How reward modulates mimicry: EMG evidence of greater facial mimicry of more rewarding happy faces

THOMAS B. SIMS,1 CARIEN M. VAN REEKUM,1 TOM JOHNSTONE,2 AND BHISMADEV CHAKRABARTI1b
1Centre for Integrative Neuroscience and Neurodynamics, School of Psychology and Clinical Language Sciences, University of Reading, Whiteknights, Reading, UK
2Autism Research Centre, Department of Psychiatry, University of Cambridge, Cambridge, UK

Abstract

Spontaneous mimicry is a marker of empathy. Conditions characterized by reduced spontaneous mimicry (e.g., autism) also display deficits in sensitivity to social rewards. We tested if spontaneous mimicry of socially rewarding stimuli (happy faces) depends on the reward value of stimuli in 32 typical participants. An evaluative conditioning paradigm was used to associate different reward values with neutral target faces. Subsequently, electromyographic activity over the Zygomaticus Major was measured whilst participants watched video clips of the faces making happy expressions. Higher Zygomaticus Major activity was found in response to happy faces conditioned with high reward versus low reward. Moreover, autistic traits in the general population modulated the extent of spontaneous mimicry of happy faces. This suggests a link between reward and spontaneous mimicry and provides a possible underlying mechanism for the reduced response to social rewards seen in autism.

Descriptors: Empathy, Mimicry, Emotion, EMG

Mimicry is an integral part of human social interaction. Humans mimic from an early stage in development (Charman et al., 1997; Meltzoff, 2002). As adults, we frequently mimic behavior of others, whether it is the mimicry of bodily postures while talking with someone (Chartrand & Bargh, 1999) or the subtle mimicry of facial expressions in others (Dimberg, 1982; Dimberg, Thunberg, & Elmehed, 2000). Spontaneous mimicry constitutes a key component of empathy (Hermans, Putman, & van Honk, 2006; Meltzoff, 2002; Sonnby-Borgstrom, 2002). Indeed, it is known that members of certain clinical groups characterized by low empathy (e.g., Autism Spectrum Conditions [ASC]) do not engage in spontaneous facial mimicry (Dimberg et al., 1999). The reward–empathy link is of particular interest for understanding communication in the conditions under which mimicry occurs. The reward–empathy link appears to be in spontaneous, uninstructed mimicry (McIntosh, Reichmann-Decker, Winkielman, & Wilbarger, 2006; Oberman, Winkielman, & Ramachandran, 2009; Stel, van den Heuvel, & Smeets, 2008). This leads to a key question of what drives spontaneous facial mimicry.

One hypothesis, which we test in the current experiment, is that spontaneous facial mimicry in the general population is driven by the reward value of the stimulus. Social psychological studies provide some crucial clues for this hypothesis by showing that people tend to mimic those who they like more or want to affiliate with (Bourgeois & Hess, 2008; Hess, 2001; Likowski, Muhlberger, Seibt, Pauli, & Weyers, 2008; Stel et al., 2010). Conversely, people find those who mimic them more likeable (Lakin & Chartrand, 2003; Smeets, 2008). Interestingly, most studies that have examined performance in instructed mimicry tasks have found that ASC has no marked deficit in volitional mimicry; the only deficits appear to be in spontaneous, uninstructed mimicry (McIntosh, Reichmann-Decker, Winkielman, & Wilbarger, 2006; Oberman, Winkielman, & Ramachandran, 2009; Stel, van den Heuvel, & Smeets, 2008). This leads to a key question of what drives spontaneous facial mimicry.

