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Returning a smile: Initiating a social interaction with a facial emotional expression influences the evaluation of the expression received in return

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ABSTRACT

Face-to-face social interactions are characterized by the reciprocal exchange of facial emotions between interaction partners. Typically, facial emotional expressions have been studied in passive observation paradigms, while interactive mechanisms remain unknown. In the current study we investigate how sending a facial emotional expression influenced the evaluation of an emotional expression received in return. Sixty-eight participants were cued to direct a facial emotional expression (happy, angry, neutral) towards a virtual agent in front of them. The virtual agent then responded with either the same or another emotional expression (happy, angry). Evaluation of the response expressions was measured via ratings of valence and arousal as well as EMG recordings of the *M. corrugator supercilii* and the *M. zygomaticus major*. Results revealed a significant interaction between the emotion of the initial facial expression and the response expression. Valence of happy response expressions were increased when participants had initially displayed a smile compared to a neutral expression or a frown. This was also reflected in the EMG responses. Initiating an interaction with a smile increased Zygomaticus activation for happy relative to angry response expressions compared to when the interaction was initiated with a frown. In contrast, no interplay of the initial and the response expression was observed in the Corrugator. These findings demonstrate that smiling or frowning at another person can modulate socio-emotional processing of subsequent social cues. Therefore, the present study highlights the interactive nature of facial emotional expressions.

1. Introduction

Human nature is inherently social and facial expressions are fundamental in coordinating social behavior. Facial expressions are ubiquitous in interpersonal encounters (Cappella, 1997) and are thought to communicate social intentions (Hess & Fischer, 2013, 2022). Smiles, for example, indicate affiliative intentions that allow to establish and orchestrate social relations (Hess et al., 2000; Martin et al., 2017), while angry expressions indicate threat (Lundqvist et al., 1999; Reed et al., 2014). Importantly, in a social setting, facial expressions of both interactive partners do not appear in isolation but are reciprocally exchanged, i.e. when we smile at other people, our interaction partners tend to return these smiles (Cappella, 1997; Heerey & Crossley, 2013; Hess & Bourgeois, 2010). This coordinated exchange of facial emotional expressions might help to establish social bonds. In turn, if an interaction partner answered a smile with an incongruent, angry expression, this would reflect a salient social signal that might indicate a non-affiliative social intention or even a threat. Importantly, the intent of the sender might also influence how a facial expression received in return is evaluated (Fischer & Hess, 2017). When a sender has a strong intent to affiliate with another person, a smile answered with an angry expression might be interpreted as a social rejection and lead to a more negative evaluation compared to when the sender does not have a strong affiliative intent. Furthermore, there might be an influence of the social relation between interacting partners, as a person's wish to affiliate might differ depending on the person of the interaction partner. This interdependence of facial expressions in the sender and in the perceiver suggests an important influence of social context in the processing and evaluation of facial expressions during social interactions (Seibt et al., 2015).

The relation of facial expressions in the sender and in the perceiver has been mostly studied with respect to facial mimicry. In general, mimicry describes a mechanism where the behavior of one person elicits a similar behavior in another person (Chartrand et al., 1999). This process, also referred to as "chameleon effect", is unconscious, unintentional, and has been demonstrated for different behaviors like

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posture and body movement (Chartrand et al. 1999; Hale & Hamilton, 2016; Lakin et al., 2003) but also facial expressions (Dimberg, 1982; Dimberg et al., 2000). With respect to facial expressions, Dimberg (1982) could show that EMG activity of the *M. zygomaticus major*, a muscle group mainly activated during smiling, and the *M. corrugator supercilii*, a muscle group mainly activated during frowning, was affected by observing pictures of happy and angry facial expressions respectively. This effect has been termed "emotional mimicry". Subsequent studies have demonstrated that mimicry is an automatic process (Dimberg et al., 2000). Mimicry has further been demonstrated for static picture stimuli and for dynamic video stimuli, with stronger responses in the latter (Rymarczyk, Zurawski, Jankowiak-Siuda & Szatkowska, 2016). While most studies investigated reactions to pictures or videos of real persons, similar facial mimicry effects have also been observed for virtual agents (Weyers et al., 2006, 2009), human-like androids (Hofree et al., 2014), and even stick figures (Wessler & Hansen, 2021). This highlights emotional mimicry as a fundamental mechanism of social behavior.

While emotional mimicry seems to be an automatic and involuntary process (Dimberg et al., 2000), there is evidence that context, especially social context, affects mimicry. Bourgeois and Hess (2008) could show that mimicry of negative facial emotions was only observed for persons with shared but not with different political attitudes. Another study by Weyers et al. (2009) demonstrated that mimicry effects were only observed in a collaborative, but not in a competitive context. In contrast, competitive priming induced "counter empathetic" responses, i.e. a positive emotional response in reaction to a sad face. These results suggest that emotional mimicry of facial expressions is sensitive to social context. Furthermore, while mimicry has been shown to increase sympathy towards an interaction partner (see Hale & Hamilton, 2016), there is also evidence that the initial liking of another person leads to more mimicry towards that person (Salazar Kämpf et al., 2018). These data suggest emotional mimicry as a mechanism to establish reciprocal affiliative relations. Mimicry might be used to have one's wish to affiliate, i.e. liking someone, be answered with reciprocal behavior of another person, i.e. being liked in turn. This is in line with social accounts of emotional mimicry that highlight mimicry as a social and communicative act in the presence of an affiliation goal (Hess & Fischer, 2022; Wang & Hamilton, 2012). Overall, these results suggest a functional role of emotional mimicry in the regulation of social relations (Hess, 2021; Hess & Fischer, 2022). Importantly, it has been argued that in social interactions congruent and incongruent facial expressions may also arise as a reaction to an emotional signal of another person and may not necessarily be imitative (Fischer & Hess, 2017).

