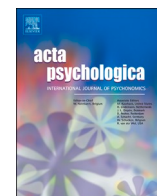


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## The effects of self-relevance vs. reward value on facial mimicry

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## ABSTRACT

Facial mimicry is a ubiquitous social behaviour modulated by a range of social cues, including those related to reward value and self-relevance. However, previous research has typically focused on a single moderator at a time, and it remains unknown how moderators interact when studied together. We compared the influence of reward value and self-relevance, by conditioning participants to associate certain faces with winning or losing money for themselves, or, with winning or losing money for another person. After conditioning, participants watched videos of these faces making happy and angry facial expressions whilst we recorded facial electromyographic activity. We found greater smile mimicry (activation of the Zygomaticus Major muscle) in response to happy expressions performed by faces associated with participants' own outcomes vs. faces associated with another person's outcomes. In contrast to previous research, whether a face was associated with winning or losing money did not modulate facial mimicry responses. These results, although preliminary, suggest that when faces are associated with both self-relevance and reward value, self-relevance could supersede the impact of reward value during facial mimicry.

## 1. Introduction

Self-relevance acts as an “integrative glue” whereby perception, memory and decision-making are enhanced for stimuli related to the self, compared to stimuli related to others (see [Sui & Humphreys, 2015](#) for a review). A similar bias is seen towards rewarding stimuli, whereby more rewarding stimuli are chosen more frequently ([Samejima et al., 2005](#)), are better remembered ([Madan & Spetch, 2012](#)), and are responded to more quickly ([Wruse et al., 2007](#)).

Facial mimicry is the ubiquitous tendency to spontaneously and unconsciously imitate the facial expressions of other people and may serve important social functions, such as affiliation ([Chartrand & Bargh, 1999](#); [Wang & Hamilton, 2012](#)). Facial mimicry may also contribute to emotion recognition ([Barsalou, 2008](#); [Wood et al., 2016](#)). There is evidence to suggest that both self-relevance and reward effects can impact mimicry responses. For example, facial mimicry is greater towards more rewarding faces ([Hofman et al., 2012](#); [Korb et al., 2019](#); [Sims et al., 2012](#)) and in-group members ([de Klerk et al., 2019](#); [van der Schalk et al., 2011](#); [Blocker & McIntosh, 2016](#); but see [Sachisthal et al., 2016](#)). However, self-relevance and reward are often confounded, for example, highly self-relevant individuals, such as our friends or partners, are often

the sources of rewards. Moreover, there is debate as to whether self-relevance and reward effects operate via the same mechanisms ([de Greck et al., 2008](#); [Northoff & Hayes, 2011](#)). Thus, the current study aimed to compare the influence of self-relevance and reward value on facial mimicry responses.

## 1.1. Facial mimicry: rewards and self-relevance

Greater facial mimicry towards more rewarding stimuli has been demonstrated across several studies. For example, [Sims et al. \(2012\)](#) asked participants to play a gambling task in the presence of different faces. Certain faces were associated with a higher probability of winning money than others. When participants later saw these faces smiling, they showed greater facial mimicry responses - increased electromyographic (EMG) activity in the Zygomaticus Major (ZM) muscle - towards those faces associated with a higher probability of winning. In other words, after conditioning, smiles of faces associated with a higher reward value were mimicked more. In a follow up fMRI study, [Sims et al. \(2014\)](#) showed that when participants viewed smiling faces with a higher reward value, there was increased functional connectivity between the ventral striatum and inferior frontal gyrus - regions involved in reward

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processing and mimicry, respectively. The modulation of facial mimicry by reward value was replicated by Korb et al. (2019) using the same conditioning paradigm. Although, Korb et al. argued that the mimicry differences in response to faces of different reward values are the result of greater *inhibition* of mimicry towards the less rewarding faces, rather than increased mimicry towards the more rewarding faces. Similarly, Hofman et al. (2012) asked participants to play an economic game with fair and unfair players and found reduced smile mimicry towards the unfair players (i.e. those associated with losing points). Anger mimicry was also greater towards unfair players and reduced towards fair players.

Stimuli which are self-relevant, such as one's name or an in-group member, confer processing advantages (Sui & Humphreys, 2015). For example, Sui et al. (2012) used a shape-label matching task in which they asked participants to associate different shapes with themselves, their best friend or a stranger (e.g. circle = you; square = friend; triangle = stranger). On each trial, participants saw a shape-label pair for 100 ms and had to judge as quickly and as accurately as possible whether this matched the pairings they had been given at the start of the task. Across several experiments, they found consistent self-relevance effects whereby participants were faster and more accurate at matching shapes to self-labels compared to labels for their friend or a stranger (Sui et al., 2012). This self-bias may also influence facial mimicry responses. For example, de Klerk et al. (2019) showed that 11-month-old infants mimicked the facial movements of speakers of their native language more than those of a foreign speaker. Similar effects have been shown in adults with greater anger and fear mimicry towards in-group compared to out-group members (van der Schalk et al., 2011; Blocker & McIntosh, 2016; but see Sachisthal et al., 2016). Moreover, teenagers show greater facial mimicry responses towards expressions performed by their peers than those performed by adults (Ardizzi et al., 2014).

