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SUBLIMINAL INTERDEPENDENCE PRIMING MODULATES CONGRUENT AND INCONGRUENT FACIAL REACTIONS TO EMOTIONAL DISPLAYS

Beate Seibt
Instituto Universitário de Lisboa (ISCTE-IUL)

Peter Weyers, Katja U. Likowski, Paul Pauli and Andreas Mühlberger
University of Würzburg

Ursula Hess
Humboldt University, Berlin

To investigate how facial reactions to facial emotional displays are modulated by cues about social interdependence processed outside of awareness, 84 women were subliminally primed with cooperation or competition or neutrally primed. Thereafter, they viewed computer-generated faces with happy, neutral, sad, and angry expressions while facial EMG was recorded over three muscles. As expected, we observed congruent facial reactions in the neutral and cooperation conditions to happy and sad but not to angry faces. In the competition condition, we found almost no congruent reactions. Furthermore, we observed incongruent reactions to angry expressions: participants primed with competition and participants primed with cooperation showed positive reactions, but on different muscles. We argue that these incongruent reactions are based on reward contingencies and on habitual communicative goals to support a partner, respectively.

Imagine bumping into a competing job candidate who has a broad smile on her face. You might interpret that smile as indicating that she excelled in the interview, or that she received the job offer, which in turn might make you sad because you see your chances dwindle. Now imagine she looks angry instead. You might as-

Beate Seibt is now at the Department of Psychology, University of Oslo, Norway. Andreas Mühlberger is now at the Department of Psychology, University of Regensburg, Germany.

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Correspondence concerning this article should be addressed to Peter Weyers, Department of Psychology, Marcusstr. 9-11, 97070 Würzburg, Germany; E-mail: weyers@psychologie.uni-wuerzburg.de.

sume that her interview did not go so well, and nourish greater hopes for yourself. Thus, your emotional reactions would be incongruent with the emotional expression perceived. Now imagine instead that you bump into a coauthor on an article who greats you with a happy smile. You might interpret that smile as indicating that she made good progress. In such a situation, you would probably share her emotion and smile back. In other words, you would react with her, showing a congruent expression. But what if she looks angry? You might assume that she is frustrated about the progress. Given that you are a team, you might try to encourage her with a supportive smile. Thus, you would show an incongruent reaction in order to regulate her mood. Here, a congruent anger reaction would be risky for the relation and for the common goal (Hess & Bourgeois, 2010).

As these examples suggest, whether an individual competes or cooperates with another influences her reactions to the other's facial displays. Here, we study the effects of activating the concepts of cooperation and competition outside of awareness. We propose that in competitive contexts, facial displays will be incongruent with the expressed emotion, whereas in cooperative contexts, we expect congruent reactions to smiles, but supportive smiles to anger expressions. In neutral contexts, we expect congruent reactions to smiles and sad expressions but not to angry expressions. We now review the available evidence for these claims.

INTERDEPENDENCE

Both cooperation and competition are characterized by interdependence: Whether one can achieve a goal depends on the behavior of another person. Cooperative situations are characterized by positive interdependence, where individuals work together to reach a common goal. By contrast, competitive situations are characterized by negative interdependence, where one can only succeed if the other fails. Cooperation and competition are basic elements of human relationships. On one hand, evolution is based on competition, on the other hand for humans as a social species cooperation is a fundamental necessity (see e.g., Nowak, 2006). Hence, it may not be surprising that both cooperation and competition are intrinsically rewarding. Festinger (1954) posits a competitive drive as the desire "to be slightly better than the others with whom one compares oneself" (p. 127). On the other hand, there is ample evidence that students prefer cooperative classroom situations (Johnson & Johnson, 1974). While there is cultural and interpersonal variation with regard to the preference of cooperative or competitive strategies (e.g., Kagan & Madsen, 1971), most children use both strategies in their games (Lewis & Bedson, 1999). This means that they acquire experience with both types of interdependence.

FACIAL DISPLAYS AS INDICATING AFFECTIVE REACTIONS TO REWARDS AND PUNISHMENTS

Englis, Vaughan, and Lanzetta (1982) first suggested that experience with interdependence leads to context-specific affective reactions to facial expressions. More specifically, Lanzetta and Englis (1989) suggest that "children must learn to discriminate between game participants with whom they may share the joy of victory or the dismay of defeat while also learning that a competitor's display of joy indicates that one has lost or that the competitor's display of distress indicates that one has won" (p. 545). Given that individuals have ample exposure to both types of interdependence, these contingencies should become well learned. Arguably, over time, opposite affective reactions can become conditioned to the same facial expressions in function of the type of context, such that in a cooperative context expressions will be congruent (positive display = positive reaction and negative display = negative reaction) and in a competitive context they will be incongruent (positive display = negative reaction and negative display = positive reaction).

While several theories predict congruent reactions in cooperative situations (Bargh & Chartrand, 1999; Hess & Fischer, 2013; Niedenthal, Mermillod, Maringer, & Hess, 2010), only the conditioning account (Englis et al., 1982) predicts incongruent reactions in competitive situations. Therefore, we will next examine empirical evidence for this prediction. Englis et al. showed participants videotaped smiles and grimaces of pain and then delivered shocks and monetary rewards to participants in a congruent (shocks following grimaces and rewards following smiles) or incongruent (shocks following smiles and rewards following grimaces) fashion. After the conditioning phase, the authors observed negative facial reactions to grimaces of pain in the congruent condition, and positive facial reactions in the incongruent condition. Their participants also experienced the congruent condition as cooperative and the incongruent condition as competitive, even though they did not interact with the videotaped actors.