It has to be noted that most studies investigated socio-affective processing of facial expressions in a one-way direction, i.e. by measuring an observers passive reaction to an emotional facial expression. In real life, however, social interactions consist of reciprocal behavior between interactive partners. This reciprocal exchange of behavior has been suggested as a defining feature of real social interactions (Gallotti et al., 2017) Importantly, investigating such interactive mechanisms requires interactive paradigms. While naturalistic interactive behavior can be obviously observed in freely interacting dyads (Heerey & Crossley, 2013; Hess & Bourgeois, 2010; Lahnakoski et al., 2020), such studies typically come with a loss of experimental control. This drawback, however, could be mitigated by using paradigms with virtual agents that allow both for a naturalistic setting and a highly controlled experimental environment (Bohil et al., 2011; Hadley et al., 2022). The implementation of virtual interactions with a "closed loop" design, i.e. an experimental setting where the action of one partner triggers a reaction in the virtual agent, can be used to explicitly manipulate interactive behavior in face-to-face social interactions (Kroczek et al., 2020; Wilms et al., 2010). This approach allows to extend previous findings by investigating how the reciprocal exchange of emotional facial expressions influences social processing.

More specifically, the goal of the present study was to investigate how *sending* a particular facial expression towards a virtual agent would affect the evaluation of a further facial emotional expressions shown by the agent. For that reason, participants were cued to send a facial emotional expression (initial happy, initial angry, or initial neutral) towards a virtual agent in front of them (*Initial Expression)*. The virtual agent then showed another facial emotional expression directed at the participant (happy response or angry response, *Response Expression*). Note, that we chose the terms initial expression and response expression to differentiate between the facial emotional expression that was first displayed by the participant (initial expression) and the facial emotional expression that was subsequently displayed by the virtual agent (response expression). We measured ratings of arousal and valence as well as facial EMG of the *M. zygomaticus major* and *M. corrugator supercilii* in order to characterize participants' evaluation of the response expression on a self-report and a physiological level. We hypothesized that the evaluation of the response expression would be modulated as a function of the initial sender expression and the type of the response expression. Based on the emphasis of happy facial expressions in affiliative behavior (Salazar Kämpf et al., 2018), we expected that sending a happy facial emotional compared to sending a neutral or angry facial expression would increase valence and arousal of a subsequent happy but not angry facial expression given in response. Furthermore, we hypothesized to find an interaction between the *Initial Expression* and *Response Expression* in the EMG signal. More specifically, we expected to find that the relative increase in EMG activation of the *M. zygomaticus* for happy versus angry response expressions would be greater after sending an initial happy compared to a neutral or angry expression. While we expected to find the reversed pattern in M. corrugator, with a higher relative increase in EMG activation for angry versus happy response expressions after sending an initial angry compared to neutral or happy expression. Please note, that we investigated the effect of *Initial Expression* only with respect to the relative differences between happy and angry response expression in the EMG signal. This approach allowed to control for general differences in the EMG signal that resulted from the active display of happy, angry, or neutral facial expressions when sending the initial expression.

2. Methods

2.1. Participants

Seventy-six healthy volunteers were recruited at the University of Regensburg. Due to technical problems during data acquisition eight participants had to be excluded from the analysis. Therefore, data were analyzed for a sample of N = 68 (M_{age} = 21.75, SD_{age} = 4.24, 37 females). The sample size of 68 was greater than the required sample size of 66 that was calculated for small to medium effects (d = 0.35). Power analysis was estimated for dependent t-tests with 1-β = 0.8 and alpha = 0.05. Participants did not report any neurological or mental illness and had normal or corrected-to-normal vision. Psychology students were offered credit points as compensation for their participation. All participants gave written informed consent. The experimental procedure was approved by the ethics committee of the University of Regensburg and conducted in accordance to the Declaration of Helsinki.

2.2. Material

Short video clips of different virtual agents were presented as stimulus material. Four virtual agents (two females, two males) were created using MakeHuman (v 1.1.1, www.makehuman.org). These agents were then animated using Blender (v2.79, Blender Foundation, Amsterdam, Netherlands). Two emotional expressions, happy and angry, were implemented in accordance to the facial action coding system (FACS; Ekman & Friesen, 1978). Expressions were identical across all virtual agents. In order to increase liveliness and naturalness, virtual agents were animated to show eye blinks and slight head motion. We created five different animations of eye blinks and head motion that were identical across virtual agents and emotional expressions. Video stimuli were rendered with 60 fps and had a total length of six seconds. For all video clips, agents displayed a neutral expression in the initial four seconds of the video clips. Then, the neutral expression changed within 500 ms to an emotional expression (happy or angry) and remained in that expression for another 1500 ms. In total, 40 different video clips (4 agents x 2 emotions x 5 movement animations) were presented in the experiment.

In order to evaluate the stimulus material, after the main experiment participants were asked to rate pictures of the full-blown emotional expressions presented in the video clips. Participants discriminated between emotional expressions for all virtual agents with respect to valence and arousal. Happy emotional expressions were rated as most pleasant and angry emotional expressions were rated as least pleasant (neutral expressions were intermediate). Furthermore, participants rated angry emotional expression as most arousing, followed by happy and neutral expressions. A full analysis of the stimulus ratings is presented in the supplementary material.

2.3. Experimental design and procedure

The experiment had a 3-by-2 (*Initial Expression* x *Response Expression*) within-subject design. The independent variable *Initial Expression* (Levels: initial happy, initial angry, initial neutral) referred to the facial emotional expression that participants directed at the agents, while *Response Expression* (Levels: response happy, response angry) referred to the facial emotional expressions that were displayed by the virtual agents in response. In total, 120 trials were presented in a pseudo-randomized order with 20 trials per condition.

Before the start of the experiment, participants received instructions about the procedure of the experiment. They were instructed to interact with a virtual agent in front of them by directing a facial emotional expression at the agent once a cue was presented on the screen and that the agent would then react to them. For EMG measurements, electrodes were attached to the face (see below) and participants were seated in front of a 21.5-inch LCD-screen (HP E221c, 1920 ×1080 resolution, 60 Hz) with a distance of 50 cm.