Greater mimicry towards more rewarding and more self-relevant faces is consistent with the view that mimicry may have important social functions. For example, if mimicry promotes affiliation, then mimicking those who are associated with a higher probability of reward may help to ensure rewards in the future (Chartrand & Bargh, 1999; Wang & Hamilton, 2012). Similarly, increased mimicry to self-relevant others, such as in-group members, may foster harmonious social interactions and promote group cohesion (Wen et al., 2016). This enhanced mimicry for more rewarding and more self-relevant faces fits with developmental accounts of mimicry (Heyes, 2016). Mimicry responses are likely to develop through, and be fine-tuned by, sensorimotor contingencies - associations between observed and performed actions (Heyes, 2016). For example, caregivers often copy the smiles of infants, which strengthens the connection between the visual and motor representation of a smile in the infant's brain. When the infant subsequently sees a smile, the motor representation of a smile is activated resulting in facial mimicry. Heyes (2013) argued that these mimicry responses are subject to *input modulation* and *output modulation*. Input modulation refers to the processing of the action stimulus, and output modulation refers to the extent to which the associated motor representation is inhibited. For example, we would expect both rewarding and self-relevant faces to modulate facial mimicry via input modulation. This is because we pay greater attention to these faces, which enhances the encoding of the movements produced by them. This results in greater activation of the associated motor representation and, consequently, more facial mimicry. Thus, reward effects and self-relevance effects on facial mimicry are consistent with theories outlining its possible social functions (Chartrand & Bargh, 1999; Wang & Hamilton, 2012) and those describing how mimicry develops (Heyes, 2016).

### 1.2. Self-relevance vs. reward effects – a shared mechanism?

Some have argued that self-relevance effects are driven by enhanced reward processing for self-related information. In the shape-label matching task described above, when the shapes were associated with

different monetary reward values, comparable processing advantages were seen for the most rewarding stimuli (Sui et al., 2012; Experiment 4B). Moreover, brain regions associated with self-related stimuli overlap with those responsive to reward-related stimuli (de Greck et al., 2008; Enzi et al., 2009; Northoff & Hayes, 2011). For example, in an fMRI study de Greck et al. (2008) showed participants pictures of food (e.g. cake, tomatoes), alcohol (e.g. beer, wine), and gambling (e.g. slot machines, roulette), and participants had to decide whether these items were high or low in self-relevance. Participants were also presented with the same pictures and had to imagine they were gambling about the content of the pictures. Participants “bet” by pressing left or right and received feedback as to whether they had won (reward win trials) or lost (reward lose trials) money. The pictures that participants rated as high in self-relevance were associated with activity in the nucleus accumbens, ventromedial prefrontal cortex, and the ventral tegmental area, and these same regions were also activated during reward win trials. These findings suggest that self-relevance and rewards activate similar neural mechanisms. If both effects activate similar neural mechanisms, then we could expect them to have similar effects on facial mimicry, which is what we explored in the current study.

Yet, Humphreys, Sui, and colleagues have argued that perceptually (i.e. in the shape-label matching task) the mechanisms underlying self-relevance and reward effects are distinct. Firstly, there is no overall correlation across participants between self-relevance and reward effects, so those participants who displayed a stronger self-bias did not necessarily display a stronger reward-bias (Sui and Humphreys, 2015). Secondly, by investigating “redundancy gains” – the decrease in reaction time when two stimuli are presented together – Sui et al. (2015) argued that self-relevant stimuli may have a more fundamental impact on early visual processing than rewarding stimuli. However, it has recently been demonstrated that self-relevance effects may also operate via different mechanisms in different domains. For example, Nijhof et al. (2020) showed that the magnitude of self-relevance effects for one's own name were not correlated in a perceptual task (shape-label matching) and an attention task (attentional blink). Thus, the current study aimed to investigate the impact of self-relevance within a facial mimicry task and compare this to the role of reward effects. If self-relevant stimuli have a “unique gain” compared to rewarding stimuli and thereby uniquely impact early visual processing (Sui & Humphreys, 2015; p. 1954), we should expect self-relevance to supersede the effect of reward on facial mimicry. Especially, when we consider the bidirectional relationship between facial mimicry responses and visual processing (Sessa et al., 2018; Wood et al., 2016). Alternatively, if the effect of reward and the effect of self-relevance are comparable and operate via similar mechanisms (de Greck et al., 2008), they should combine to have additive effects on facial mimicry. This is what we explored in the current study.