Yet, the conditioning did not influence evaluations of the target. Accordingly, incongruent facial reactions can be a function of a certain reward structure in the absence of conflict between the individuals. This is in line with the observation that groups of friends enjoy playing competitive games (Lewis & Bedson, 1999), and that there is a social agreement about competition: being competitive is the normative behavior in activities like sports, many games, some classroom activities, or the market place. This notion is also in line with the observation that individuals routinely compare themselves with close others (Mussweiler & Rüter, 2003). Thus, an anger display in competitive situations is more likely caused by a setback than by the other's competitive behavior *per se*.

Further supporting the conditioning account is the finding of some incongruent facial behavior for participants expecting competition, whereas those expecting cooperation showed only congruent facial behavior (Lanzetta & Englis, 1989). Weyers, Mühlberger, Kund, Hess, and Pauli (2009) subliminally primed half of their participants with competitive words and the other half with neutral words. They found congruent expressions to happy and sad displays after neutral, but not after competition priming. However, no significant evidence for incongruent reactions was found. In a recent study by Likowski, Mühlberger, Seibt, Pauli, and Weyers (2011) participants were told that they would play either with or against an avatar (or no such instruction). They were then shown computer generated faces of these avatars with emotional displays and were told that these displays were reactions to situations in the game. The authors found a *Corrugator supercilii* relaxation, which is one indicator of a happiness display, in response to sad and angry facial expressions of avatars presented as competitors. This relaxation was fully mediated by self-reported joy in the case of angry displays.

Given that individuals should be particularly tuned to situations of interdependence (see Kurzban, Tooby, & Cosmides, 2001), cues to interdependence should be processed even under suboptimal conditions such as brief exposure. Going beyond previous evidence, we therefore predict that incongruent reactions should even be observable when a competitive context is activated subliminally, that is without opportunity to consciously reflect on the implications of the display based on that context. This has not been shown before, and it would present stronger evidence for the conditioning account. Because the emotion of joy presupposes an awareness of the rewarding event (see Leander, Moore, & Chartrand, 2009; Neumann, Seibt, & Strack, 2001), we did not expect the same mediation by joy as was found for the openly competitive situation (Likowski et al., 2011).

However, facial displays do not only reflect reactions to rewards and punishments, but they are also means for achieving social goals, such as to conceal emotions, to threaten, to affiliate, to bluff, or to indicate submission. There is ample evidence suggesting that affiliation goals are habitually and reliably pursued in cooperative situations, leading to a shared perspective and emotional mimicry.

FACIAL DISPLAYS AS SIGNALS OF AFFILIATIVE INTENT

According to Hess and Fischer (2013), “social interaction goals or inferred intentions should be minimally neutral, and preferably affiliative, for emotional mimicry to occur” (p. 152). They define emotional mimicry as reacting with the other person, as sharing her perspective. It shows in congruent facial reactions to happy and sad displays. Angry displays, conversely, are not mimicked, unless these concern a target outside the dyad. To illustrate, an anger expression shown by an ingroup member with averted gaze is mimicked, but an anger expression with direct gaze not (Bourgeois & Hess, 2008). This is because anger is a non-affiliative signal (Hess, Blairy, & Kleck, 2000; Knutson, 1996) and therefore cannot be used to signal affiliative intent. Thus, emotional mimicry does not occur when social interaction goals are either absent or non-affiliative. Accordingly, watching emotional expressions with a non-affiliative interaction goal inhibits congruent reactions. For example, mimicry is reduced for individuals not sharing one’s goals (McHugo, Lanzetta, & Bush, 1991), and for those from an outgroup (Bourgeois & Hess, 2008; Van der Schalk et al., 2011). A different pattern is observed when emotional expressions are presented without any social context: Here, facial reactions are congruent to the valence of the perceived expression independent of the affiliative signal value of that expression (e.g., Dimberg, 1982; Dimberg, Thunberg, & Elmehed, 2000; Dimberg, Thunberg, & Grunedal, 2002). This pattern likely reflects affective reactions “to the content of the image, similar to the smiles people show when seeing baby animals and the frowns elicited by dangerous objects” (Hess & Fischer, 2013, p. 144).

Prior findings introducing avatars as computer game characters suggest that this context is sufficient to induce social interaction goals (Likowski, Mühlberger, Seibt, Pauli, & Weyers, 2008, 2011; Weyers et al., 2009). For example, presenting avatars as nice characters in a computer game led to more congruent reactions to their happy and sad displays than presenting them as neutral characters, whereas presenting them as negative characters led to incongruent reactions (Likowski et al., 2008). Furthermore, sad and happy expressions of alleged computer game characters in neutral and cooperative contexts were mimicked, but anger expressions were not (Likowski et al., 2011). In addition, in this study, participants in the neutral and cooperative conditions exhibited more cognitive empathy (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001) than those expecting competition, and this fully mediated their increased (congruent) *Zygomaticus major* activation to happy displays. This further suggests that the experimental situation indeed evoked social interaction goals and that a neutral situation is enough to activate an affiliation goal.

In most social situations, a smooth and harmonious interaction and a good relationship are desirable, so emotional mimicry should be observable (Chartrand & Lakin, 2013). In competitive situations, however, affiliation should not be the focal goal. In line with this, individuals show less congruent behavior in competitive situations (Lanzetta & Englis, 1989; Likowski et al., 2011; Weyers et al., 2009). Going beyond prior research, we test here whether the mere framing of avatars as computer game characters is enough to induce an interaction goal. In neutral and cooperative contexts, this should activate an affiliation goal, leading to sadness and happiness mimicry while inhibiting anger mimicry. This would be evidence that the default reaction to angry expressions in interpersonal contexts is not to mimic them.

