Running head: TRUSTWORTHINESS MODULATES EMOTIONAL
MIMICRY

Untrustworthiness inhibits congruent facial reactions to happy faces

Tomomi Fujimura¹²³ and Kazuo Okanoya¹²⁴

Institutional affiliations

1 Okanoya Emotional Information Project, ERATO, Japan Science and
Technology Agency, Wako, Saitama, Japan

2 Emotional Information Joint Research Laboratory, Brain Science
Institute, RIKEN, Wako, Saitama, Japan

3 Human Informatics Research Institute, National Institute of Advanced
Industrial Science and Technology, Tsukuba, Ibaraki, Japan

4 Department of Life Sciences, Graduate School of Arts and Sciences,
The University of Tokyo, Meguro, Tokyo, Japan

Correspondence: Tomomi Fujimura

Human Informatics Research Institute,

National Institute of Advanced Industrial Science and Technology (AIST)

Central 2, 1-1-1, Umezono, Tsukuba, Ibaraki, 305-8568, Japan

E-mail: t.fujimura@aist.go.jp

TEL: +81-29-861-0441

Abstract

This study investigated how trustworthiness modulates facial reactions to emotional faces, specifically emotional mimicry. In order to manipulate the trustworthiness of others, we used the trust game. The participants ($N = 37$) perceived the partners as trustworthy or untrustworthy based on whether the partners tended to behave fairly or unfairly in the game with a within-subjects design. Facial electromyograms were measured while viewing the emotional faces displayed by the partners. The results demonstrated that the zygomaticus major activity in response to happy faces was greater for the trustworthy partners than for the untrustworthy partners. The results suggest that emotional mimicry of happiness is more inhibited for those who are non-affiliative and unfavorable, such as the untrustworthy partners. On the other hand, there was no effect of trustworthiness on congruent facial reactions to sad and angry faces. However, the zygomaticus major activity for angry faces was smaller for the trustworthy partners than for the untrustworthy partners, suggesting that positive expressions to angry faces of the trustworthy partners are inhibited. Trustworthiness constructed by social exchange modulates not only emotional mimicry for happy faces but also incongruent facial reactions to angry faces.

Keywords: emotional mimicry, facial electromyography, affiliative relationship, trustworthiness, the trust game

1 **1. Introduction**

2 Congruent facial reactions spontaneously occur when looking at the
3 emotional facial expressions of others (Dimberg & Thunberg, 1998;
4 Dimberg, Thunberg, & Elmehed, 2000). These facial reactions can be
5 measured by facial electromyography (EMG), which can assess subtle and
6 brief facial expressions. Previous studies using EMG have revealed that
7 corrugator supercilii muscle activity (brow lowering) is evoked in response
8 to angry and sad faces, and that zygomaticus major muscle activity (pulling
9 the corner of the lip) is evoked in response to happy faces (Fujimura, Sato,
10 & Suzuki, 2010; Hess & Blair, 2001; Lundqvist, 1995; Lundqvist &
11 Dimberg, 1995).

12 These congruent facial reactions have been considered to reflect
13 emotional mimicry that is the result of an understanding of emotional
14 signals in social contexts, as opposed to simply copying the specific facial
15 movements of others (Hess & Fischer, 2013, 2014). A growing body of
16 literature has reported that social context, especially the affiliative
17 relationship between observer and expresser, modulates facial reactions to
18 emotional faces (Bourgeois & Hess, 2008; Fischer, Becker, & Veenstra,
19 2012; Hofman, Bos, Schutter, & van Honk, 2012; Lanzetta & Englis, 1989;
20 Likowski et al., 2008; McHugo et al., 1985; van der Schalk et al., 2011).
21 For example, Likowski et al. (2008) have revealed participants to have
22 congruent facial reactions to happy and sad faces of characters toward
23 which they have a positive attitude, but not to those toward whom they have
24 a negative attitude. Moreover, congruent facial reactions to smiles evoked
25 after disgust and pride stimuli occur only among intimates (Fischer et al.,
26 2012). According to the evidence, it can be assumed that emotional mimicry
27 is likely to be inhibited in non-affiliative relationships. In other words,

1 emotional mimicry is motivated behavior to reciprocate affiliation and build
2 affiliative relationships with others.