Stimulus presentation was controlled using Psychtoolbox-3 (Pelli, 1997) implemented in Matlab 8.6 (MathWorks, Natick, MA, USA). A schematic overview of the trial structure is displayed in Fig. 1. Trials started with the presentation of a fixation cross for 1000 ms. Next, participants were instructed about the facial emotional expression they had to direct at the agent. For that reason, the emotion was presented on the screen for 2000 ms (i.e. *happy*, *neutral, angry*). After another fixation cross had been displayed for 1000 ms, the video clip was presented in the center of the screen (video size on screen: 1519 ×854). Video clips started with the display of a virtual agent showing a neutral facial expression. After a random delay between 300 and 1100 ms, a white rectangular frame appeared around the video, which served as a cue for participants to direct the instructed emotional expression at the virtual agent. The cue had a duration of 1200 ms. Participants were instructed to show the instructed emotional expression only when the cue was visible and to stop showing the emotion once the cue disappeared. After the cue disappeared, the virtual agent remained with the neutral expression for another 1700–2500 ms (depending on the delay before the onset of the cue). Then, exactly 4000 ms after the onset of the video, the expression of the virtual agent changed from neutral to an emotional expression (happy or angry) with a transition length of 500 ms and the expression was displayed for 1500 ms until the end of the video clip. After video offset the experiment continued with either the next trial or a rating phase.

In 20 % of the trials (i.e. four trials per condition), a rating phase followed the presentation of the video clip. Ratings were obtained for arousal (“*How high was your emotional arousal with the previous person?*”) and valence (“*How pleasant or unpleasant did you feel with the previous person?*”). Participants responded on a 7-point Likert scale (from 1 = “*very low*”/ ”*very unpleasant*” to 7 = “*very high” /”very pleasant”)* by mouse click. There were no time limits for the responses. Rating questions explicitly referred to valence and arousal with respect to the agent in order to measure participants’ evaluation of the complete interaction with the virtual agent and not only of the facial expression.

Trial duration was 10 s for regular trials and about 15 s when ratings were obtained. Three practice trials were presented before the start of the experiment to accustom participants to the experimental procedures. In total, the experiment lasted for about 60 min (including electrode application).

2.4. Measures

Besides ratings of arousal and valence, participants’ response towards the facial emotional expression of the virtual agents was investigated by obtaining EMG measures at the *M. zygomaticus major* (Zygomaticus) and the *M. corrugator supercilii* (Corrugator). For each muscle, two 8 mm Ag/AgCl electrodes were attached to the surface of the skin. Before electrode attachment, skin was prepared using alcohol and an abrasive paste (Skin-Pure, Nihon Kohden, Tokio, Japan). Impedances (Imp) were kept below 50 kOhm ($M_{Imp.}$ = 16.68 kOhm, $SD_{Imp.}$ = 19.67). Electrode positions followed the guidelines by Fridlund and

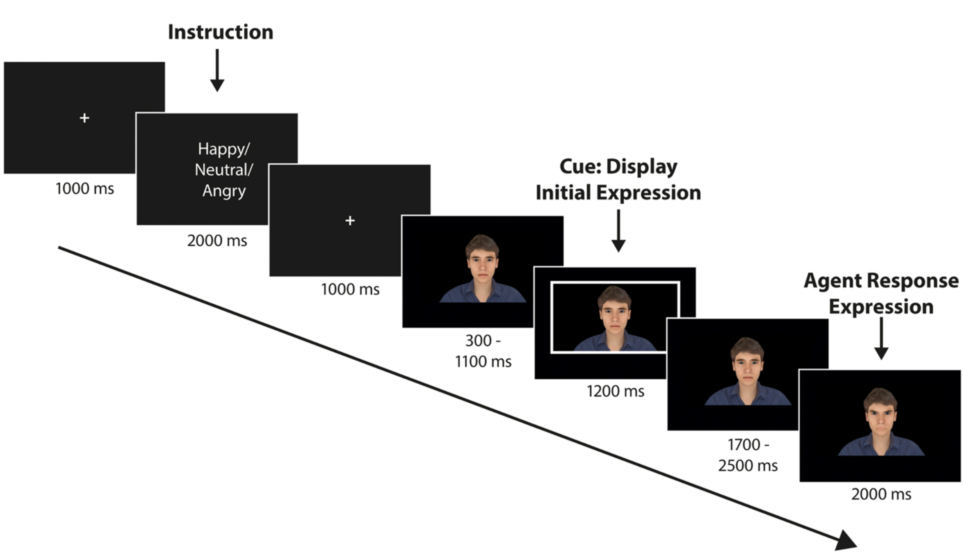

Fig. 1. Schematic overview of the experimental trial structure. The instruction informed participants which facial emotional expressions had to be directed towards the virtual agent (Happy = smile, Neutral = neutral expression, Angry= frown). The cue then prompted the participant to direct the instructed facial emotional expression at the virtual agent (Initial Expression). Following the participant’s facial expression, the virtual agent then responded with another facial expression (Response Expression: happy, angry).

Cacioppo (1986) with the ground electrode placed on the center of the forehead. During recording the left mastoid served as reference. Data was sampled with 1000 Hz using a V-Amp amplifier (BrainProducts, Gilching, Germany).

Data preprocessing was conducted in Matlab 8.6 (MathWorks, Natik, MA; USA) using the fieldtrip toolbox (v 20180501, Oostenveld et al., 2011). First, the two electrodes of each muscle were re-referenced to each other. Next, a bandpass filter between 30 and 500 Hz and a notch filter of 50 Hz were applied. All filters were implemented as windowed-sinc finite impulse response filters (−6 dB, half amplitude, onepass-zerophase, Kaiser window, maximum passband deviation of .001; Widmann et al., 2015). Data were then rectified and integrated using a moving average with a window size of 125 ms. Data were z-transformed for each muscle and participant in order to control for differences between muscle sites (Bush et al., 1993; Hess et al., 2017). For analysis, data segments were defined from 0.5 s before the onset of the facial emotional expression of the virtual agents (Receiver Response Expression) to 2 s after the onset of the facial emotional expression of the virtual agents. Data were baseline corrected using the mean of the pre-stimulus interval. Segments with values exceeding a z-score of +/− 1.69 (probability of data < 5 %) in the interval before onset of the agent emotion were marked as artifacts and rejected from further analysis (mean number of rejected trials = 5.49, SD = 5.64).