In the current study, we tested the extent to which spontaneous mimicry is dependent on the reward value of a social stimulus in the general population. We manipulated the reward value associated with a face through the use of an evaluative conditioning...
paradigm (de Houwer, Thomas, & Bayens, 2001), adapted to condition socially relevant stimuli (M. E. Dawson, Rissling, Schell, & Wilcox, 2007; Gottfried, O’Doherty, & Dolan, 2002; Todrank, Bymes, Wrzesniewski, & Rozin, 1995). We implicitly conditioned expressively neutral faces of four actors with different reward values (see Figure 1) by engaging the participants in a simple card game (Cox, Andrade, & Johnsrude, 2005). In a subsequent phase, we tested the spontaneous mimicry of happy expressions made by these actors by measuring facial electromyographic (EMG) activity from the congruent muscle (Zygomaticus Major). We predicted higher Zygomaticus Major activity in response to happy expressions displayed by faces conditioned with the highest reward relative to low reward conditions. To ensure that this effect was specific to the congruent muscle, we also recorded EMG over the Corrugator Supercilii muscle, which is not known to be active during smiling or in response to a smile. In addition, to ensure that any observed effect was driven by increased spontaneous mimicry and not by a generalized increase in positive affect in response to actors conditioned with a high reward, we included a control condition where people watched angry faces made by the same actors.

Finally, we assessed individual differences in autistic traits and social interaction using the Autism Spectrum Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). The AQ is a 50-item questionnaire measure of autistic traits that consists of two main factors: social interaction and attention to detail (Hoekstra, Bartels, Cath, & Boomsma, 2008). The subscale of social interaction was of particular interest for the current study because higher scores are thought to be related to decreased social reward sensitivity. Accordingly, we expected participants with low AQ scores to demonstrate greater mimicry of high reward happy faces versus low reward happy faces whereas we did not expect a difference in mimicry in response to different reward conditions in participants with high AQ scores. We further predicted that there would be an interaction between reward condition and scores on the subscale of social interaction, such that only participants with low social interaction scores would mimic high reward faces more than low reward faces.

In summary, we predicted that (a) the happy expressions of faces conditioned with high reward (compared to those conditioned with low reward) would elicit greater Zygomaticus Major activity in the observers, and (b) individuals low in autistic traits would demonstrate greater spontaneous mimicry (of happy expressions of faces conditioned with high reward compared to those conditioned with low reward) when compared to individuals high in autistic traits.

Methods

Participants

Thirty-three participants (26 female) aged between 18 and 35 years (M = 26.01, SD = 4.25) were recruited from the University of Reading campus and were paid £5 or given course credit for their participation. All participants had normal or corrected-to-normal vision. Ethical approval for the study was obtained from the University Research Ethics Committee of the University of Reading, and all participants provided informed consent.

Stimulus Materials

Stimuli used in the conditioning phase consisted of static images of four target faces (2 male, 2 female) with a neutral expression. Stimuli used in the test phase consisted of eight 4,000-ms video clips (frame size: 15.25 × 11.5 cm) showing dynamic expressions of emotion made by the same four target faces. The facial expressions reached their apex between 1,000 ms and 2,000 ms after stimulus onset and then plateaued for the remainder of the clip. Dynamic expressions were used in the test phase, as they are more ecologically valid than static images (Hess & Blairy, 2001). All stimuli were selected from the Mindreading set (Baron-Cohen, Golan, Wheelwright, & Hill, 2004; available at www.jkp.com/mindreading). These stimuli have been shown to have high interrater reliability and external validity (Golan & Baron-Cohen, 2006; Golan, Baron-Cohen, & Hill, 2006).
Procedure

After arriving at the laboratory and after providing informed consent, participants sat at a distance of 55 cm from a Viewsonic VE510s monitor (color TFT active matrix XGA LCD 30.5 cm × 23 cm). All stimuli were displayed on the monitor using E-Prime 2.0 (Psychology Software Tools, PA). The sensors were placed over the facial muscles (see below). The participants were then introduced to the implicit evaluative conditioning task. The instructions for the task were presented to the participant on the monitor and read aloud by the experimenter. To ensure that participants were not focusing on their facial muscles, they were informed that the sensors were being used to measure sweat gland activity (e.g., Dimberg, 1982). The experimenter left the room during the conditioning task. After the conditioning task had been completed the experimenter returned to the room and introduced the test phase. Again the instructions for the task were presented on the monitor and also read aloud by the experimenter. After completion of the test phase participants were debriefed and dismissed.