3 One of the factors in relation to affiliative relationships between the
4 expressers and observers is trustworthiness. Past research has shown that
5 the neurotransmitter oxytocin involved in the development of human
6 affiliation increases trusting behavior toward others (Kosfeld et al., 2005;
7 Zak, Kurzban, & Matzner, 2005) and perceived facial trustworthiness
8 (Theodoridou, Rowe, Penton-Voak, & Rogers, 2009). In fact, people are
9 more cooperative with partners who are subjectively rated as more
10 trustworthy (van't Wout & Sanfey, 2008). Moreover, a neuroimaging study
11 also revealed that the level of activation of the amygdala is greater when
12 rating faces as more untrustworthy (Freeman, Stoller, Ingbretsen, &
13 Hehman, 2014; Winston, Strange, O'Doherty, & Dolan, 2002). This is
14 supported by the evolutionary perspective that the evaluation of
15 trustworthiness is essential for human survival when building social
16 relationships with others (Cosmides & Tooby, 1992). According to this
17 evidence, trustworthiness is a key factor in the construction and
18 maintenance of the affiliative relationship between the expresser and
19 observer.

20 Trustworthiness is not only automatically evaluated from facial
21 appearance (Todorov, Pakrashi, & Oosterhof, 2009), but is also constructed
22 through social exchange. A study using a debt game showed that
23 participants tend to decide whether or not to borrow money from a lender
24 based on lenders' behavior (i.e., demanding no interest or high interest)
25 learned through an interaction, rather than the facial trustworthiness of the
26 lenders (Suzuki & Suga, 2010). Thus, the form of trustworthiness
27 constructed by social exchange seems to be more effective for manipulation

1 of affiliative relationship than the form of trustworthiness perceived from
2 facial appearance. For manipulation of trustworthiness through social
3 exchange, the trust game (Berg, Dickhaut, & McCabe, 1995) can be useful.
4 In this game, two players play the role of either an investor or a trustee. The
5 investor invests money with the trustee, which causes the total amount
6 available for distribution between the players to increase. If the trustee
7 shares the amount equally between the players or returns money to the
8 investor corresponding to an investment, the investor typically regards the
9 trustee as fair. On the other hand, when the trustee retains the money for
10 him/herself or return less money to the investor, the investor typically
11 regards the trustee as unfair. In the multi-round version of the game, as the
12 investor learns if the trustee tends to behave fairly or not, the
13 trustworthiness of the trustee is gradually constructed (Franzen et al., 2011).
14 By assigning participants (i.e., observers) to the role of investor and their
15 partners (i.e., expressers) to the role of trustee, we can manipulate the
16 trustworthiness of expressers in the eyes of observers.

17 A previous study using the trust game examined if fairness reputation
18 modulates facial reactions to emotional faces (Hofman et al., 2012). The
19 result showed that unfair reputation of partners acquired by iterated unfair
20 offers during the game enhanced corrugator supercilii activity for angry
21 faces of partners presented after the game. However, in the study by
22 Hofman et al. (2012) emotional faces were presented not only after playing
23 the game, but also immediately after a partner's offer during the game.
24 Thus, it is possible that viewing emotional faces with offers during the
25 game contaminated the effect of fairness reputation on the facial reactions
26 to emotional faces presented after the game. Furthermore, it remains
27 unclear whether perceived fairness or trustworthiness modulated facial

1 reactions to emotional faces, as the participants were not asked to give any
2 subjective ratings about the partners in the study by Hofman et al. (2012).

3 To clarify the effect of trustworthiness constructed by social exchange on
4 facial reactions to emotional faces, we presented emotional faces of their
5 partners only after playing the multi-round version of the trust game and
6 asked participants to evaluate the trustworthiness of their partners. Dynamic
7 emotional faces were presented as morph sequence instead of actual
8 expressions of the partners for uniform stimulus duration. For emotion
9 categories, we focused on sadness in addition to happiness and anger used
10 in Hofman et al. (2012). Previous research has demonstrated that emotional
11 mimicry of sadness is modulated by affiliative intent toward expressers
12 (Bourgeois & Hess, 2008; Likowski et al., 2008). Given that mimicking
13 sadness incurs high social cost as sad people who expect to receive help and
14 succor may require support (Bourgeois & Hess, 2008), mimicry of sadness
15 exhibited by untrustworthy partners might be inhibited.