The continuous measurement of facial EMG allowed to check whether participants were actually following the experimental instruction, i.e. to direct a particular emotional expression at the agents when cued. A semi-automatic procedure was applied to check whether EMG activity (in the correct facial muscle) increased following the presentation of the cue. Individual and muscle-specific thresholds were calculated by extracting the maxima of the EMG signal following the cue (2 s segments, baseline corrected using a 0.5 s pre-onset interval) and then scaling the 90 %-percentile of all maxima with a factor of 0.2. The resulting thresholds were then compared against the EMG magnitude in single trials. Trials were rejected when (1) Zygomaticus magnitude was below the Zygomaticus threshold in trials where participants had been instructed to show a smile, (2) Corrugator magnitude was below Corrugator threshold in trials where participants had been instructed to show a frown, or (3) when either Corrugator or Zygomaticus magnitude were above the respective thresholds in trials where participants had been instructed to show a neutral facial expression (mean number of rejected trials = 1.45, SD = 3.05). Averages of EMG response in the cue segments are presented in the supplementary material (Fig. S4). Finally, segments relating to the facial emotional expression of the agents were averaged across conditions and then exported for statistical analyses.

2.5. Statistical analyses

Statistical analyses were calculated using the R environment (R Core Team, 2016) with packages ez (Lawrence, 2016) and *tidyverse* (Wickham et al., 2019) installed. Arousal and valence ratings were analyzed separately using repeated measurements ANOVAs with the factors *Initial Expression* (3) and *Response Expression* (2). Statistical analysis of the EMG data was conducted for time-windows of 500 ms length (i.e. [0−500], [500–1000], [1000–1500], [1500–2000]). EMG data was then analyzed using repeated measurement ANOVAs with the factors *Initial Expression* (3), *Response Expression (2)* and *Time* (4). Analyses were performed separately for Zygomaticus and Corrugator. For all analyses, Greenhouse-Geyser correction was applied in case of violations of sphericity (Greenhouse & Geisser, 1959). In these cases, epsilon values are reported. Post-hoc t-test were conducted to test for differences between conditions and Holm procedure was used to correct for multiple comparisons (Holm, 1979). Alpha level was determined to be 5 %. Cohen's d was calculated as effect size for paired t-tests (interpretation: d = 0.2 as small, d = 0.5 as medium, and d = 0.8 as large). For repeated measures ANOVAs, partial eta squared served as effect size (interpretation: $\eta_p^2 = 0.01$ as small, $\eta_p^2 = 0.06$ as medium, and $\eta_p^2 = 0.14$ as large).

2.6. Open science statement

All experimental stimuli, presentation scripts, anonymized data of ratings and EMG recordings, as well as analysis scripts are accessible in a public repository (https://osf.io/s7av2/). We did not pre-register hypotheses, data pre-processing or analyses prior to data acquisition.

3. Results

3.1. Ratings

3.1.1. Valence

Valence ratings were analyzed using a repeated measurement ANOVA with the factors *Initial Expression* and *Response Expression* (see Fig. 2, left). The analysis revealed a significant interaction of *Initial Expression* x *Response Expression,* $F(2134) = 40.62$, $p < .001$, $\eta_p^2 = 0.38$ ($\varepsilon = 0.76$), as well as a main effect of *Response Expression*, $F(1,67) = 251.70$, $p < .001$, $\eta_p^2 = 0.79$, and a main effect of *Initial Expression*, $F(2134) = 15.81$, $p < .001$, $\eta_p^2 = 0.19$ ($\varepsilon = 0.87$).

Post-hoc t-test were used to follow-up on the interaction effect. The evaluation of a particular response expression was modulated as a function of the initial expression. Agents responding with happy expressions were rated as most pleasant when participants had first smiled at them, as intermediate pleasant when participants had displayed a neutral expression, and as least pleasant when participants had displayed an initial angry expression (results for happy response condition: initial happy vs. initial angry, $t(67) = 8.14$, $p < .001$, $d = 0.99$; initial happy vs. initial neutral, $t(67) = 5.10$, $p < .001$, $d = 0.62$; initial neutral vs. initial angry, $t(67) = 6.00$, $p < .001$, $d = 0.73$). In contrast, agents responding with angry expressions were rated as more pleasant in the initial angry compared to the initial neutral condition, $t(67) = 2.50$, $p = .045$, $d = 0.30$, and compared to the initial happy condition, $t(67) = 2.42$, $p = .045$, $d = 0.29$, but there was no difference between the initial neutral and the initial happy condition, $t(67) = 0.27$, $p = .784$, $d = 0.03$.

Furthermore, a simple effects analysis of valence ratings as a function of the response expression was conducted. Regardless of initial expression, agents with happy response expressions were always rated as significantly more pleasant than agents with angry response expressions (initial angry: $t(67) = 7.65$, $p < .001$, $d = 0.93$; initial neutral: $t(67) = 13.26$, $p < .001$, $d = 1.61$; initial happy: $t(67) = 14.64$, $p < .001$, $d = 1.78$). Finally, t-tests were conducted to follow-up on the main effect of the participants' initial expression. An initial angry expression lead to increased valence ratings compared to a neutral initial expression, $t(67) = 3.61$, $p = .003$, $d = 0.44$, and an angry initial expression, $t(67) = 4.79$, $p < .001$, $d = 0.58$. In addition, neutral compared to angry initial expressions lead to increased valence ratings, $t(67) = 2.68$, $p = .037$, $d = 0.32$.

In summary, directing an initial facial emotional expression towards virtual agents modulated how participants rated pleasantness of agents responding with happy and angry facial expressions. Agents responding with happy expressions were rated as more pleasant when participants had first directed a smile compared to a frown or neutral expression at the virtual agents. Interestingly, agents responding with angry emotional expressions were rated as more pleasant when participants had previously frowned at the agents compared to when they had smiled or had shown a neutral expression.

3.1.2. Arousal

Another repeated measurement ANOVA was conducted with respect to the arousal ratings (see Fig. 2, right). There was a significant main effect of *Initial Expression*, $F(2134) = 16.73$, $p < .001$, $\eta_p^2 = 0.20$ ($\varepsilon = 0.94$), but no main effect of *Response Expression,* $F(1,67) = 0.73$, $p = .395$, $\eta_p^2 = 0.01$, and no interaction, $F(2134) = 0.48$, $p = .620$, $\eta_p^2 < 0.01$.