### 1.3. The current study

Participants played a simple card game in which we conditioned neutral faces with different reward values – *win faces* were associated with a 90% chance of winning money, whereas, *lose faces* were associated with a 90% of losing money (Sims et al., 2012). Orthogonally to this, some faces were associated with the participants' own outcomes (*self faces*), whereas other faces were associated with the outcomes of another participant (*other faces*). This created four conditions with one face in each condition: *win-self*, *lose-self*, *win-other*, *lose-other*. The face-condition association was counterbalanced across participants. Following conditioning, participants watched videos of the conditioned faces displaying happy and angry facial expressions whilst facial EMG activity was recorded from two muscles: Zygomaticus Major (ZM, involved in smiling) and Corrugator Supercilii (CS, involved in frowning). We tested the following hypotheses:

*Additive hypothesis* – this assumes that the effect of reward and the effect of self-relevance are comparable, and should combine to have additive effects on facial mimicry (de Greck et al., 2008). This

hypothesis predicts that happy expressions of *win faces* (compared to *lose faces*) should elicit greater ZM activity in participants (Korb et al., 2019; Sims et al., 2012). Secondly, happy expressions of faces associated with participants' own outcomes (*self faces*) should elicit greater ZM activity than those faces associated with other people's outcomes (*other faces*). Thus, *win-self* faces should elicit the most facial mimicry and *lose-other* the least. Moreover, there should be no interaction between the effects of reward and self-relevance.

*Supersedence hypothesis* – this assumes that self-relevance has a greater impact on facial mimicry than reward value, given its more fundamental impact on visual processing and attention (Sui et al., 2012; Sui & Humphreys, 2015). This predicts a main effect of self-relevance, so happy expressions of faces associated with participants' own outcomes (“self faces”) should elicit greater ZM activity than those faces associated with other people's outcomes (“other faces”). Crucially, this effect of self-relevance should be greater than (or supersede) the impact of reward on facial mimicry.

We focused our hypotheses on activation of the ZM to happy expressions, given the reliable reward effects seen for smile mimicry in previous studies (Korb et al., 2019; Sims et al., 2012; Sims et al., 2014). Angry expressions were included as a control condition, and because some previous studies investigating in-group effects (a reasonable proxy for self-relevance) showed mimicry effects only for negative emotions (van der Schalk et al., 2011; Bourgeois and Hess, 2008). However, other studies have shown in-group effects for positive (Peng et al., 2020) and neutral facial expressions (de Klerk et al., 2019), and others have failed to replicate in-group/out-group effects on facial mimicry at all (Sachisthal et al., 2016).

## 2. Methods

### 2.1. Participants

Forty-nine participants took part in the study. One participant was excluded due to missing data as a result of a technical issue during the EMG recording, leaving a final sample of 48 participants (29 male; mean age = 24 years, SD = 3.75 years, range 19–35 years). We based our study

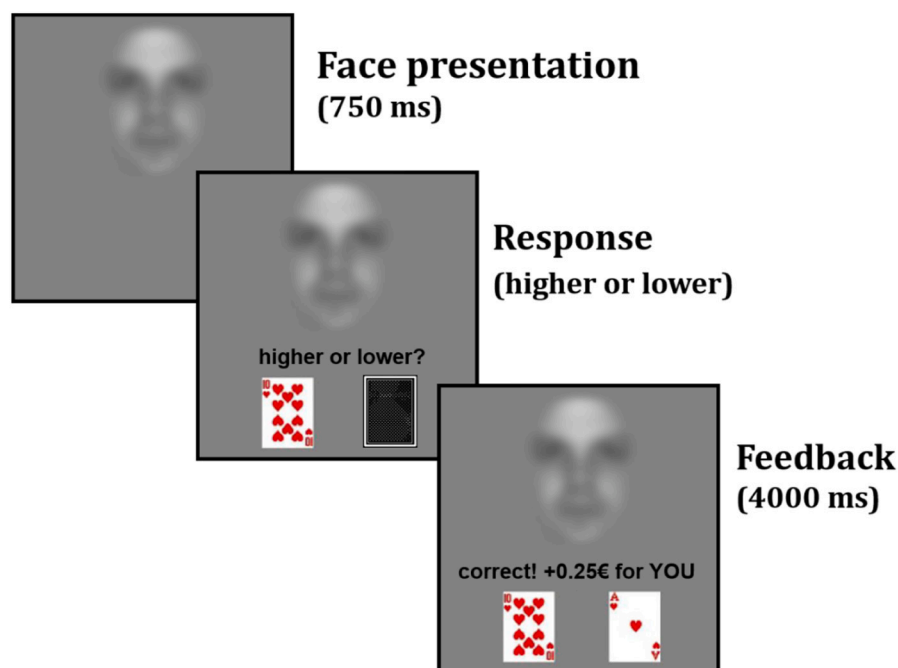
design on that of Sims et al. (2012), who conducted a very similar study with a sample of 32 participants. They found an effect size of  $d = 0.51$  for the most important comparison between the most rewarding face and the least rewarding face. More recently, Korb et al. (2019) replicated the finding of Sims et al. (2012) inside the MRI scanner with a final sample of 35 participants. To ensure 80% power for such a medium effect size would have required 33 participants using a within-subject design. Given the phenomenon of the “winner's curse,” we decided to increase the sample size by 50% to ensure sufficient power (Button et al., 2013). All participants had normal or corrected-to-normal vision and provided informed consent. Ethical approval for the study was obtained from the Research Ethics Committee at the University of Vienna.