16 In this study, we investigated how trustworthiness related to the
17 affiliative relationship between the observers and expressers modulates
18 facial reactions to emotional faces. Given that emotional mimicry functions
19 as a way to reciprocate affiliation with others, we predicted that congruent
20 facial reactions to emotional faces would be enhanced for trustworthy
21 partners, but not or less for untrustworthy partners. Thus, we aimed to
22 reveal the effect of trustworthiness constructed by social exchange on facial
23 reactions to emotional faces and to provide a clue to understanding the
24 functions of emotional mimicry in social interaction.

25

1 **2. Methods**

2 **2.1. Participants**

3 Thirty-seven undergraduate and graduate students (mean age = 20.05
4 years, $SD = 1.68$, age range = 18–23 years) participated in this experiment.
5 All participants were female because facial reactivity to others' emotional
6 faces is more evident for females than for males; however, facial reactions
7 to emotional faces are not qualitatively different between females and males
8 (Dimberg & Lundquist, 1990). Participants received compensation for their
9 participation. All participants had normal or corrected-to-normal vision. All
10 experimental procedures were approved by the ethics committee of the
11 Japan Science and Technology Agency.

12 **2.2. Stimulus Materials**

13 Facial stimuli consisted of happy, sad, angry, and neutral faces, each of
14 which was expressed by four Japanese females. Examples of facial stimuli
15 are shown in Figure 1a. Their emotional faces were rated as more intense
16 than those of any other models in a larger pool of facial stimuli developed
17 by Fujimura and Suzuki (2007). In a pilot study, 24 participants (13 women,
18 11 men, mean age = 33.33 years, $SD = 8.06$, age range: 21–54 years) who
19 did not participate in the present study rated the facial expressions of
20 happiness, sadness, and anger presented as static images. The emotional
21 faces were rated with regard to the intensity of each of the six emotions (i.e.,
22 happiness, anger, sadness, surprise, disgust, and fear) on a 7-point rating
23 scale (1 = not at all, 7 = extremely) in order to select the best expressions of
24 the target emotions and exclude facial stimuli that express mixed emotion
25 (ex., anger and disgust). The neutral faces were rated with regard to
26 trustworthiness on a 7-point rating scale (i.e., “How much do you trust her?”
27 1 = not at all, 7 = very much). For all the emotional faces, the target

1 emotion for each emotional face was indicated by the highest rating scores.
2 For the neutral faces, trustworthiness was indicated by the middle rating
3 scores in order to manipulate trustworthiness by playing the trust game.
4 Means and standard deviations ($M \pm SD$) for the intensity of the target
5 emotion and the trustworthiness of the selected facial stimuli were as
6 follows: target emotion, 5.03 ± 0.37 for sad faces, 5.10 ± 0.81 for angry
7 faces, and 5.64 ± 0.30 for happy faces; trustworthiness, 3.97 ± 0.49 for
8 neutral faces.

9 Happy, angry, and sad faces were presented as dynamic images generated
10 by a morphing technique. First, 42 intermediate images between a neutral
11 face and each emotional face were created using computer-morphing
12 software (SQIRLZ MORPH v. 2.1: Xiberpix, Solihul, UK,
13 www.xiberpix.com). Each intermediate image was presented for 13.3 ms
14 (i.e., corresponding to 75 frames/second), the first image (i.e., an original
15 neutral face) was presented for 480 ms, and the last image (i.e., an original
16 emotional face) was presented for 2960 ms. The total duration of the
17 movies was 4000 ms.

(a)

1

(b)

2

3

4 *Figure 1.* (a) Samples of facial stimuli. The emotional faces are the final
 5 images to create dynamic facial expressions using a morphing technique.
 6 The neutral face was used for creating dynamic facial expressions and
 7 presented in the trust game and the trustworthiness rating. (b) Single round
 8 in the trust game. In this round, a participant (i.e., investor) invested 2
 9 points with a partner (i.e., trustee) and then the partner returned 2 points to
 10 the participant (i.e., "just return" allocation). Actual sentences in screens
 11 were written in Japanese.