We suggest that subliminally induced neutral and cooperative contexts lead to emotional mimicry, because this is the habitual response in those contexts. Accordingly, the goal and the response can be activated in an automatic fashion by these contexts (see Hess & Fischer, 2013). Further, once affiliative intent is present, facial displays are shaped by this goal rather than by one's own emotional reactions. Conversely, competitive contexts usually lack affiliative interaction goals, and therefore facial reactions in those contexts should reflect one's own emotional reactions as detailed above.

Finally, affiliative intent does not always lead to congruent reactions. Our last prediction concerns supportive smiles, which are incongruent reactions out of affiliative intent. Likowski et al. (2011) found that participants who expected positive interdependence spontaneously showed a *Zygomaticus major* activation (consistent with a supportive smile) to sad (and descriptively also to angry) displays of their partners. This reaction was fully mediated by the self-reported desire for harmonious interactions. Thus, the reasons for incongruent facial expressions to angry and sad expressions depend on the type of interdependence: in competition they can occur due to an affective reaction, as the mediation by joy indicates, while in cooperation they can occur due to interpersonal goals.

The fact that these smiling reactions occurred with static computer-generated images suggests that they are habitualized responses to negative expressions in a cooperative context. Likewise, individuals with a cooperative stance toward their romantic partner (as evidenced by high communal strength; Mills, Clark, Ford, & Johnson, 2004), show increased *Zygomaticus major* activity in response to an angry expression of their partner within the first second of exposure (Häfner & Ijzerman, 2011). Furthermore, in dyadic situations where one partner narrates an anger episode, the listeners do not mimic anger expressions but show Duchenne smiles (Hess & Bourgeois, 2010). Accordingly, like smiles to negative displays of romantic or cooperation partners, these smiles might serve the function to signal encouragement and affiliation in order to maintain a trustful, cooperative relationship.

Accordingly, we predict a spontaneous tendency to encourage their partner for participants primed with cooperation, more specifically, a *Zygomaticus major* activation to angry expressions. We did not predict a supportive smile to sad expressions because the default reaction to a sad display of a partner seems to be a congruent expression, to communicate empathy and understanding (Häfner & Ijzerman, 2011; Kennifer et al., 2009; Sheldon, Ellington, Barrett, Dudley, Clayton, & Rinaldi, 2009).

OVERVIEW OF THE EXPERIMENT

We examine whether facial reactions to emotional displays are influenced by the activation of positive and negative interdependence in a context where the individual has no conscious awareness of the activated schemas. We expect congruent reactions to smiles in the cooperation and neutral, but not in the competition condition. These congruent reactions should be evident in a contraction of the *Zygomaticus major* and the *Orbicularis oculi* (see Ekman, Davidson, & Friesen, 1990; Messinger, Cassel, Acosta, Ambadar, & Cohn, 2008), as well as in a relaxation of the *Corrugator supercilii* (Weyers et al., 2009). Therefore, we record activity from these three muscles during presentation of facial expressions with EMG after priming participants with cooperation, neutral, or competition words. We also expect congruent reactions to sad expressions in the neutral and the cooperation condition, that is, a contraction of the *Corrugator supercilii*. Going beyond prior findings with subliminal priming of interdependence (Weyers et al., 2009), we include a cooperation condition, stimuli with angry displays and a third muscle, the *Orbicularis oculi*. These improvements allow us to test more specific assumptions about congruent facial reactions. In particular, we assume angry displays not to evoke congruent responses, and we expect congruent responses to smiles to also include the *Orbicularis oculi*, in both neutral and cooperation contexts. The lack of anger mimicry would be in line with the assumed affiliative nature of these congruent displays (Bourgeois & Hess, 2008), and the involvement of the *Orbicularis oculi* would be more evidence that the congruent smiles communicate positivity and cooperative intent (Hess & Bourgeois, 2010; Mehu, Grammer, & Dunbar, 2007; Messinger et al., 2008).

In the competition condition, we expect incongruent reactions to sad and angry displays. Specifically, based on the findings by Likowski et al. (2011), we predict a relaxation of the *Corrugator supercilii* in response to sad and angry displays, which they found to be mediated by joy. However, in their study, participants were instructed about the interdependent nature of the alleged game, and also about the meaning of the facial expressions shown. Here, we test whether a subliminal competition priming is enough to produce these incongruent reactions. The results reported by Weyers et al. (2009) were in line with this assumption but failed to reach significance. We therefore extend their design by increasing the sample size to have more power, and by adding male avatars and angry expressions as contextual factors that might increase the applicability of the competitive mindset.

In the cooperation condition, we expect an incongruent reaction to angry expressions. Our specific prediction of a contraction of the *Zygomaticus major* is based on Likowski et al. (2011), where this pattern was mediated by the desire for a harmonious interaction, and hence can be interpreted as a supportive smile to help the other cope. This is the first study to test whether evidence of supportive smiles can be found in response to angry expressions after subliminal cooperation priming. This would support the assumption that such smiles are a fairly automatic form of encouragement (Häfner & Ijzerman, 2011). All predictions were tested in a study with female participants, to make the results comparable to those of Likowski et al. (2011).

METHOD

PARTICIPANTS

Eighty-nine female university students, majoring in a broad range of subjects, participated individually. They were recruited on a campus in Germany and received €10 compensation. Recruitment was limited to women because of earlier findings (Dimberg & Lundqvist, 1990) indicating that women show more pronounced, but not qualitatively different, facial EMG responses than men. Data from five participants had to be excluded from EMG analyses due to exceptionally high numbers of trials with artifacts. Hence, EMG analyses were conducted on the remaining sample of 84 women (28 per condition), aged between 18 and 27 years ($M = 23$, $SD = 2.5$). One participant from the cooperation group did not finish the avatar ratings leaving 27 participants in this group for the statistical analyses of these variables.

