affiliative behaviors, such as in how individuals mimic another person's facial expressions. Previous work with children indeed showed that attachment modulate facial mimicry of emotional facial expressions (Vacaru et al., 2020, 2019). Our findings thus raise important questions about the role of attachment for the modulation of affiliative behaviors throughout the lifespan. While children have relatively few social partners and have their parents fulfil attachment functions most often, adults' social-emotional life is richer and more diverse. Thus, other factors might have a stronger impact on affiliative mimicry behaviors in adults, such as social status (Bourgeois & Hess, 2008) or attractiveness of the model (Karremans & Verwijmeren, 2008; for a review see Hess & Fischer, 2016).

The findings of our study differ from two previous studies that did report evidence for an association between adult attachment and mimicry (Hall et al., 2012; Sonnby-Borgstrom & Jonsson, 2004). However, these studies point to this relationship being present only under specific circumstances. For instance, Hall et al. (2012) examined the impact of attachment, in combination with attractiveness, on mimicry of opposite-sex models only. Sonnby-Borgstrom and Jonsson (2004) also assessed attachment styles, in combination with emotional empathy, and reported generally more positive affect (indexed only by zygomaticus muscle activation) irrespective of the emotion observed, in a small sample of dismissing individuals, compared to the rest of the sample. Taken together, this evidence (Hall et al., 2012; Sonnby-Borgstrom & Jonsson, 2004) remains inconclusive with respect to the specific effect of attachment on mimicry behaviors.

Our study instead presents EMG findings based on a large sample (N = 100) compared to previous facial mimicry studies (e.g., N = 61 in Sonnby-Borgstrom & Jonsson, 2004; N = 25 in Likowski et al., 2008; N = 68 in Olszanowski et al., 2020; etc.). This large sample allowed us to not only replicate the phenomenon of mimicry, but also provide convincing evidence that attachment does not modulate adults' affiliative behaviors as manifested in facial mimicry.

It is important to note that in our study, we assessed attachment styles in the non-clinical range, and clinically relevant attachment insecurity (e.g., AAI, Main & Goldwyn, 1998) may still affect adults' behaviors to achieve affiliation goals. In accordance with this notion, Ardizzi et al. (0, 2016) demonstrated that older children and adolescents with a story of maltreatment show altered facial mimicry responses to positive and negative expressions. One future research avenue could be the investigation the modulatory role of early attachment on affiliative behaviors in developing population with subclinical and clinical attachment patterns. Moreover, attachment security to one's primary caregiver is thought to foster the development of internal working models (Bowlby, 1973), or in other words, schemas that children tend to apply in their future adult relationships (Pietromonaco & Barrett, 2000). In our study, we assessed adult attachment via self-report with respect to close relationships, and not specifically their early parent-child relationship (Cozzarelli et al., 2000). This distinction may contribute the lack of a relation between adult attachment styles and facial mimicry in our study, and may also represent a key methodological difference with previous findings with children (Vacaru et al., 2020, 2019).

In conclusion, this study provides important evidence that adult attachment styles do not contribute to the modulation of social affiliative behaviors through means of facial mimicry, in contrast to previous findings on young children (Vacaru et al., 2020, 2019). These results indicate that attachment styles in adults may not be a strong determinant of social affiliative behaviors. Yet, more research is needed to understand the contribution of different aspects attachment to social affiliations across the lifespan.

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Data availability statement

The data described in this article are openly available at https://data.donders.ru.nl/collections/di/dcc/DSC_2017.00097_354.

Open scholarship

This article has earned the Center for Open Science badges for Open Data and Open Materials through Open Practices Disclosure. The data and materials are openly accessible at https://data.donders.ru.nl/collections/di/dcc/DSC_2017.00097_354.

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