12

2.3. Apparatus and EMG Measurement

Experimental events were controlled by a program written in Inquisit 3.0 (Millisecond) and were implemented on a computer (Vostro 420, Dell) using the Microsoft Windows XP operating system. Stimuli were presented on a 19-inch LCD monitor (E1902S, Iiyama; 1024×768 pixels, 75-Hz refresh rate). The facial stimuli subtended a visual angle of about $14.25^\circ \times 11.42^\circ$.

Facial muscle activity was assessed electromyographically on the left side of the face. Electromyographic activity was measured using Ag/AgCl electrodes, with 4 mm diameter Ag/AgCl detection surfaces placed over the corrugator supercilii and zygomaticus major muscle regions using the placement recommended by Fridlund and Caccioppo (1986).

Electromyogram signals were acquired and recorded using an integrated system (MP 150 system; BIOPAC systems Inc., Goleta, CA) and software package (AcqKnowledge 4.1; BIOPAC systems Inc., Goleta, CA) controlled by a PC (Latitude E5400; DELL). Electromyogram signals were amplified, filtered, and digitized using a BIOPAC amplifier (EMG100C; BIOPAC systems Inc., Goleta, CA). The electromyogram raw signals were digitized at a sampling rate of 10 kHz and a bandpass filter of 10–5000 Hz. The stored signals were resampled at 2 kHz and then bandpass filtered further between 20 and 500 Hz off-line and rectified using AcqKnowledge 4.1 (BIOPAC systems Inc., Goleta, CA) (De Wied et al., 2009; van Boxtel, 2001).

2.4. Procedure

Experimental sessions were conducted individually in an electronically shielded and sound-proof room. Upon arrival, participants were told that the

1 electrodes that would be used were harmless and that they could withdraw
2 from the experiment at any time. All participants completed an informed
3 consent form and agreed to participate in the experiment. Participants were
4 told that this study aimed to investigate how people behave in an economic
5 game (i.e., the trust game) and how they respond to their partners'
6 emotional faces.

7 The experiment consisted of three parts: the trust game, emotional face
8 viewing, and trustworthiness ratings. In the emotional face viewing, facial
9 EMG in response to the partners' emotional faces were measured. First, to
10 confirm if the facial stimuli were capable of inducing facial reactions,
11 emotional face viewing was conducted. Next, to assess trustworthiness
12 perceived from facial appearance, participants were asked to rate the
13 trustworthiness of the partner's neutral face. After playing the trust game
14 (i.e., manipulation of trustworthiness), participants engaged in the
15 emotional face viewing and the trustworthiness ratings again.

16

17 **2.4.1. Trust Game**

18 Figure 1b shows one round of the trust game. The two players, the
19 investor and trustee, exchanged points. Participants were always assigned to
20 the role of investor, and the partners were assigned to the role of trustee.
21 Participants were endowed with 160 points at the beginning of the game
22 and played ten rounds randomly with each of the four partners, resulting in
23 40 rounds per game. To bring the experimental situation closer to real
24 social exchange, they were told that they would receive money according to
25 the final points they gained. After completing all of the sessions, they were
26 told that the money paid to them was actually fixed, regardless of their final
27 points.

1 Each round began with a 1000-ms fixation point, followed by a partner's
 2 neutral face for 3520 ms. Participants then decided whether they wanted to
 3 invest two or four points with the partner. After the decision was presented
 4 for 1000 ms on the screen, it was invested with the partner and then tripled.
 5 The tripled amount was presented for 3000 ms, and then the partner split
 6 the points between herself and the participant. The allocation between them
 7 was presented for 5000 ms, followed by an inter-round interval of 3000 ms.
 8 The partner's neutral face remained on screen throughout the round.