PROCEDURE

Participants were recruited for a study described as consisting of several unrelated experiments. After participants had signed a consent form, EMG electrodes were placed. This was followed by the priming task, the passive avatar observation, during which facial reactions were assessed, an assessment of mood, avatar ratings, a manipulation check, and an awareness check. Finally, participants were probed for suspicion, debriefed, and thanked. None was aware of the hypotheses, and none suspected that facial muscular reactions were measured.

Priming. The priming procedure followed the recommendations by Bargh and Chartrand (2000) and was closely modeled after Weyers et al. (2009). It was described as a test of visual acuity and reaction time. Primes were presented parafoveally for 90 ms followed by a 90 ms masking string of letters (*XQFBZRMQWGBX*). Intertrial intervals varied from 2000 to 7000 ms. For each trial a fixation cross was presented in the middle of the screen. Participants were instructed to look at this cross and to indicate on which side of the screen a flash appeared, corresponding to the primes/masks at one of four possible locations on the screen. They were asked to respond as quickly and as correctly as possible by pressing one of two keys labeled "left" and "right." Participants first completed six practice trials. In the cooperation condition, participants saw four words related to the concept of cooperation: *KOOPERIEREN* (cooperate), *PARTNER* (partner), *ZUSAMMEN* (together), and *VERBÜNDETER* (confederate). Primes in the competition condition were: *KONKURRIEREN* (compete), *RIVALE* (rival), *GEGNER* (opponent), and *WETTBEWERB* (competition). The primes for the control condition were: *NEU-*

TRAL (neutral), *HINTERGRUND* (background), *STRASSE* (street), and *TAFEL* (blackboard). Each word was presented 20 times, and the order was randomized.

Passive Avatar Observation. To not alert participants to the fact that their facial reactions were assessed, participants were told that we would assess their skin conductance reactions to avatars we planned to use in computer games. The participants' task was simply to look at the facial expressions of six avatar characters. To ensure that participants paid attention to the stimuli they were told that they would be asked about the pictures later on. Each avatar was shown with a happy, neutral, sad, and angry expression resulting in 24 stimuli, presented in randomized order. A warning tone and a fixation cross announced each trial, and the stimuli remained on screen for 6 seconds. Intertrial intervals varied from 19 to 23 seconds. During picture presentation, *Zygomaticus major*, *Corrugator supercilii*, and *Orbicularis oculi* activity were recorded.

Mood Assessment. Directly following the task, participants completed the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988; German adaption: Krohne, Egloff, Kohlmann, & Tausch, 1996) to test for potential priming effects on mood.

Avatar Ratings. To assess whether priming affected the perception of the avatar expressions per se, participants saw the avatar expressions again and this time rated them on 9-point Likert scales with regard to their valence (1 = very negative to 9 = very positive), arousal (1 = not at all to 9 = very arousing), and how much they liked the avatar (1 = very dislikable to 9 = very likable).

Manipulation Check. Following the experimental tasks, participants completed the priming procedure once again. This was done to ensure the persistence of the priming effects, and the following game was conducted: Participants were told to claim a share of 9 monetary units and that an avatar would claim a share, too. They would only be informed about the avatar's choice after they both had made their choice. If the sum of both shares was smaller than or equal to 9 both would receive their claimed share. If the sum was greater than 9 both would get nothing. In such a situation, a high claim indicates competitive behavior because in a competition situation a player should aspire to not receive less than her counterpart even if this means going away empty-handed. In the cooperation condition we expected a smaller amount of claimed monetary units than in the control condition because in this situation a player should try to maximize the profit for both, herself and the partner.

Awareness Check. To assess whether the priming procedure was in fact subliminal we followed the procedure recommended by Bargh and Chartrand (2000): we repeated four of the original priming trials at the end of the experiment such that each of the primes was presented once again for the same brief duration. Participants now were informed that words would be presented, and they were asked to identify or guess them. Note that in this task the awareness of the primes presented during manipulation check is assessed, but also any recollection of primes that might have been consciously perceived during the priming phase, as participants are instructed to guess anything they think they might be seeing or might have seen in the priming phase. No participant was able to recognize and name any of the primes. Hence we can conclude that subliminal presentation was achieved.

APPARATUS AND MATERIALS

Facial EMG. Activity over the *Zygomaticus major* (the muscle that turns the corners of the lips up), the *Corrugator supercilii* (the muscle responsible for frowning), and the *Orbicularis oculi* (the muscle producing wrinkles around the eyes) regions was recorded on the left side of the face using bipolar placements of 13/7 mm Ag/AgCl surface-electrodes according to the guidelines established by Fridlund and Cacioppo (1986). The EMG raw signal was measured with a BrainAmp MR amplifier (Brain Products Inc.), digitalized with a 16-bit analogue-to-digital converter, and stored on a personal computer with a sampling frequency of 1000 Hz. Raw data were filtered offline with a 30 Hz to 500 Hz bandpass filter and a 50 Hz notch filter. Data were rectified and smoothed using a 125 ms moving average filter. Trials with an EMG activity above 8 μV during the baseline period and above 30 μV during the stimuli presentation were excluded (less than 5%). Before statistical analysis, difference scores were computed and the EMG data were collapsed over the six trials with the same emotional expression.

Avatar Emotional Facial Expressions. Avatar facial emotional expressions were created with *Poser* software (*Curious Labs*, Santa Cruz, CA) and the software extension offered by Spencer-Smith et al. (2001), which allows one to manipulate action units separately according to the facial action coding system (Ekman & Friesen, 1978). The facial stimuli were presented on a computer screen one meter in front of the participants with a picture size of about 19 × 25 cm. Four emotional facial expressions were created from a prototypic female and a prototypic male face: a neutral, a happy, a sad, and an angry expression (for details see Spencer-Smith et al., 2001). Each male and female emotional expression was then combined with three types of hairstyles (blond, brown, and black hair), resulting in 24 stimuli (for examples see Weyers et al., 2009).