### 2.2. Materials

All the face stimuli were selected from the Nimstim Database (Tottenham et al., 2009) and the Chicago Face Database (Ma et al., 2015). To reduce variation due to differences in the background and hairstyle, a grey frame with an oval-shaped aperture was superimposed on the faces (see Fig. 1). Stimuli used in the conditioning phase consisted of static images of four target faces showing a neutral expression (two male, two female).

Stimuli used in the test phase consisted of eight videos, each 3000 ms in length, showing dynamic facial expressions of happiness and anger made by the same four actors. Each video began with the face showing a neutral expression, which turned into a happy or angry expression. The actor reached the full expression by 1000 ms and then held this expression until the end of the video. We used Fanta Morph 5 (<http://www.fantamorph.com>) to create the videos by morphing the images showing a neutral facial expression with those showing either an angry or a happy facial expression.

Facial EMG was recorded bipolarly from the left ZM and CS muscles using Ag/AgCl electrodes with 4 mm inner and 8 mm outer diameter. A ground electrode was placed on the participants' forehead. EMG data was sampled at 1024 Hz with impedances below 20 kOHM using a TMS International Refa8 amplifier and the Portilab2 software ([www.tmr.si.com](http://www.tmr.si.com)).



**Fig. 1.** The trial sequence of the conditioning task. The color of the text throughout the task (black = self; blue = other), and the words “for YOU” or “for THOMAS” shown during feedback, indicated whether participants were playing for themselves or for another participant. The face has been blurred in the manuscript to protect the integrity of the database. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

## 2.3. Procedure

### 2.3.1. Conditioning task

The conditioning task was based on Sims et al. (2012, see also Korb et al., 2019). At the start of each trial participants saw a face on the screen (Fig. 1). After 750 ms, two cards appeared on the screen - one card was face up and the other was face down. Above the cards was written “higher or lower?”, and participants’ task was to guess whether the face down card was higher or lower than the face up card using the arrow keys (up = higher; down = lower). Following their response, the value of the face down card was revealed and participants received feedback as to whether they had guessed correctly (“correct!” or “wrong!”; note that all text was displayed in German) and whether they had won or lost money (+0.25€; −0.20€). Participants were told that if the text was black, they were playing the game for themselves (self-condition), whereas, if the text was blue, they were playing for another participant (other condition). Participants were told that any money they won would be added to their compensation fee at the end of the experiment. This difference was also reflected in the feedback text (e.g. “+0.25€ for YOU” vs. “+0.25€ for THOMAS”). Unbeknown to the participants, the reward probabilities of the faces were fixed, so regardless of the participant’s response, the faces in the win condition resulted in a reward (+0.25€) on 90% of trials and a loss (−0.20€) on 10% of trials, and vice-versa for the faces in the lose condition. Moreover, the assignment of each face to one of the four conditions (*win-self*, *lose-self*, *win-other*, *lose-other*) was counterbalanced across participants. Each face was presented 30 times, creating 120 trials in total. Before and after conditioning, participants rated the attractiveness and likeability of the four different faces on an 11-point Likert scale.

### 2.3.2. Test phase

After conditioning, participants engaged in a memory task, in which they were asked to identify through a keypress faces that they had not previously seen in the study (Korb et al., 2019; Sims et al., 2012). This ensured they maintained their attention on the screen. During this oddball task, facial EMG was recorded whilst participants watched videos of happy or angry facial expressions made by the four previously conditioned faces, and by four unknown faces. Each video clip was 3000 ms in duration, followed by a jittered fixation cross (2000–3000 ms) between trials. Each video of known faces was presented eight times in a randomized order. Videos depicting faces of actors that were not displayed during the conditioning task were randomly distributed throughout the presentation of the target faces. There were seven of these “oddball” trials in total. As a cover story to avoid that participants focused on their facial expressions, we informed them that EMG electrodes were used to measure sweat gland (as opposed to muscle) activity.