9 There were three types of partner allocation: fair return, just return, and
 10 unfair return. In fair return, the partner split the amount of points equally
 11 between herself and the participant. In just return, the partner simply
 12 returned the points the participant had invested with her. In unfair return,
 13 the partner kept all the points and returned nothing to the participant. Two
 14 of the partners made fair returns in eight rounds and just returns in two
 15 rounds, while the rest of the partners made unfair returns in eight rounds
 16 and just returns in two rounds. Assignment of the partners to these
 17 conditions was counter-balanced among participants.

18 Actually, the partners did not exist and their decisions (i.e., point
 19 allocation) in the game were totally controlled by an experimenter. To
 20 convince participants that their partners' decision was made of their own
 21 free will, a cover story was provided as follows: "Your partners have
 22 already participated as a trustee in this experiment, and their point
 23 allocation when playing with you were based on actual decision they have
 24 made. Your decisions as an investor will be also used for another
 25 experiment." None of the participants doubted the cover story and
 26 participants' decision were not actually used in a follow-up experiment.

27 **2.4.2. Emotional face viewing**

1 Electromyogram was recorded while the participants viewed a sequence
 2 of dynamic emotional faces exhibited by their partners in the game. As a
 3 cover story, participants were told that electrodes on their face were to
 4 measure sweat gland activity and that at the end of this experiment we
 5 would take a picture of their emotional faces for use in a follow-up
 6 experiment. To keep their attention on the sequence, they were asked to
 7 select one emotion word that best corresponded to the presented emotional
 8 face. A trial began with a 1000-ms fixation point followed by a 4000 ms
 9 dynamic emotional face. Then, three emotion words were presented on a
 10 screen and the participants made their choice using a numeric keypad. After
 11 making their choice, a blank screen was presented during an 8000–10000
 12 ms inter-trial interval. Each facial stimuli was randomly presented four
 13 times, resulting in a total of 48 trials in each run before and after the trust
 14 game.

15 **2.4.3. trustworthiness rating**

16 Participants were asked to rate the trustworthiness of the partner's
 17 neutral face on a 7-point scale ("How much do you trust her?") where 1 =
 18 *not at all* and 7 = *very much*. In a trial, a neutral face was preceded by a
 19 1000-ms fixation point and presented until participants responded. Inter-
 20 stimulus interval was 2000 ms. The neutral faces of the four partners were
 21 each presented once in the rating task.

22

23 **2.5. Data Analysis**

24 Using AcqKnowledge 4.1 (BIOPAC systems Inc., Goleta, CA), we
 25 analyzed the rectified EMG for each trial with different periods between the
 26 first and second emotional face viewing (i.e., before and after the game). In
 27 order to make a direct comparison between the trustworthy condition and

1 the untrustworthy condition after manipulating trustworthiness, we analyzed
 2 the EMG data obtained from the second viewing independently. To assess
 3 the temporal course during which the effect of trustworthiness on emotional
 4 mimicry emerged, we analyzed the EMG data over eight separate time
 5 periods for the second viewing. For the first viewing, to confirm whether
 6 our facial stimuli induced facial reactions, we analyzed the EMG activity
 7 during the whole stimulus presentation.

8 For the first viewing, EMG activity was averaged over 4 s during
 9 stimulus presentation. For the second viewing, EMG activity was averaged
 10 in 500-ms intervals during 4-s stimulus presentations. Next, averaged EMG
 11 was standardized according to each participant's baseline EMG activity
 12 during 1 s before stimulus onset. To minimize artifact outliers, z -
 13 transformed EMG greater or smaller than 3 $SDs \pm$ mean were set equal to 3
 14 $SDs \pm$ mean (Tukey, 1977).

15 For the first viewing, z -transformed EMG was averaged for each emotion.
 16 We conducted a one-way (happy, angry, and sad) repeated-measures
 17 analysis of variance (ANOVA) separately for each muscle activity. For the
 18 second viewing, z -transformed EMG was averaged for each emotion and
 19 trustworthiness condition. We conducted a 2 (trustworthiness: trustworthy,
 20 untrustworthy) $\times$ 3 (emotion: happy, angry, and sad) $\times$ 8 (period) repeated-
 21 measures within-subjects ANOVA separately for each muscle activity.
 22 Effect sizes are reported as η^2 (eta squared). The Greenhouse-Geisser
 23 adjustment (Greenhouse & Geisser, 1959) was applied when needed, and
 24 the corrected p and the epsilon values were reported along with uncorrected
 25 degrees of freedom. Multiple comparisons were conducted with Tukey's
 26 HSD.