We used avatars, which often stand for real persons in computer games and social media, in order to minimize variance unrelated to the hypothesis. Several studies have compared reactions to avatars with reactions to humans, finding that individuals recognized emotional expressions of avatars and of photographed actors equally well (Spencer-Smith et al., 2001), that facial emotional expressions by avatars and by humans triggered comparable amygdala activation (Moser, Derntl, Robinson, Fink, Gur, & Grammer, 2007), that avatars who mimicked participants' behavior were liked more than those who did not (Bailenson & Yee, 2005), just like humans who mimic are liked more (Chartrand & Bargh, 1999), and that negative attitudes and a competitive stance toward avatars decreased facial mimicry (Likowski et al., 2008, 2011). These results suggest that reactions to avatars don't differ qualitatively from those to humans.

RESULTS

MANIPULATION CHECK

Participants' claims differed significantly as a function of condition, $F(2, 81) = 7.2$, $p = .001$, $\eta p^2 = .150$. Post-hoc LSD tests showed that in the competition condition more monetary units ($M = 4.5$, $SD = 1.00$) were claimed than in the cooperation

(M = 3.9, SD = .60) or the control condition (M = 3.8, SD = .61), $t(81) = 2.98$, p = .004 and $t(81) = 3.51$, p = .001, respectively. The cooperation and the control group did not differ in their claims, $t < 1$, p = .60. To illustrate, whereas only 14% of those in the cooperation and 11% in the neutral conditions claimed more than half the monetary units available, 50% of those in the competition condition did. The best explanation for this risky strategy after competition priming seems to be a focus on getting more than the other, something well documented for competitive intergroup behavior (Tajfel, Billig, Bundy, & Flament, 1971). Thus, according to the results of this behavioral measure our manipulation seems to have succeeded in priming competition. Participants primed with cooperation and those primed with neutral words both behaved cooperatively, as evidenced by their low claims (less than 4 of 9 units). However, this task might not be sensitive enough to distinguish between somewhat cooperative and very cooperative behavior: claiming slightly less than half the shares is both cooperative, as an equal distribution is considered fair in this context, and also rational, as claiming more than half entails the risk of losing all. Claiming much less than half is arguably neither more rational, as it would minimize the joint gains, nor more cooperative, as it deviates from the equality norm.

FACIAL EMG

A 3 (priming condition) × 4 (avatar emotion) × 3 (muscle) mixed model ANOVA[1] on the EMG data revealed significant main effects of Emotion, $F(3, 79) = 4.0$, p = .013, $\eta p^2 = .047$, and Muscle, $F(2, 80) = 6.9$, p = .003, $\eta p^2 = .078$, which were qualified by significant Emotion × Muscle, $F(6, 76) = 8.2$, $p < .001$, $\eta p^2 = .092$, and Priming × Emotion × Muscle, $F(12, 152) = 2.2$, p = .03, $\eta p^2 = .051$, interactions. To test our specific hypotheses regarding congruent and incongruent reactions, this was followed up by separate Muscle × Emotion mixed model ANOVAs within each priming condition. In case of a Muscle × Emotion interaction, we then calculated simple effects within each muscle comparing reactions to the emotional displays with those to the neutral display.[2]

Neutral Priming. A 3 (muscle) × 4 (avatar emotion) mixed model ANOVA for participants primed with neutral words revealed a significant Muscle × Emotion interaction, $F(3, 78) = 3.1$, p = .034, $\eta p^2 = .10$, all other Fs < 2.4, ps > .1. As shown in Figure 1, happy as compared to neutral expressions produced a significant increase in *Zygomaticus major* (M = .30, SD = .45 vs. M = -.02, SD = .46, $t[27] = 3.83$, p =.001), and *Orbicularis oculi* (M = .33, SD = 1.09 vs. M = -.15, SD = 1.75, $t[27] = 2.23$, p = .034) activity, and a decrease in *Corrugator supercilii* (M = -.25, SD = .60 vs. M = -.10, SD = .42, $t[27] = -2.07$, p = .049) activity.

1. In cases of a significant Mauchly-test for sphericity we used the Greenhouse-Geisser correction.

2. Instead of comparing reactions to emotional displays with those to neutral displays one can also compare them to the EMG signal prior to onset of the stimulus, that is, to the baseline (see, for example, Likowski et al., 2008, 2011). In order to allow comparisons across studies, we also used the latter strategy by performing t-tests against 0, which corroborated all significant results. In case of marginal effects, we used these tests as a second criterion to evaluate the evidence. We also confirmed that none of the reactions to neutral displays differed from zero.

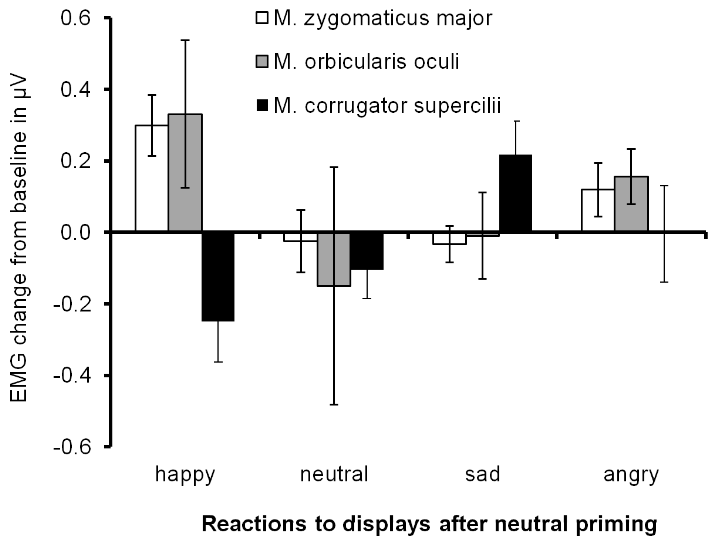

FIGURE 1. Mean EMG change in µV for the three recorded muscles in response to happy, neutral, sad, and angry facial displays in the neutral priming condition. Error bars indicate standard errors of the means.