## 2.4. Preprocessing and analysis

EMG data were preprocessed in Matlab R2014b ([www.mathworks.com](http://www.mathworks.com)), partly using the EEGLAB toolbox (Delorme & Makeig, 2004). After applying a 20–400 Hz bandpass and a 50 Hz notch filter, data were rectified and smoothed with a 40 Hz lowpass filter. Three second-epochs were extracted starting at the beginning of the video (stimulus onset) and were expressed as percentage of the baseline (500 ms preceding stimulus onset). Trials with values that were more than two SDs above or below the mean (for that subject and muscle), were removed from analyses. For the statistical analysis, EMG data were averaged over windows of 500 ms and z-scored for each muscle for each participant using the *scale\_within* function in R (R Core Team, 2019). Repeated measures ANOVAs were conducted in SPSS (IBM).

## 3. Results

### 3.1. Ratings

To demonstrate the effect of conditioning, ratings before conditioning were subtracted from those after conditioning.

#### 3.1.1. Liking

A  $2 \times 2$  repeated measure ANOVA with the factors Agent (Self, Other) and Reward (Win, Lose) revealed a main effect of Agent [ $F(1,47) = 13.57, p = 0.001, \eta_p^2 = 0.224$ ], with self-relevant faces ( $M = 1.13, SD = 1.61$ ) showing a greater increase in liking than other-relevant faces ( $M = 0.083, SD = 1.77$ ) after conditioning. There was also a main effect of Reward [ $F(1,47) = 35.88, p < 0.001, \eta_p^2 = 0.433$ ], with win faces ( $M = 1.47, SD = 1.63$ ) showing a greater increase in liking than lose faces ( $M = -0.260, SD = 1.77$ ). The interaction between Agent and Reward was not significant ( $p > 0.93$ ; Fig. 2).

#### 3.1.2. Attractiveness

We conducted the same analysis on participants’ attractiveness ratings. This revealed a main effect of Reward [ $F(1,47) = 9.24, p = 0.004, \eta_p^2 = 0.164$ ], with win faces ( $M = 0.885, SD = 1.49$ ) showing a greater increase in attractiveness after conditioning than lose faces ( $M = 0.104, SD = 1.28$ ). The effect of Agent and the interaction between Reward and

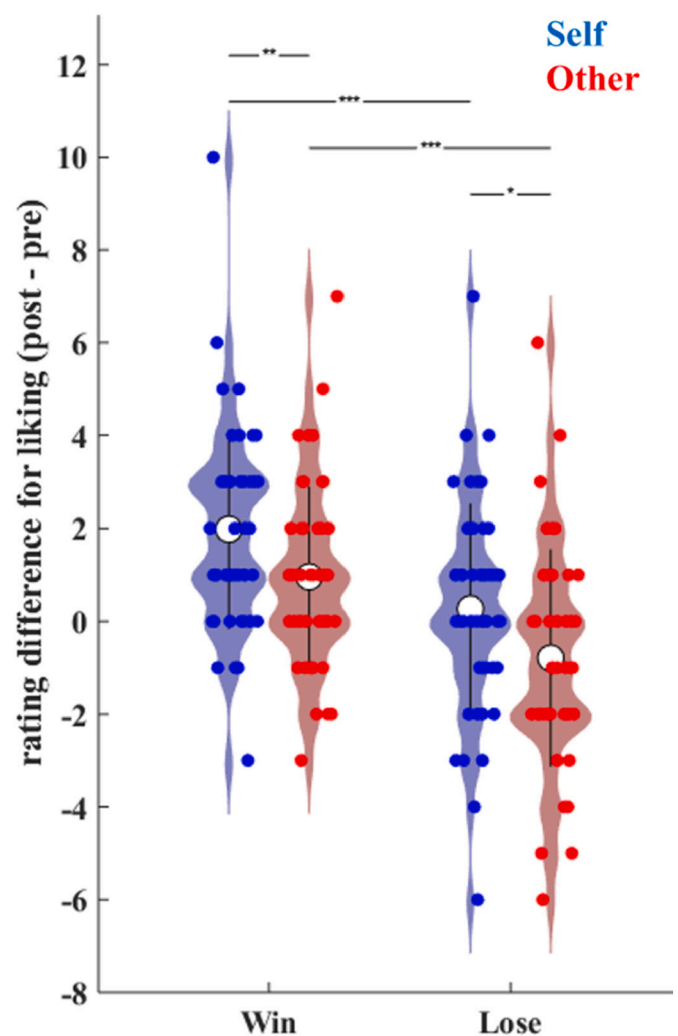


Fig. 2. The effect of conditioning on liking ratings for the faces in the different conditions. Each dot represents a participant. The group means and SDs for each condition are shown by white circle and black lines.