27

1 **3. Results**

2 **3.1. Trustworthiness of the Partners**

3 Table 1 shows the trustworthiness ratings for neutral faces before and
4 after the trust game. To confirm whether the trustworthiness of the partners
5 was successfully manipulated by playing the trust game, we conducted a 2
6 (trustworthiness: trustworthy, untrustworthy) $\times$ 2 (time: before the trust
7 game, after the trust game) repeated-measures, within-design ANOVA for
8 the trustworthiness ratings of neutral faces. The results fit predictions:
9 There were significant main effects of both trustworthiness condition ($F(1,$
10 $36) = 108.69, p < .01, \eta^2 = .28$) and time ($F(1, 36) = 7.18, p < .05, \eta^2 = .02$),
11 as well as a significant interaction between trustworthiness and time ($F(1,$
12 $36) = 170.84, p < .01, \eta^2 = .31$). A simple main effect test revealed that
13 neutral faces in the trustworthy condition were rated as more trustworthy
14 than those in the untrustworthy condition after the game ($F(1, 72) = 268.90,$
15 $p < .01, \eta^2 = .58$), while there was no difference between these conditions
16 pre-game ($F(1, 72) = 0.22, n.s.$). Additionally, neutral faces in the
17 trustworthy condition were rated as more trustworthy after the game than
18 before the game ($F(1, 72) = 47.50, p < .01, \eta^2 = .09$), while neutral faces in
19 the untrustworthy condition were rated as more untrustworthy after the
20 game than before the game ($F(1, 72) = 117.29, p < .01, \eta^2 = .23$). These
21 results indicate that the attempted manipulation of the trustworthiness of the
22 partners was successful and that the trustworthiness of the partners was
23 based on the results of social exchange in the game and not on their facial
24 appearance.

25

26

27

1 Table 1. Means and standard errors of trustworthiness ratings for neutral
 2 faces as a function of the trustworthiness condition before and after the
 3 trust game.

	Trustworthy		Untrustworthy	
	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>
Before Game	4.46 ^a	0.18	4.55 ^a	0.18
After Game	5.78 ^b	0.11	2.47 ^c	0.17

4
 5 Note. All ratings were evaluated on 7-point scale, with higher scores
 6 indicating greater trustworthiness. Row means with different superscripts
 7 differ at $p < .05$.

8

9 **3.2. Facial Reactions to Emotional Faces before Manipulating** 10 **Trustworthiness**

11 The averaged EMG activity of emotional faces in the first viewing is
 12 presented in Figure 2. As expected, corrugator supercilii activity in
 13 response to angry and sad faces was greater than those in response to happy
 14 faces ($F(2, 72) = 5.51, p < .01, \eta^2 = .24, \varepsilon = .67$) ($HSD = 0.25, \alpha = .05$), and
 15 zygomaticus major activity in response to happy faces were greater than
 16 those in response to angry and sad faces ($F(2, 72) = 2.42, p < .05, \eta^2 = .07,$
 17 $\varepsilon = .55$) ($HSD = 0.42, \alpha = .05$). Taken together, facial activity congruent
 18 with the emotional face of the other was greater than those incongruent with
 19 the emotional face of the other.

Figure 2. Means and SEMs of EMG activity for each emotional face without manipulation of trustworthiness. (a) zygomaticus major activity (b) corrugator supercilii activity.

3.3. The Effect of Trustworthiness on EMG Activity for Emotional Faces

3.3.1. Zygomaticus major EMG

The mean zygomaticus major activity in response to the emotional faces in the second viewing is presented in Figure 3. A trustworthiness $\times$ emotion $\times$ period repeated measures ANOVA yielded significant main effects of emotion ($F(2, 72) = 5.25, p < .05, \eta^2 = .05, \epsilon = .55$) and period ($F(7, 252) = 4.29, p < .05, \eta^2 = .01, \epsilon = .25$), and significant interactions of emotion $\times$ trustworthiness ($F(2, 72) = 4.83, p < .05, \eta^2 = .01, \epsilon = .69$) and emotion $\times$ period ($F(14, 504) = 6.62, p < .05, \eta^2 = .01, \epsilon = .11$). These significant main effects and interactions were qualified by emotion $\times$ trustworthiness $\times$ period ($F(14, 504) = 3.37, p < .05, \eta^2 = .003, \epsilon = .27$).