In addition, participants showed an increase in *Corrugator supercilii* activity for sad displays compared to neutral ones (M = .22, SD = .50 vs. M = -.10, SD = .42), $t(27) = 2.3$, $p = .03$.[3] Thus, as expected, we found evidence for congruent responses to happy displays on all three muscles and to sad displays on the *Corrugator supercilii*.

Competition Priming. A 3 (muscle) × 4 (emotion) mixed model ANOVA revealed a main effect of muscle, $F(1.4, 36) = 7.5$, $p = .005$, $\eta p^2 = .22$, which was qualified by a marginal emotion by muscle interaction, $F(3.4, 92) = 2.4$, $p = .066$, $\eta p^2 = .081$. Participants showed a decrease in *Corrugator supercilii* activity to happy (M = -.42, SD = .56 vs. M = -.07, SD = .43), $t(27) = -3.71$, $p = .001$, and to angry (M = -.53, SD = .72 vs. M = -.07, SD = .43), $t(27) = -3.82$, $p = .001$, as compared to neutral faces (see Figure 2). The also expected relaxation of the *Corrugator supercilii* to sad faces (M = -.35, SD = .89 vs. M = -.07, SD = .43) failed to reach significance, $t(27) = -1.62$, $p = .117$.[4] Thus, participants in the competition condition showed a congruent reaction to happy faces on one of the three recorded muscles, the *Corrugator supercilii.* No congruent responses were shown to sad or angry faces. Rather, as expected, angry faces led to a relaxation of the *Corrugator supercilii*, which can be a sign of a positive affective reaction (Likowski et al., 2011). The evidence for reactions to sad faces was less clear.

Cooperation Priming. A 3 (muscle) × 4 (emotion) mixed model ANOVA revealed a main effect of emotion, $F(2, 62) = 4.7$, $p = .010$, $\eta p^2 = .15$, which was qualified by an emotion by muscle interaction, $F(3, 75) = 7.0$, $p < .001$, $\eta p^2 = .20$. As with the

3. For this and the following analyses, no significant simple effect other than the reported ones emerged, all *p*s > .15.

4. However, a significant *t*-test against 0, $t(27) = -2.1$, $p = .045$, showed that participants reacted to sad displays with a relaxation of the *Corrugator supercilii* as compared to the baseline prior to stimulus onset.

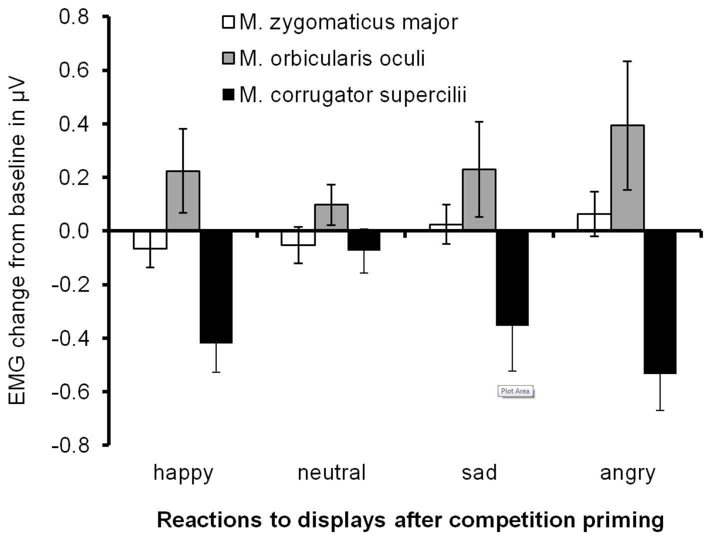

FIGURE 2. Mean EMG change in µV for the three recorded muscles in response to happy, neutral, sad, and angry facial displays in the competition priming condition. Error bars indicate standard errors of the means.

neutral priming, we found congruent responses for happy displays in comparison to neutral displays on all three muscles, with contractions of *Zygomaticus major* (M = .33, SD = .49 vs. M = -.11, SD = .41), $t(27) = 3.36$, $p = .002$, *Orbicularis oculi* (M =.62, SD = 1.28 vs. M = -.03, SD = .44), $t(27) = 2.89$, $p = .007$, and a relaxation of *Corrugator supercilii* (M = -.34, SD = .85 vs. M = .07, SD = .27), $t(27) = -2.56$, $p = .016$ (see Figure 3). In addition, we found congruent reactions to sad displays in the form of increased activity of the *Corrugator supercilii* (M = .31, SD = .55 vs. M = .07, SD = .27), $t(27) = -2.45$, $p = .021$.

Furthermore, we found an incongruent reaction to angry compared to neutral displays on the *Zygomaticus major* (M = .24, SD = .62 vs. M = -.11, SD = .41), $t(27) = 2.38$, $p = .025$, and the *Orbicularis oculi* (M = .32, SD = .57 vs. M = -.03, SD = .44), $t(27) = 3.0$, $p = .006$.[5] Thus, as expected, we obtained evidence for a congruent reaction to happy and sad displays, and for an incongruent reaction to angry displays, which can be a sign of a supportive smile (Häfner & Ijzerman, 2011; Likowski et al., 2011).