Conditioning

In each trial a target face with a neutral expression (see Figure 1) appeared alongside a card guessing game. At the start of each trial participants were presented with two standard playing cards. The first card was face up, and the second card was face down. Participants used one of two keys on the keyboard to predict whether they believed the second card would be of greater or lesser value than the first card. There was no time limit in which the participants were required to respond. If they were correct in their prediction then they won 25 p. If they were incorrect they lost 20 p. This feedback was displayed for 4,000 ms. If the cards were of equal value, then the participant neither won nor lost money. Each target face was presented 30 times. The outcome of all of the trials, regardless of participant response, was predetermined and the feedback adjusted accordingly. The reward level attributed to each target face was manipulated by adjusting the number of trials that were won or lost in the presence of each face. In the highest reward (“Pos90”) condition, participants won 90% of the trials that were paired with that face. In the lowest reward (“Neg90”) condition, participants lost 90% of the trials. Two other conditions “Pos60” (participants winning 60% of the trials) and “Neg60” (participants losing 60% of the trials) were introduced to prevent participants from guessing the underlying structure of the game. All trials that were not won or lose were “tie” trials (i.e., the value of the second card was equal to that of the first card). The faces in the four conditions (Pos90, Pos60, Neg60, Neg90) were counterbalanced across participants. The presence of the faces alongside the cards was explained by informing the participants that the second half of the study would involve a simple memory task.

Test Phase

After conditioning, the participants engaged in an oddball task, when they viewed emotion expressions made by the faces they were conditioned to in the earlier phase. There were two emotion expressions for each of the four faces: happy and angry. Each of the clips was 4000 ms in duration and was presented eight times in a random order. The clips were preceded by a 1,000-ms fixation cross. A blank screen was presented for 1,000 ms between each trial. Randomly distributed throughout the presentation of the target clips there were four clips that contained an emotion expres-

EMG Measurement

EMG activity was measured in the test phase using sensors placed over the Zygomaticus Major and Corrugator Superficii. Placement of these sensors was in accordance with Fridlund and Cacioppo (1986). A ground electrode was also placed on the upper forehead. To decrease impedance, the skin was first cleansed using prep pads drenched in 70% alcohol (Professional Disposables, Inc., USA TD-230). Four-millimeter Ag/AgCl surface sensors (Discount Disposables, USA) were filled with Isotonic Electrode Gel (Mansfield R & D, UK) and attached to the skin using 5-mm electrode collars (Discount Disposables). The sensors were bipolarly placed on the left side of the face with a constant distance between sensors of 5 mm. The raw signal was recorded by a ML-870 Power Lab (AD Instruments, Australia) and passed through a ML-138 Octal Bio amplifier (AD Instruments), which amplified the signal 10,000 times. The data were acquired using Lab Chart 7.0 (AD Instruments). The raw signal was sampled at 1 kHz and digitized with 16-bit precision. This was then digitally filtered with a low-pass filter set to 500 Hz and a high pass filter set to 10 Hz.

Data Scoring

In accordance with Tassinary and Cacioppo (2000), the raw EMG signal was rectified in order to remove negative values. The data were screened for movement artifacts and then logarithmically transformed to minimize the impact of extreme values. The baseline was established for each individual trial as the mean magnitude in activity for the period 500 ms prior to stimulus onset. The mean EMG magnitude for the period 2,000 ms to 4,000 ms after stimulus onset was then calculated and then divided by the baseline (de Wied, Van Boxtel, Posthumus, Goudena, & Matthys, 2009). The period 2,000 ms to 4,000 ms after stimulus onset was used as the window of interest, as the dynamic emotion expressions reached their maximal point around 2,000 ms, and this also represented the point at which the Zygomaticus Major response peaked (Figure 2). A measure of participants’ happy face specific Zygomaticus Major response for each of the four reward conditions was calculated by dividing the mean Zygomaticus Major response to happy faces by the mean Zygomaticus Major response to angry faces within the same reward condition. The average scores for the positively conditioned (i.e., Pos90 and Pos60) happy faces and negatively conditioned (i.e., Neg90 and Neg60) happy faces were then calculated and used to assess interactions between reward condition and trait measures (see below). One participant’s data were removed from the trait measure analysis as the combined Pos90 and Pos60 score fell more than 2.5 standard deviations from the mean.