Arousal was greater in the initial happy condition compared to the

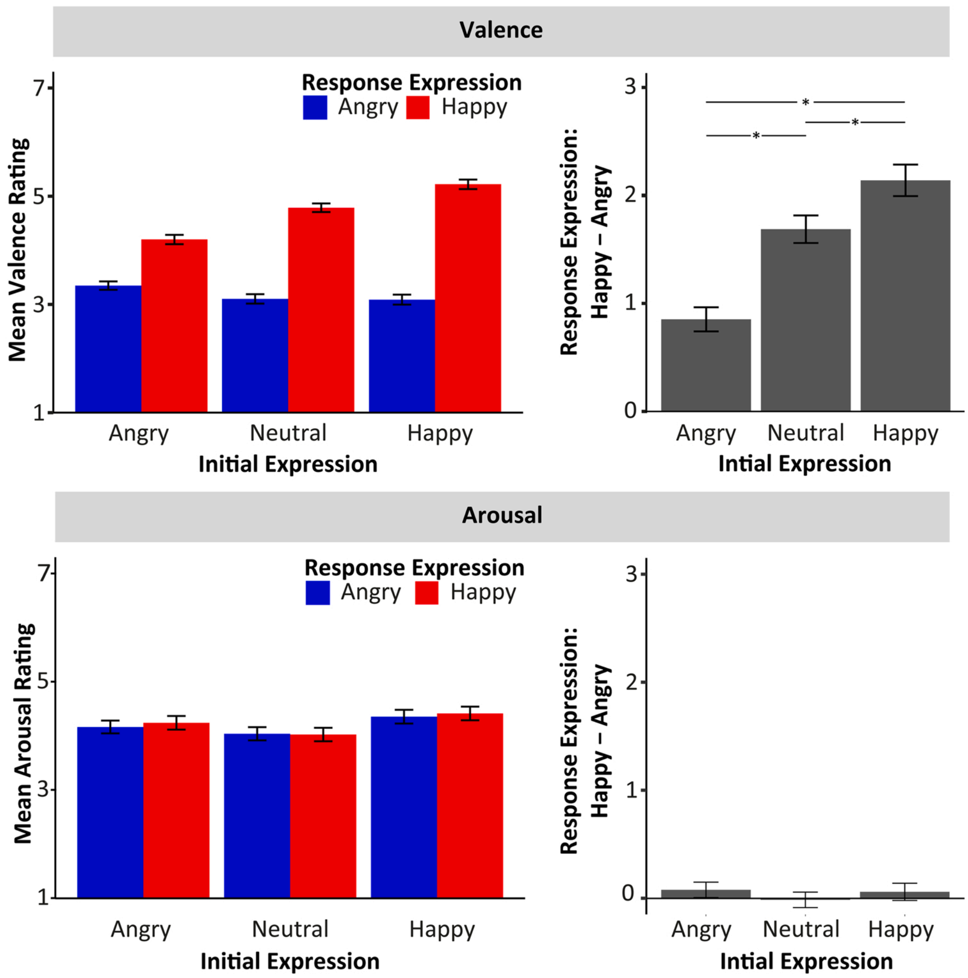

Fig. 2. Valence and arousal ratings. Top row shows valence results, bottom row shows arousal results. Left bar graphs show mean ratings as a function of Initial Expression and Response Expression. Participants answered on a scale from 1 to 7 (Valence: “very unpleasant” to “very pleasant”, Arousal: “very low” to “very high”). Right graphs show the differences in valence or arousal between happy and angry response expression for each initial expression. Error bars reflect the standard error of the mean.

initial neutral, $t(67) = 5.37$, $p = <0.001$, $d = 0.65$, and initial angry conditions, $t(67) = 3.43$, $p = .002$, $d = 0.41$. The initial angry condition was also rated as more arousing than the initial neutral condition, $t(67) = 2.69$, $p = .009$, $d = 0.33$.

In summary, arousal was rated highest when the exchange of facial expressions was initiated with a smile, followed by the frown and

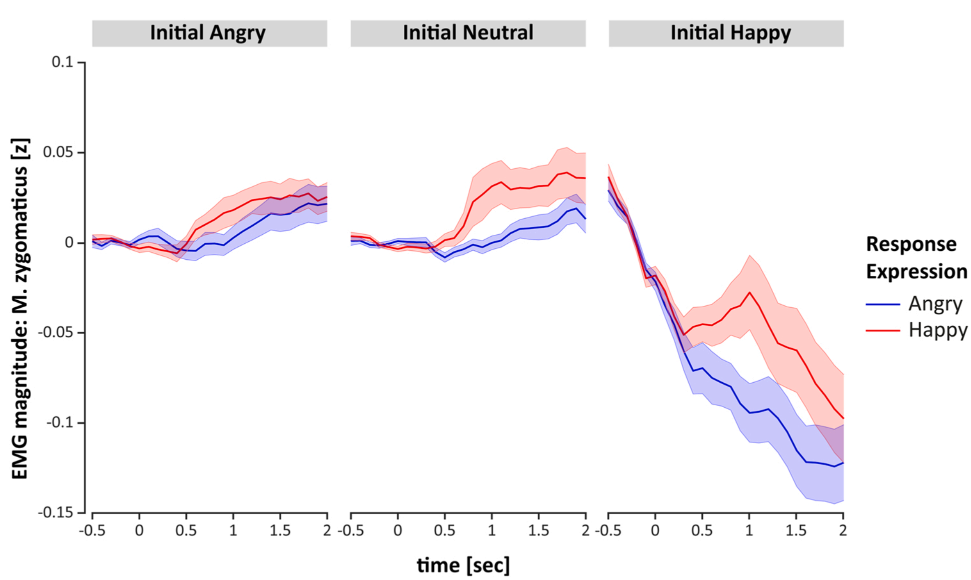

Fig. 3. Activation of the M. zygomaticus major. Graphs show EMG magnitude (z-scores) elicited by happy (red) and angry (blue) facial response expressions of the agents for different initial expressions (left: initial angry, middle: initial neutral, right: initial happy). Shaded areas reflect the standard error of the mean. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

neutral expressions. Response expressions, however, did not influence arousal ratings.