Agent were not significant (all  $p$ s > 0.84).

### 3.2. Electromyography

#### 3.2.1. Zygomaticus Major (ZM)

The data from the ZM were subject to a  $2 \times 2 \times 2 \times 6$  repeated measures ANOVA with the factors Emotion (Happy, Anger), Agent (Self, Other), Reward (Win, Lose), and, Time (windows 1–6). This revealed, as expected, a main effect of Emotion [ $F(1, 47) = 9.41, p = 0.004, \eta_p^2 = 0.167$ ], with greater activation to happy faces ( $M = 0.07, SD = 0.42$ ) compared to angry faces ( $M = -0.06, SD = 0.34$ ). There was also a main effect of Time [ $F(2.80, 131.8) = 14.92, p < 0.001, \eta_p^2 = 0.241$ ], with greater activation in later time windows, and a significant Emotion  $\times$  Time interaction [ $F(2.80, 131.5) = 3.65, p = 0.016, \eta_p^2 = 0.072$ ], indicating greater ZM activation to happy vs. angry facial expression in the later time points. All other main effects and interactions were not significant, including the hypothesised three-way interactions between Emotion  $\times$  Agent  $\times$  Time ( $p = 0.12$ ), and, Emotion  $\times$  Reward  $\times$  Time ( $p = 0.76$ ).

However, given the significant main effect of Emotion, and because our hypotheses were specific to ZM activation towards the congruent facial expression (i.e. facial mimicry), we carried out a second analysis focusing on happy facial expressions. This  $2 \times 2 \times 6$  repeated measures ANOVA included the factors Agent (Self, Other), Reward (Win, Lose) and Time (windows 1–6). It resulted in a main effect of Time [ $F(2.61, 122.7) = 10.70, p < 0.001, \eta_p^2 = 0.185$ ], and a significant Agent  $\times$  Time interaction [ $F(3.55, 166.8) = 2.614, p = 0.044, \eta_p^2 = 0.053$ ]. Post hoc  $t$ -tests revealed a significant difference in activation between self and other faces in the third time window (1500 ms after stimulus onset),  $t(47) = 2.18, p = 0.017, d = 0.31$  (uncorrected for multiple comparisons; Fig. 3). The main effects of Agent ( $p = 0.106$ ) and Reward ( $p = 0.416$ ), as well as all other interactions, were not significant (all  $p$ s > 0.7).

#### 3.2.2. Corrugator Supercilii (CS)

The data from the CS were subject to a  $2 \times 2 \times 2 \times 6$  repeated measures ANOVA with Emotion (Happy, Anger), Agent (Self, Other), Reward (Win, Lose), and Time (time window 1–6) as factors. This revealed a main effect of Emotion [ $F(1,47) = 32.70, p < 0.001, \eta_p^2 = 0.410$ ], with more activation to angry (mean = 0.11,  $SD = 0.35$ ) than to happy faces (mean =  $-0.12, SD = 0.35$ ), and a main effect of Time [ $F$

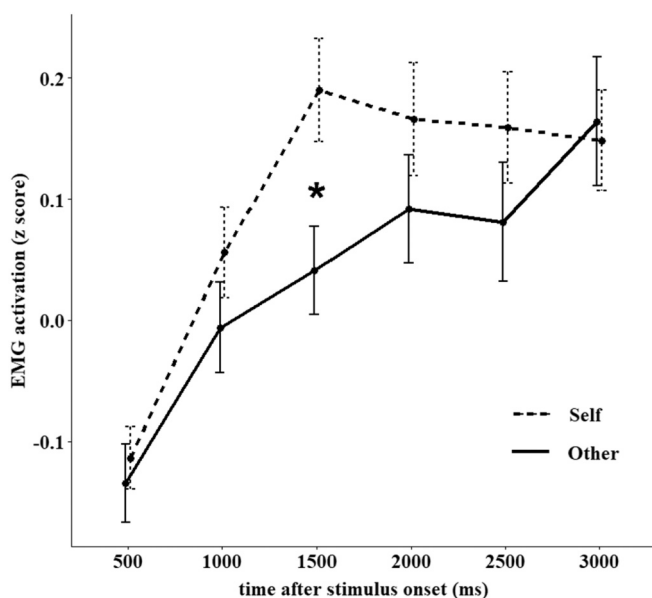


Fig. 3. Mean (+/-SEM) activation of the Zygomaticus Major to happy expressions for self and other faces.