CONTROL SCALES

We also checked whether the observed differences in facial reactivity were due to priming-induced mood differences: No significant effects of priming condition emerged for either the positive, $F(2, 81) = 1.3$, $p = .281$, $\eta p^2 = .031$, or the negative affect scale of the PANAS, $F(2, 81) = 1.2$, $p = .316$, $\eta p^2 = .028$.

5. For sad displays, there was a marginal increase in activity over the *Zygomaticus major* (M =.02, SD =.34 vs. M = -.11, SD =.41), $t(27) = -1.77$, p =.087. However, a t-test against 0 failed to corroborate this effect, $t(27) < 1$.

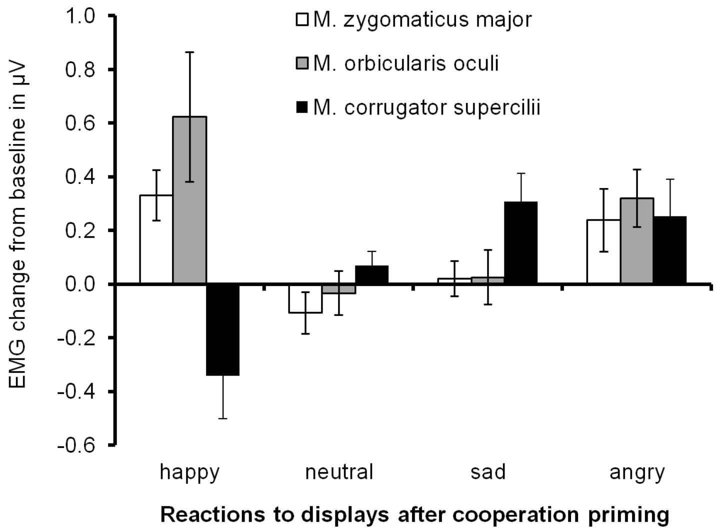

FIGURE 3. Mean EMG change in µV for the three recorded muscles in response to happy, neutral, sad, and angry facial displays in the cooperation priming condition. Error bars indicate standard errors of the means.

Finally, to check whether the priming changed the perception of the facial displays, separate Priming × Avatar Emotion mixed-model ANOVAs were conducted on the valence, arousal, and liking ratings. Neither the priming effects (all Fs < 1.09, ps > .34) nor the Priming × Emotion interactions (all Fs < 1, ps > .61) were significant. Thus, cooperation or competition priming did not significantly change the perception of the emotional facial expressions.

DISCUSSION

The present study revealed congruent reactions to happy and sad faces after subliminal priming with cooperation and with neutral words, and an almost complete lack of such congruent reactions after competition priming. Incongruent reactions to angry faces were found after competition priming in the form of a relaxation of the *Corrugator supercilii,* and after cooperation priming in the form of *Zygomaticus major* and *Orbicularis oculi* contractions. This study was thereby the first to find facial evidence for a positive affective reaction to negative displays after subliminal competition priming. It was also the first to find evidence for a positive facial display in response to angry displays after subliminal cooperation priming. This latter result might indicate a tendency for showing a supportive smile to encourage an angry collaborator. Neither competition nor cooperation priming modified the ratings of the avatar expressions or the mood of the participants. Hence, the differences between the conditions cannot be explained by differences in mood or in the perception of the avatars. We first discuss the congruent reactions observed.

CONGRUENT REACTIONS

The congruent reactions observed in the cooperation and neutral conditions are in line with emotional mimicry's function as reinforcing social bonds (Hess, 2001; Hess & Fischer, 2013; Yabar & Hess, 2007). Concerning the competition condition, mimicry to negative expressions seems to be wiped out by incongruent affect (see also Likowski et al., 2011; Weyers et al., 2009) but happy expressions can still evoke some congruent reactions in a competitive mind-set. This might be because a smile can function as a social reward (e.g., Chakrabarti, Kent, Suckling, Bullmore, & Baron-Cohen, 2006) or it might be that a smile is not as strong an indicator of a gain for the opponent as a negative expression is an indicator of a loss.

Congruent reactions to happy and sad displays are the default for the population—female German students—studied here, as we observed them also after neutral priming. According to Van Vugt, De Cremer, and Janssen (2007), women are more cooperative and less competitive than men. This may mean that cooperation is the default stance for women and that this explains both the lack of a difference between neutral and cooperation priming in the manipulation check and the congruent facial reactions in the neutral condition. If so, men might show the same amount of congruent reactions in a cooperative situation, but less in a neutral situation. This question remains to be further investigated.

Furthermore, none of the groups showed a congruent reaction to angry faces, arguably because anger signals the motivation not to affiliate (Bourgeois & Hess, 2008). However, in experimental settings that excluded all reference to social context, anger mimicry has been found (Dimberg, 1982). Accordingly, potential interactions with avatars in a computer game might be more psychologically engaging than seeing photos of strangers. We do not have evidence whether the affiliation goal was activated by our neutral and cooperative social contexts, but given prior evidence showing the mediation of habitualized responses by goal activation (Aarts & Dijksterhuis, 2000), we believe this is likely. Intergroup contexts, though clearly social, sometimes evoke mimicry of angry ingroup members (Bourgeois & Hess, 2008; Van der Schalk et al., 2011). The reason might be an activation of the collective self, which gives rise to group-level emotions (Smith, Seger, & Mackie, 2007). Rather than congruent reactions, we found incongruent reactions to anger following competition and cooperation priming, which may indicate affective and supportive reactions, respectively.

AFFECTIVE REACTIONS

In the competition condition, we found an incongruent reaction to angry displays: a relaxation of the *Corrugator supercilii*. In an explicitly competitive situation, such reactions could be explained by feelings of joy, presumably because a competitor's misfortune indicates an advantage for oneself (Likowski et al., 2011). Moreover, the competition primes led to more competitive behavior in a cooperation game than the neutral or cooperation primes. Thus, despite being only subliminally primed with competition, these participants felt and behaved as if actually competing with the other person.