3.2. EMG

3.2.1. M. zygomaticus major

M. zygomaticus major magnitude (Fig. 3) was investigated using a repeated measurement ANOVA with the factors *Initial Expression*(3), *Response Expression* (2), and *Time* (4). There was a significant interaction of *Initial Expression* x *Response Expression*, F(2134) = 4.61, p = .015, η_p^2 = .06 (ε = 0.88), a significant interaction of *Initial Expression* x *Time*, F (6, 402) = 18.36, p < .001, η_p^2 = .22 (ε = 0.34), as well as a main effect of *Response Expression,* F(1,67) = 4.93, p = .030, η_p^2 = .07, and a main effect of *Initial Expression,* F(2134) = 30.73, p < .001, η_p^2 = .31 (ε = 0.60). There was no interaction of *Initial Expression x Response Expression* x *Time*, F(6402) = 0.54, p = .677 (ε = 0.57).

Post–hoc t-tests were conducted to follow-up on the interaction between *Initial Expression* and *Response Expression* by averaging the EMG signal across time windows. First, Zygomaticus activation for happy vs. angry response expressions, were tested separately for each initial expression (one-sided tests). Happy compared to angry response expressions elicited significantly higher EMG activation in the initial happy condition, t(67) = 2.64, p = .015, d = 0.32, and marginal significantly higher activation in the initial neutral condition, t(67) = 1.95, p = .056, d = 0.24, but there was no significant difference in Zygomaticus activation between happy and angry response expressions in the initial angry condition, t(67) = 0.77, p = .221, d = 0.09. In a next step, we directly compared the EMG difference of happy and angry response expressions between initial expression conditions (two-sided t-tests). The EMG difference was significantly greater in the initial happy compared to the initial angry condition, t(67) = 2.63, p = .011, d = 0.33, but there was no significant difference between initial happy and initial neutral conditions, t(67) = 1.92, p = .120, d = 0.23, or initial angry and initial neutral conditions, t(67) = −1.25, p = .214, d = 0.15. Differences in Zygomaticus EMG between happy and angry response expressions for each initial expression condition are illustrated in Fig. 5 (left). Please note that these results could be replicated using a data-driven cluster-based permutation analysis (see Supplementary Material).

Finally, post-hoc t-tests were conducted to investigate the interaction between *Initial Expression* x *Time.* In all time windows, EMG magnitude in the initial happy condition was significantly decreased compared to the initial angry and initial neutral conditions (all p < .05), while there were no differences between initial angry and initial neutral conditions (all p > .05). Furthermore, EMG magnitude in the initial angry and initial neutral conditions increased (initial angry condition: t(67) = −3.90, p < .001, d = −0.47; initial neutral condition; t(67) = −3.54, p < .001, d = −0.43), whereas the EMG magnitude in the initial happy condition decreased from the [0 – 500] time window to the [1500–2000] time window, t(67) = 4.03, p < .001, d = 0.49. It is important to note, that the overall decreased EMG response in the initial happy condition resulted from activation in the baseline period, as EMG magnitude was still returning to zero after participants had actively smiled at the agent (see Supplementary Material).

In summary, participants' initial expression directed at a virtual agent differentially modulated Zygomaticus activation for happy and angry response expressions. An increased effect of response expression was observed when participants had first smiled at the agents compared to when they had first frowned at the agents.

3.2.2. M. corrugator supercilii

A repeated measurement ANOVA with the factors *Initial Expression* (3)*, Response Expression* (2), and *Time* (4) was conducted to analyze EMG magnitude of the M. corrugator supercilii (see Fig. 4). Results revealed a significant interaction of *Response Expression* x *Time*, F(3201) = 7.37, p = .003, η_p^2 = 0.10 (ε = 0.48), and *Initial Expression x Time*, F(6402) = 16.69, p < .001, η_p^2 = 0.20 (ε = 0.31), as well as main effects for *Initial Expression*, F(2134) = 29.84, p < .001, η_p^2 = 0.41 (ε = 0.71), and *Response Expression*, F(1,67) = 20.59, p = .001, η_p^2 = 0.24. There was no interaction of *Initial Expression* x *Response Expression*, F(2134) = 0.82, p = .423 (ε = 0.84) or *Initial Expression* x *Response Expression* x *Time*, F (6402) = 0.69, p = .560 (ε = 0.51).

Post-hoc t-tests (one-sided) were conducted to investigate the effect of facial response expressions. Across all time-windows, angry response expressions elicited greater Corrugator activity than happy response expressions, t(67) = 4.53, p < .001, d = 0.55. In addition, the difference in the EMG response between angry and happy response expression was modulated across time windows, with the late time window [1500–2000 ms] showing a greater differentiation between angry and happy response expressions than the early time window [0–500 ms], t (67) = 3.07, p = .003, d = 0.37 (two-sided test).