Trait Measurements

Prior to their participation, participants completed the AQ. Scores on the AQ ranged between 7 and 29 ($M = 13.93, SD = 6.51, \alpha = .81$),
and scores on the social interaction subscale ranged between 1 and 27 ($M = 10$, $SD = 6.1$, $\alpha = .83$). No participant scored above 32 on the full AQ, which has been found to be a reliable threshold score for a potential clinical diagnosis of ASC. The top and bottom quartiles of the AQ and its social interaction subscale were used separately to identify the high and low AQ groups and the high and low social interaction groups of participants.

Results

Data were excluded from one female participant for failure to comply with instructions, thus retaining the data for 32 participants. Data from 10 trials (0.47% of the total trials) were removed because of excessive movement artifacts. In the test phase, the oddball task (irrelevant to the question of interest) was performed with a high level of accuracy, with participants making errors on only 2.3% of trials. This indicated that the participants were attending to the stimuli.

We predicted the Zygomaticus Major response to be highest in response to the happy expression made by the face conditioned with highest reward relative to that made by the face conditioned with the lowest reward. Confirming our prediction, a one-way repeated measures analysis of variance (ANOVA) revealed a significant main effect of condition, $F(3, 93) = 2.90$, $p = .039$, $\eta^2_{H-F corrected} = .057$, partial $\eta^2 = .09$. Simple effects confirm that when participants viewed happy facial expressions, Zygomaticus Major activity was significantly greater in the Pos90 condition than in the Neg90 condition, $t(31) = 2.65$, $p = .013$, $d = 0.51$ (Figure 3). There was also significantly greater activity in the Pos60 condition than the Neg90 condition, $t(31) = 2.64$, $p = .013$, $d = 0.51$. The difference in activity between either of the high reward conditions and the Neg60 condition was not significant; Pos90 versus Neg60, $t(31) = 1.30$, $p = .202$, Pos60 versus Neg60, $t(31) = 1.22$, $p = .231$. For the control condition (watching angry faces), although the angry face in the Neg90 condition unexpectedly elicited higher levels of Zygomaticus Major activity than the other conditions, this difference was not significant, $F(3, 93) = 2.48$, $p = .066$, $\eta^2_{H-F corrected} = .094$. Importantly, neither of the positively conditioned faces elicited higher Zygomaticus Major activity in the angry expression condition. A one-way repeated measures ANOVA for Corrugator Supercilii response in the happy face condition revealed no significant effect of reward condition, $F(3, 93) = 0.08$, $p = .973$, $\eta^2_{H-F corrected} = .097$.

We predicted that the low AQ group would demonstrate greater mimicry of happy expressions of faces conditioned with high reward compared to those conditioned with low reward. A mixed-
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**Figure 4.** Values represent the mean happy face specific Zygomaticus Major activity averaged across high reward conditions (i.e., Pos90 and Pos60; dark gray) and low reward conditions (i.e., Neg90 and Neg60; light gray). High and low Autism Spectrum Quotient (AQ) groups (based on upper and lower quartiles) are represented along the x-axis.

In this study, we tested the prediction that happy faces previously conditioned to high reward would elicit greater spontaneous mimicry compared with faces conditioned to low reward. The results support our prediction. Second, the degree to which participants mimicked more rewarding happy faces was inversely related to their autistic traits. These results provide a direct test of the link between spontaneous mimicry and reward and establish how these relate to individual differences in autistic traits.

Specifically, greater Zygomaticus Major activity was seen in response to happy expressions made by faces that had been previously implicitly conditioned to high reward compared to those faces that were conditioned to low reward. It is well documented that Zygomaticus Major activity can be produced in the presence of mere positive stimuli (Brown & Schwartz, 1980; Larsen, Norris, & Cacioppo, 2003; Stel, Van Baaren, & Vonk, 2008). However, in our study, the increased Zygomaticus Major response to positively conditioned faces was specific for happy expressions and did not generalize to other facial expressions (i.e., angry). This suggests that the increased Zygomaticus Major response to happy expressions was not merely driven by an increase in positive affect in response to positively conditioned stimuli. Additionally, the increased activity could not be attributed to a generalized increase in activity across all facial muscles as there was no such trend observed for the Corrugator Superficialis in response to the happy expressions of the positively conditioned faces. This study thus provides direct evidence for the role of reward in modulating mimicry of happy faces. As spontaneous mimicry is a marker of empathy, the current set of results establishes a direct link between reward and empathy in the general population. This evidence is concordant with previous social psychological studies that have shown that people mimic those whom they like more (Likowski et al., 2008; Stel et al., 2010).