The test for simple interactions revealed significant interactions of trustworthiness $\times$ period for the happy faces ($F(7, 252) = 3.04, p < .01, \eta^2 = .004$) and the angry faces ($F(7, 252) = 3.49, p < .01, \eta^2 = .01$), but not for

1 the sad faces ($F(7, 252) = 0.76, n.s.$). For happy faces, the simple-simple
 2 main effect of trustworthiness revealed that trustworthy partners evoked
 3 greater zygomaticus major activity than untrustworthy partners did during
 4 the 2000–2500 ms ($F(1, 36) = 4.97, p < .05, \eta^2 = .02$), 2500–3000 ms ($F(1,$
 5 $36) = 6.29, p < .05, \eta^2 = .03$), and 3500–4000 ms ($F(1, 36) = 4.99, p < .05,$
 6 $\eta^2 = .04$) periods. For angry faces, zygomaticus major activity in the
 7 trustworthy condition was more inhibited than those in the untrustworthy
 8 condition during the 3500–4000 ms period ($F(1, 36) = 8.32, p < .01, \eta^2$
 9 $= .08$).

10 To assess if muscle activity occurs in response to dynamic emotional
 11 faces, we report here only the periods that significantly differed from the 0–
 12 500 ms periods where the neutral faces were presented. For happy faces,
 13 zygomaticus major activity in the trustworthy condition at 1500–2000,
 14 2000–2500, and 2500–3000 ms periods was greater than those at the 0–500
 15 ms period ($F(7, 252) = 4.54, p < .01, \eta^2 = .03; HSD = 0.57, \alpha = .05$). There
 16 was no significant difference between the 0–500 period and other periods
 17 for untrustworthy happy faces ($F(7, 252) = 2.96, p < .01, \eta^2 = .03; HSD =$
 18 $0.35, \alpha = .05$), trustworthy angry faces ($F(7, 252) = 1.22, n.s.$), and
 19 untrustworthy angry faces ($F(7, 252) = 2.65, p < .05, \eta^2 = .03; HSD = 0.16,$
 20 $\alpha = .05$)

21

1

2 *Figure 3.* Means and SEMs of z -transformed zygomaticus major activity in
 3 response to emotional faces of trustworthy partners and untrustworthy
 4 partners.

5

6 **3.3.2. Corrugator supercilii EMG**

7 The mean corrugator supercilii activity in response to the emotional faces
 8 in the second viewing is presented in Figure 4. A trustworthiness $\times$ emotion
 9 $\times$ period repeated measures ANOVA yielded a significant main effect of

1 emotion ($F(2, 72) = 6.01, p < .01, \eta^2 = .05, \varepsilon = .67$), indicating that
 2 corrugator major activity in response to angry faces and sad faces was
 3 greater than those in response to happy faces ($HSD = 0.22, \alpha = .05$). There
 4 were no other main effects or interactions.

5
 6 *Figure 4.* Means and SEMs of z-transformed corrugator supercilii activity
 7 in response to emotional faces of trustworthy partners and untrustworthy
 8 partners.

1

2 **4. Discussion**

3 In this study, we investigated whether trustworthiness constructed by
4 social exchange modulated facial reactions to partners' emotional faces. To
5 manipulate trustworthiness, we used the trust game in which partners made
6 fair or unfair offers. Participants viewed emotional faces of their partners
7 twice; before and after the trust game, while measuring EMG activity.

8 Before manipulation of trustworthiness, zygomaticus major activity in
9 response to happy faces was greater than that in response to angry and sad
10 faces, and corrugator supercilii activity in response to angry and sad faces
11 was greater than that in response to happy faces, in line with previous
12 research (Lundqvist & Dimberg, 1995). These results suggest that the
13 current emotional faces were capable of inducing congruent facial reactions
14 in observers.