This finding has implications for theories about the processes leading to affective reactions. It means that without conscious inferences, the facial display is shaped by situational factors in such a way as to contradict the visually salient affective content, in this case anger. This result supports the conditioning account of emotional reactions in situations of negative interdependence (Englis et al., 1982). According to this account, individuals learn during their socialization that a negative facial expression is a predictor of reward in the context of negative interdependence. Context-specific conditioning is well known in the animal literature (e.g., Bouton, 1993). In humans, this context-sensitivity of associations and reactions is best captured by connectionist models (see Smith, 1996). We believe that the subliminal priming procedure is the best test of the conditioning account as it activates a certain context without allowing conscious inferences based on that context. Thus, we can assume that stored context-dependent associations, affective reactions or goals are responsible for the incongruent reactions observed, and not ad-hoc constructions of the implications of the other's facial expressions for oneself.

Sad displays did not evoke a significantly different *Corrugator supercilii* response than neutral displays in the competition condition. However, we found a significant relaxation of that muscle compared to the baseline, replicating Likowski et al.'s (2011) finding. It thus seems from the available evidence that sad expressions of competitors might evoke the same incongruent reactions as angry expressions, possibly to a somewhat lesser extent. In the neutral condition, we found congruent reactions to sad displays rather than incongruent reactions, which suggests that people sympathize with others as long as their own interests are not opposite to those of the other person. In the cooperation condition, we also found an incongruent reaction to angry displays, here however as activation of the *Zygomaticus major.* This may indicate a supportive reaction.

SUPPORTIVE REACTIONS

Participants in the neutral and cooperation conditions did not differ in their reactions, except to angry displays, where participants in the cooperation condition responded with *Zygomaticus major* and *Orbicularis oculi* contractions. This result is in line with earlier work showing evidence of incongruent displays to negative expressions of cooperation partners (Likowski et al., 2011) and romantic partners (Häfner & Ijzerman, 2011). In the study by Likowski et al., these incongruent displays were mediated by the desire for harmonious interaction. In the study by Häfner and Ijzerman, only those high in communal strength (Mills et al., 2004), who have a more cooperative stance in their partnership than those low in communal strength, showed them. These patterns are in line with the idea that incongruent reactions to negative displays in a situation of positive interdependence can be an expression of the social goals to encourage, to soothe, to support, or to accommodate. However, this study is the first to show that individuals even show this incongruent reaction when just subliminally primed with positive interdependence. This is remarkable because there was no communicative context in this study: Participants just watched pictures of avatars and expected to answer questions about them later.

However, with the present data, we cannot verify whether indeed two different processes are responsible for the incongruent reactions in competitive and in cooperative contexts. Therefore, designing more direct tests of the assumed underlying processes applicable to subliminal priming contexts would be a great extension to the present work. This means that at present, our interpretation of the observed incongruent reactions after cooperation priming as due to social goals has to remain tentative. If it holds, it would mean that most of us have learned that regulating the mood of cooperation partners is conducive to reward, either because it is good for the relationship, or because it motivates the partner to sustain efforts toward the common goal.

This lesson might be learned early in life. Vygotsky (1998) argues that other-regulation necessarily precedes self-regulation. This means that children learn to regulate negative affect by first helping others regulate their negative affect, and by being helped by others to regulate their own affect. From this perspective, it is not surprising that the tendency to cheer others up is rather well learned and automatic. The presumed origin of the supportive smile as a goal-directed communication fits with finding the activation primarily over the *Zygomaticus major*, which can be easily activated (Mehu, Mortillaro, Bänziger, & Scherer, 2012) and easily detected and understood by the receiver (Niedenthal et al., 2010). In addition, we observed a co-activation of the *Orbicularis oculi*, which is part of the happiness display ("Duchenne smile," see Ekman, 2003). This might mean that participants in the cooperation condition did not try to conceal negative emotions evoked by the anger display, but rather produced a genuinely friendly expression. Consistent with this interpretation, Hess and Bourgeois (2010) observed that individuals in dyadic social situations who are told an anger-eliciting event show a high rate of Duchenne smiles but no anger mimicry, presumably to signal social intent. Other studies have found Duchenne smiles as markers of altruism, sociability, generosity, and of cooperative intent (Brown, Palameta, & Moore, 2003; Mehu, Grammer, et al., 2007; Mehu, Little, & Dunbar, 2007). Supportive smiles might similarly mark a disposition to keep trusting the other and his or her good intentions.

More evidence is needed about when sad displays can elicit a supportive smile. In the present study, we found only congruent reactions to sad displays in the cooperation condition. This finding is in line with a general tendency to share a partner's grief, which does not necessarily help to end it (Rimé, 2009). However, in explicit cooperative contexts, sad displays can evoke a mixed display of a *Zygomaticus major* activation along with a *Corrugator supercilii* activation (Likowski et al., 2011). In that study, however, participants were told that the facial expressions they saw showed the response of the partner to his or her result. In such a situation, encouragement is arguably more adequate than mirroring the sadness.

CONCLUSION

Facial reactions to emotional displays in a rather impoverished situation are modulated by subliminally primed interdependence goals in a manner very similar to the modulation by explicit interdependence goals. This modulation shows that cooperation and competition afford a different set of behaviors, emotions, and interpersonal goals. These different reactions can be learned during prior exposure to situations of interdependence but they can also have a component that is evolutionarily prepared (see Kurzban et al., 2001). The findings can be used to better understand nonverbal communication and to analyze interpersonal differences (cf. Häfner & Ijzerman, 2011).

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