Theoretically, we speculate that a connection between the brain regions involved in empathy and those involved in reward processing results in spontaneous mimicry during social interactions being reinforced. Such a link could provide the basis for a mechanism by which reward processes reinforce general social behavior, similar to how reward processes reinforce other human behaviors such as feeding (Hnasko, Szczypka, Alaynick, Doering, & Palmier, 2004), sex, (Giuliano & Allard, 2001), and initiating love (Aron et al., 2005). The proposed link also shows how interactive partners can implicitly accrue reward value through empathic behaviors such as reciprocal mimicry (Kuhn et al., 2010) and joint attention (Schilbach et al., 2010) during everyday social interaction.

Consequently, if low empathy is associated with a dysfunctional connection between these brain regions, it could explain why people with low empathy are less motivated to attend to social stimuli. In particular, a disruption of this link between empathy and reward can potentially underlie conditions such as ASC, which are marked by both an impaired response to social rewards (G. Dawson et al., 2002; Kohls, Peltzer, Herpertz-Dahlmann, & Konrad, 2009; Scott-Val Zeitland, Dapretto, Ghahremani, & Poldrack, & Bookheimer, 2010) and reduced spontaneous mimicry of social stimuli (McIntosh et al., 2006).

Consistent with this possibility, we found that low AQ participants, but not high AQ participants, demonstrated greater mimicry for high reward faces compared with low reward faces. This supports the view that individuals within the general population with high autistic traits are not as sensitive to reward value attached to social stimuli as individuals who score lower in this trait measure.

It should be noted that studies that report impaired spontaneous mimicry in ASC largely tend to use facial imitation; findings from studies using hand imitation are less consistent (see Spengler, Bird, & Brass, 2010). It has been proposed that the development of face and hand imitation might rely on different processes. Although infants are able to visually match their own hand movements to those of others, they have no visual reference for their own facial expressions. It is therefore suggested that facial imitation must rely on processes that are, in part at least, genetically prewired (Casile, Caggiano, & Ferrari, 2011). The consistent finding of a deficit in spontaneous mimicry of faces, but not of hands, in ASC participants suggests that any deficits in the ASC mimicry mechanisms are limited to the prewired system.

An unexpected finding was the large Zygomaticus Major response in the Neg90 condition (relative to the other reward conditions) when participants viewed angry faces. Surface EMG recordings taken from the Zygomaticus Major area are especially susceptible to cross talk because of the muscle’s proximity to
the buccinator and masseter muscle groups (Larsen, Norris, & Cacioppo, 2003; Tassinari & Cacioppo, 2000), which are linked to negative emotions such as frustration (e.g., Tan et al., 2011; Unz & Schaub, 2005). Zygomaticus Major can also be evoked by grimacing in response to unappealing scenes (Lang, Greenwald, Bradley, & Hamm, 1993) or at the appearance of a perceived enemy (van Reekum, 2000). It is conceivable that angry expressions of faces associated with low reward in the current study provoke a grimace similar to that of a perceived enemy. Thus, although not predicted, it is not uncommon to find Zygomaticus Major activity occurring in response to negative valence as a result of either cross talk or grimacing.

In conclusion, we found that happy faces associated with a high reward value produced greater spontaneous EMG activity in the congruent facial muscle than happy faces associated with a low reward. We attribute this activity to facial mimicry, as no difference in EMG activity was found in response to angry faces associated with different values of reward or in incongruent facial muscles. As spontaneous facial mimicry is a marker of empathy, this study provides direct evidence of a link between the brain’s reward and empathy systems. We speculate that a disruption to this link may be a contributing factor in psychopathological conditions characterized by deficits in empathy and social reward sensitivity (e.g., ASC). This is supported by our finding that those who scored higher in measures of autistic traits within our sample also demonstrated less sensitivity to the different levels of reward associated with the social stimuli. Future studies should test this link directly in people with ASC.

References

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