The main effect of *Initial Expression showed* greatest Corrugator

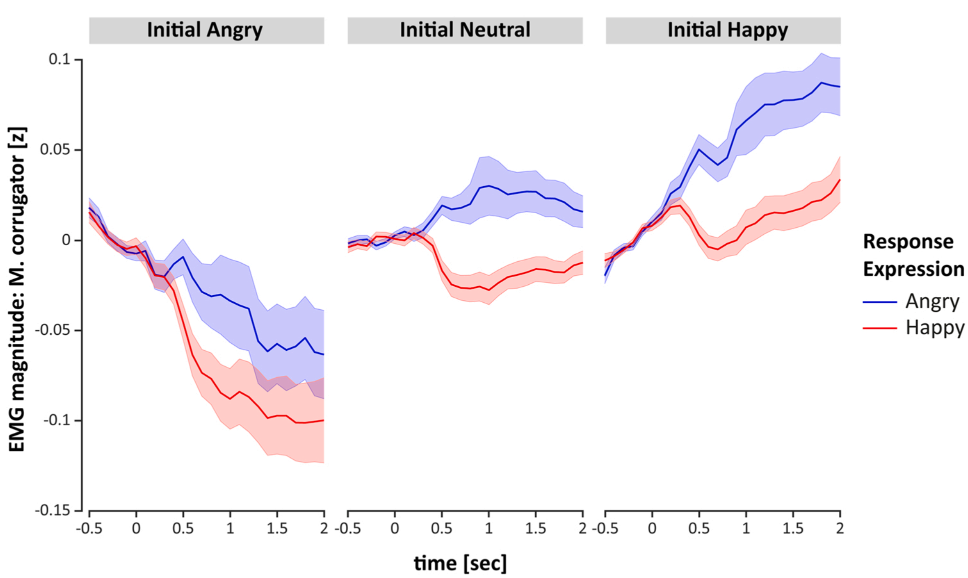

Fig. 4. Activation of the M. corrugator supercilii. Graphs show EMG magnitude (z-scores) elicited by happy (red) and angry (blue) facial response expressions of the agents for different initial expressions (left: initial angry, middle; initial neutral, right: initial happy). Shaded areas reflect the standard error of the mean. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

magnitude in the initial happy condition, followed by the initial neutral condition and the initial angry condition (initial happy vs. initial angry: $t(67) = 6.74$, $p < .001$, $d = 0.82$; initial happy vs initial neutral: $t(67) = 4.78$, $p < .001$, $d = 0.58$, initial neutral vs. initial angry: $t(67) = 4.10$, $p < .001$, $d = 0.50$). In addition, these differences increased over time, with greater differences in the late [1500–2000 ms] window compared to the early [0–500 ms] window (all $p < .001$). Again, baseline effects, related to the slow decline of Corrugator EMG activation after participants had frowned at the agents, can explain the overall decrease in EMG magnitude in the initial angry condition (see Supplementary material).

In summary, EMG activation in the Corrugator showed increased activation to angry response expressions compared to happy response conditions. However, this effect was not modulated by the initial expression displayed by the participants (see Fig. 5, right).

4. Discussion

The present study investigated how sending a facial emotional expression influences the evaluation of a subsequent facial emotional expression. Participants were prompted to either smile, frown, or direct a neutral expression towards a virtual agent. Agents then showed either a happy or an angry facial expression. As hypothesized, experience in these minimal interactions was modulated by the interplay of the initial expression of the participant and the subsequent facial emotional expressions of the virtual agent. For happy response expressions, pleasantness was rated higher when the expression was in response to an initial happy expression compared to when the expression was in response to an initial neutral or angry expression. Whereas for angry response expressions, pleasantness was higher when the expression was in response an angry compared to a neutral or happy initial expression. In contrast, the experience of arousal was only influenced by the initial emotional expression itself but not by the response expression of the agents. Displaying an emotional expression increased arousal compared to displaying a neutral expression and smiling elicited more arousal than frowning. More importantly, the relation of sending a facial emotional expression and receiving a response expression from an interactive partner was also reflected in the facial EMG signal. We observed increased Zygomaticus activation for happy relative to angry response expressions when participants had initiated the interaction with a smile compared to a frown. In contrast, Corrugator activity was higher for angry compared to happy response expression, but this effect was not modulated by the initial emotional expression. Overall, the present data demonstrate that the evaluation of the facial expressions of an interactive partner is modulated by one's own preceding facial expression.

The present results highlight interactive mechanisms in the processing of facial emotional expressions. In real-life, facial emotional expressions do not appear in isolation but are always embedded in the interactive exchange between communicative partners (Frith, 2009). When a facial emotional expression is perceived as a response towards one's own behavior, the expression may gain meaning beyond the meaning of the isolated facial expression. For example, when a smile follows an initial smile, this can indicate that a person's affiliative intention is reciprocated by the other person, whereas when a person responds with a smile to an initial angry expression this may indicate conflict avoidance. The present study demonstrates that persons evaluate facial emotional expressions on basis of the behavior that preceded the emotional expressions. This suggests that the initial facial expression serves as contextual information during social interactions and that further emotional facial expressions are interpreted in the light of this context (Seibt et al., 2015). This highlights the interactive and interdependent nature of facial emotional expressions.

Interestingly, we found a dissociation between the effects of the initial facial emotional expression based on muscle site. Activation in the *M. corrugator supercilii,* which is related to frowning, was not modulated by the initial facial emotional expression, whereas activation in the *M. zygomaticus major*, which is related to smiling, differed as a function of the initial facial emotional expression. This suggest that interactive mechanisms may be especially important for affiliative behavior. The experience of having the own smile answered with another smile by the interactive partner might increase affiliation in a way that goes beyond the perception of a single smile in isolation. A potential mechanism for this finding might be the rewarding function of smiles (Mühlberger et al., 2011) that might enhance the emotional experience of the person who initiated the smile. This is in line with our finding that agents with happy facial expressions were also rated as more pleasant when participants had first smiled compared to frowned at the agents. Interestingly, however, we also observed that angry response expressions were rated as more pleasant when participants had initially frowned compared to smiled at the agents. This might reflect participants experience of eliciting a congruent response in the virtual agent. In line with this, a previous study found that experiencing gaze behavior as interactive, increased activation in the ventral striatum, a brain area linked to reward processing (Pfeiffer et al., 2014). Alternatively, this finding