(2.83, 133.0) = 5.11,  $p = 0.003, \eta_p^2 = 0.098$ ]. The interaction between Emotion and Time [ $F(3.87, 181.9) = 9.18, p < 0.001, \eta_p^2 = 0.163$ ] was also significant – angry facial expression produced greater CS activation in the later time points compared to happy expressions. There was also a significant three-way interaction between Emotion, Reward, and Time [ $F(5, 235) = 2.34, p = 0.043, \eta_p^2 = 0.047$ ]. No other main effects or interactions were significant (all  $p$ s > 0.31).

To explore the three-way interaction, we looked at the Reward  $\times$  Time interaction in each Emotion (see Fig. S1 in the Supplementary Materials). The Reward  $\times$  Time interaction was significant for incongruent happy faces [ $F(5, 235) = 2.59, p = 0.027, \eta_p^2 = 0.052$ ], but not for congruent angry faces ( $p > 0.6$ ). Post hoc  $t$ -tests for happy faces revealed that there were no significant differences between win and lose happy faces at any time point following stimulus onset (all  $p$ s > 0.2; see Fig. S1).

As above, a further analysis focused on the CS-congruent expression, i.e. anger. This  $2 \times 2 \times 6$  repeated measures ANOVA included the factors Agent (Self, Other), Reward (Win, Lose) and Time (windows 1–6). There was a marginal effect of Time [ $F(3.27, 153.5) = 2.29, p = 0.075, \eta_p^2 = 0.047$ ] with a trend towards less activation later following stimulus onset (see Fig. S1; left panel). No other main effects or interaction effects were significant (all  $p$ s > 0.23).

## 4. Discussion

We compared the impact of self-relevance and reward value on facial mimicry responses to estimate their independent and combined effects. Our main findings are as follows. Firstly, participants mimicked happy and angry facial expressions, as demonstrated by the Emotion  $\times$  Time interaction in both the ZM and CS. Next, we explored whether this facial mimicry was modulated by reward and self-relevance and found that self-relevance modulated smile mimicry. Participants showed an enhanced increase in ZM activity towards happy expressions displayed by the faces associated with their own outcomes (self faces) compared to those associated with another participant's outcomes (other faces). However, it is important to interpret this two-way interaction between Agent  $\times$  Time for ZM activity towards smiles with caution, given the absence of a significant three-way interaction between Emotion  $\times$  Agent  $\times$  Time ( $p = 0.12$ ; Nieuwenhuis et al., 2011). There was no evidence to suggest that self-relevance impacts mimicry of angry expressions. Finally, the reward value of the faces – whether they were associated with winning or losing money – did not modulate facial mimicry responses. We discuss these findings in terms of theories of self-bias effects and facial mimicry.

The *supersede hypothesis* outlined above predicted that self-relevance would have a greater impact on facial mimicry responses than reward value, as self-relevance has a more fundamental impact on visual processing and attention (Sui et al., 2012; Sui & Humphreys, 2015). Our results provide suggestive evidence for this hypothesis and are broadly consistent with neuroimaging and eye-tracking studies showing that self-relevant stimuli have enhanced attentional salience (Sui et al., 2013; Turk et al., 2011; Yankouskaya et al., 2017). It was not the case, as predicted by the *additive hypothesis*, that self-bias effects and reward bias effects combined to have additive or incremental effects on facial mimicry responses (de Greck et al., 2008). This suggests that self-relevance could be a more significant modulator of smile mimicry than reward, although future studies are needed to confirm this. Our data lend tentative support to the view that self-relevant stimuli confer a “unique gain” compared to rewarding stimuli, suggesting that these effects could operate via distinct mechanisms (Sui & Humphreys, 2015; p. 1954). Alternatively, it is also possible that self-relevance and reward effects operated via the same mechanism, and self-relevance effects used up the resources that would normally be used for processing rewarding stimuli. Future neuroimaging studies could shed light on this issue by comparing activation towards self-relevant vs. rewarding faces.

Prominent theories of mimicry emphasise its possible social

functions (for an overview, see Farmer et al., 2018). For example, unconsciously copying the actions of others may act as a “social glue” by promoting affiliation and fostering harmonious social interactions (Chartrand & Bargh, 1999). A range of studies have shown that mimicry is modulated by social cues, including those linked to self-referential processes and reward processing (Wang & Hamilton, 2012). For example, 11 month old infants showed increased facial mimicry towards those speaking their native language compared to a foreign language (de Klerk et al., 2019) and analogous effects have been seen in mimicry responses to in-group members in adults (van der Schalk et al., 2011; Bourgeois and Hess, 2008; but see Sachisthal et al., 2016). Other self-relevant cues, such as direct eye-gaze (Forbes et al., 2017; Wang et al., 2011) and joint attention (Neufeld et al., 2016), also modulate mimicry responses. Our findings suggest that self-relevance could also modulate facial mimicry responses, but future studies are needed to confirm the reliability of these effects.

Our findings suggest that not all social cues modulate facial mimicry to the same extent. For example, reward did not modulate facial mimicry in the presence of self-referential cues. Future studies investigating the modulation of mimicry may benefit from pitting different modulators against each other and creating a hierarchy of modulators. During every day social interactions, a wide range of social cues, such as, eye gaze, liking, attractiveness, and affiliative motives (Wang & Hamilton, 2012), all have the potential to influence our mimicry behaviour. Discovering which of these cues are the most important modulators of mimicry, and how these different cues interact with each other, is an important avenue for future work. For example, in terms of the current study, participants liked the rewarding faces more after conditioning (e.g. *self-win* faces were liked more than *self-lose* faces; see Fig. 2), however, this increase in liking did not impact participants’ facial mimicry towards them. This suggests that whether someone is self-relevant could be more important for our mimicry behaviour than whether that person is rewarding or liked. If mimicry has prosocial consequences, then showing more mimicry towards a person, who has *any* potential to bring us rewards or losses, could be a useful strategy, as this could increase the chances of rewards in the future (or at least reduce the chances of losses; Wang & Hamilton, 2012). This modulation of facial mimicry, which may rely on a neural network encompassing the medial prefrontal cortex (Korb et al., 2019; Wang et al., 2011), likely takes place unconsciously, as suggested by the discrepancy reported here between participants’ explicit ratings of liking and attractiveness, and their subsequent mimicry of the same faces as measured with facial EMG.

This study has several limitations. First, our findings must be interpreted with caution given the absence of a significant three-way interaction between Emotion  $\times$  Agent  $\times$  Time (despite the significant Agent  $\times$  Time interaction towards smiles; Nieuwenhuis et al., 2011). Moreover, a significant difference between self and other was only found in one of the six time points after stimulus onset (uncorrected) and with a small effect size. Thus, our data are not conclusive and at best provide suggestive evidence for the supersedence hypothesis. Future studies with larger samples are needed to test the robustness of any potential self-relevance effects on facial mimicry.

A further limitation of our study is that the effects of reward and self-relevance were not matched for saliency. There are several reasons why the self vs. other manipulation may have been more salient than the win vs. lose manipulation. Firstly, the amount of money participants could win or lose on each trial was small (+0.25 or -0.20€). Although, this was similar to the amount used in previous studies, which found reliable effects of reward value (Korb et al., 2019; Sims et al., 2012). Future studies could increase the saliency of the reward value (e.g. with larger monetary rewards) and/or decrease the saliency of the self-relevant manipulation (e.g. by having participants play for themselves and their best friend, rather than for an anonymous other). Secondly, during conditioning, the self faces were always (100% of the time) linked to self-outcomes, whereas, the win faces were linked to winning on only 90% of trials. Again, this could have increased the saliency of the self-

relevance manipulation. Although, these reward probabilities modulated facial mimicry responses in previous studies (Korb et al., 2019; Sims et al., 2012) and it is important to note that both the reward and self-relevance manipulation had large effects on participants’ ratings of liking. Even so, more studies with tighter controls for saliency are needed to further disentangle the effects of self-relevance and reward value on facial mimicry.

To conclude, we compared the influence of self-relevance and reward value on participants’ facial mimicry responses. We found increased smiling mimicry (ZM activity) towards happy expressions performed by those faces associated with participants’ own outcomes, compared to faces associated with another person’s outcomes. The reward value of the face did not modulate facial mimicry responses. Our findings, although not statistically conclusive, provide tentative evidence to suggest that self-relevance could supersede the impact of reward value during facial mimicry. Finally, we highlight the importance of directly comparing the influence of different modulators of mimicry to further our understanding of this phenomenon.

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#### Data availability

The data associated with this manuscript is available here <https://osf.io/SZ367/>.

#### CRedit authorship contribution statement

**Paul Forbes, Sebastian Korb, Alexandra Radloff, Claus Lamm:** Conceptualization, Methodology, **Paul Forbes:** Project administration, **Alexandra Radloff:** Investigation, **Paul Forbes, Sebastian Korb:** Formal analysis, **Paul Forbes:** Visualisation, **Paul Forbes, Alexandra Radloff:** Writing-Original draft preparation, **Paul Forbes, Sebastian Korb, Claus Lamm:** Writing-Reviewing and Editing, **Claus Lamm:** Funding acquisition.

#### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.actpsy.2020.103193>.

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