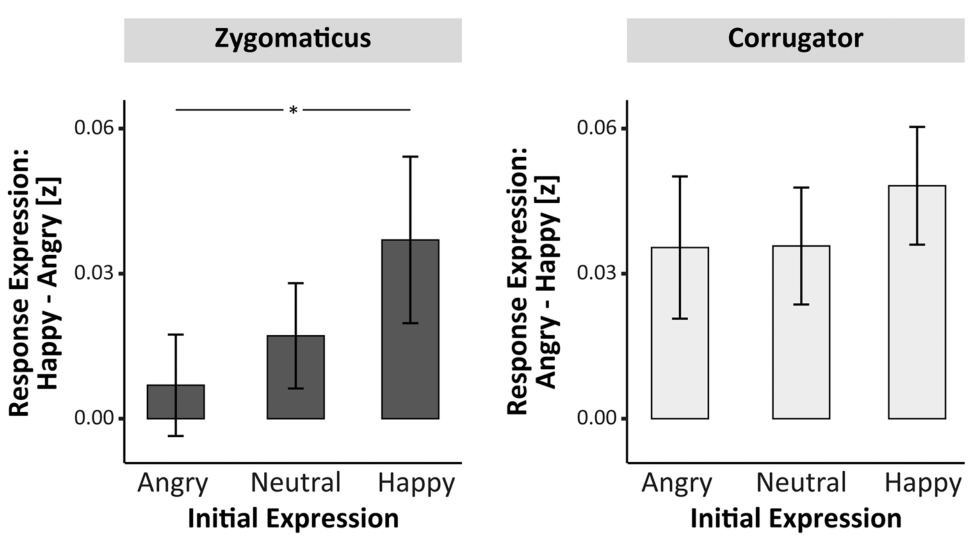

Fig. 5. Differences between response expressions in the Corrugator and Zygomaticus muscle for each initial expression condition. Bars show differences in EMG response averaged across time (0–2000 ms post onset of facial expression). For the Zygomaticus, EMG differences were calculated as happy minus angry response expressions. For the Corrugator, EMG differences were calculated as angry minus happy response expressions. Error bars reflect the standard error of the mean.

might reflect social evaluative processing where participants judge their initial expression as justified once the same expression is shown by the agent (Hareli et al., 2009). Overall, our results suggest that reciprocal exchange of facial expressions is especially relevant for affiliative behavior, e.g. when both interaction partners signal approach.

It is an interesting question whether the effects observed in the present study do reflect a mimicry response elicited by the facial emotional expression of the virtual agents or whether they reflect a modulation of the initially produced facial expression. In line with the former, the EMG results do show the typical mimicry pattern with an increased magnitude in the Zygomaticus in response to smiles compared to frowns and an increased magnitude in the Corrugator in response to frowns compared to smiles (Dimberg, 1982). However, the EMG signal is also affected by the facial expression that was initially produced by the participants, resulting in overall negative EMG magnitudes after baseline correction in the Zygomaticus after participants had smiled and in the Corrugator after participants had frowned. Due to this overlap, the observed effects might also be explained as a modulation of the EMG response of the initially produced facial expression and thereby be more in line with evaluative processes rather than actual mimicry. Future studies might test this by initiating interactions without actual facial emotional expressions, for example by sending an emoji so that the EMG response elicited by the facial expression of the virtual agent remains unaffected by the initial interactive behavior (Kaye et al., 2017). Importantly, however, while we refrain from making specific claims about the underlying mechanisms that drives the EMG response, this does not affect our main conclusion, that sending a facial emotional expression to an interactive partner modulates the evaluation of a facial emotional expression that is received in return.

While the present study provides first insights into the interactive role of facial expressions during face-to-face social interactions, there are some limitations that need to mentioned. First, the present study did not observe spontaneous social interactions, but rather an approximation of interaction, i.e. a pseudo-interaction, by cueing the participant to direct an emotional expression at the virtual agent on the screen. The response of the virtual agent was then displayed after a random delay. Because the exchange of facial expressions followed a fixed experimental procedure it remains unclear whether participants interpreted the facial expression of the agent as a response elicited by their own facial expression. It should be noted that the temporal order of the facial expressions might allow for a causal interpretation of events (Lagnado & Sloman, 2006). Further evidence comes from a recent study using a similar paradigm where participants' rating of interactivity was investigated as a function of temporal delay between facial expressions. Interestingly, while interactivity was highest at delays around 700 ms, the results also show that interactivity ratings remained high at longer latencies (Kroczek & Mühlberger, 2022). As both studies used similar paradigms it seems plausible that a similar degree of interactivity was elicited in the present study.

While this paradigm allowed for high experimental control, future studies might provide more immersive virtual reality setups, for example via a Head Mounted Display, and further increase the naturalness of social interaction by investigating spontaneous facial expressions of participants that automatically elicit a contingent response in the virtual agents. Another limitation concerns the temporal delay between the facial emotional expressions of the participant and the agent. In the current study, the onsets of the cue and an agent's expressions was at least 1700 ms apart and the interval was also randomly jittered (within a range of 800 ms). Previous studies, however, have found that facial expressions are typically exchanged within 1000 ms with a major proportion of exchanges occurring in less than 200 ms (Heerey & Crossley, 2013). Furthermore, a recent study using a similar paradigm found that the feeling of interactivity peaked at temporal delays between facial expression around 700 ms (Kroczek & Mühlberger, 2022). Future studies should therefore test whether shorter intervals between facial expressions can increase the effect of the initial expression.

Finally, it should be discussed that due to the virtual nature of the interaction in the present paradigm, there may have been aspects which differ from real-world interactions. This includes the missing social relation between interactive partners, which might have affected participants intent to affiliate with a virtual agent, as well as missing consequences linked to the expressions of the virtual agents. In real interactions, angry expressions might be a more salient signal as they can indicate social exclusion or threat. As a consequence, individual differences, for instance in coping behavior, might be less pronounced in virtual paradigms (Mauersberger et al., 2015). Future studies should try to enrich social contexts and outcomes in virtual paradigms to investigate these factors.

In summary, social interaction is fundamental for humans and facial expressions are an important part of such interaction. The present study sheds light on how the reciprocal exchange of facial emotional expressions between a participant and a virtual agent affects the socio-affective evaluation of the facial emotional expression produced in the response. The results highlight the interactive nature of facial emotions, in particular smiles, and suggest a functional role of the reciprocal exchange of smiles in social affiliative behavior.

Author contributions

L.K. and **A.M.** designed research, **L.K.** created stimuli, supervised data acquisition, and analyzed data. **L.K.** and **A.M.** wrote the paper.

Competing financial interests

The authors declare no conflict of interest.

Data availability

All experimental stimuli, presentation scripts, anonymized data of ratings and EMG recordings, as well as analysis scripts are accessible in a public repository (https://osf.io/s7av2/).

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.biopsycho.2022.108453.

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