15 We found that viewing happy faces of the trustworthy partners produced
16 greater zygomaticus major activity than viewing happy faces of the
17 untrustworthy partners. As expected, congruent facial reactions were
18 enhanced when expressers were trustworthy. Additionally, for happy faces
19 of the untrustworthy partners, but not the trustworthy partners, there were
20 no significant difference of zygomaticus major activity between the period
21 of 0–500 ms (i.e., a neutral face presentation) and the others. These results
22 indicate that emotional mimicry of happiness occurs in the trustworthy
23 condition but not in the untrustworthy condition. This is the first evidence
24 of the effect of trustworthiness constructed by social exchange on emotional
25 mimicry of happiness. In the study by Hofman et al. (2012), in which
26 emotional faces were presented not only after the game but also during the
27 game, the effect of fair reputation on emotional mimicry of happiness was

1 not found. Hence, our finding is exclusively based on the trustworthiness
2 constructed by fair and unfair offers in the game. Our result is consistent
3 with findings that the affiliative relationship between expressers and
4 observers produced or facilitated emotional mimicry of happy faces
5 (Fischer et al., 2012; Likowski et al., 2008; McIntosh, 2006). These results
6 are also supported by the notion that emotional mimicry occurs in social
7 relationships that are potentially affiliative (Hess & Fischer, 2013, 2014).

8 However, contrary to our results, two previous studies have reported that
9 congruent facial reactions to happy faces occur independently of affiliative
10 relationships (Bourgeois & Hess, 2008; van der Schalk et al., 2011). This
11 may be due to the fact that these studies created relationship such as group
12 membership defined by a political attitude (Bourgeois and Hess, 2008;
13 Study 1), a preference in sport (Bourgeois and Hess, 2008; Study 2), and a
14 field of studies (van der Schalk et al., 2011; Study 1). In these relationships,
15 although the out-group members are less affiliative than the in-group
16 members, observers are unlikely to have a negative attitude toward the out-
17 group members. On the other hand, in the present study, as untrustworthy
18 partners produced an economic loss for participants in the trust game, the
19 participants might personally have a strong negative attitude toward the
20 untrustworthy partners. Additionally, Hofman et al. (2012) demonstrated
21 that emotional mimicry of happy faces is absent after participants are
22 confronted with a one-time unfair offer in the trust game. Together these
23 results suggest that emotional mimicry of happiness might be inhibited
24 when expressers are unfavorable for observers. This is likely to be an
25 adaptive behavior in social situations. Considering that emotional mimicry
26 of happiness functions to convey affiliative signals to the other (Hess &
27 Fischer, 2013, 2014), mimicry of happy faces exhibited by unfavorable

1 partners should be decreased. Our finding may be due to social function of
2 emotional mimicry as motivated behavior.

3 The present study also revealed the temporal course during which the
4 effect of trustworthiness on emotional mimicry emerged. Greater
5 zygomaticus major activity for happy faces of the trustworthy partners than
6 for happy faces of the untrustworthy partners was evident during 2000–
7 4000 ms after stimulus onset. It is noteworthy that the effect of
8 trustworthiness on emotional mimicry emerged slowly relative to the
9 occurrence of facial reactions within a half- to full-second after viewing
10 emotional faces (Dimberg, 1982). This suggests that emotional mimicry
11 modulated by trustworthiness might therefore not be an entirely automatic
12 and spontaneous response, but rather motivated behavior to reciprocated
13 affiliation in relationships.

14 There was no effect of trustworthiness on the level of corrugator
15 supercilii activity in response to angry faces. Our result is not in line with
16 the finding of Hofman et al. (2012), in which corrugator supercilii activity
17 for angry faces was enhanced by an unfair reputation earned during the trust
18 game. Considering that an unfair partner is not affiliative, the enhanced
19 congruent facial reactions to angry faces of the unfair partners that Hofman
20 et al. (2012) found may reflect emotional reactions to threat signals, rather
21 than emotional mimicry of anger. In this study, angry faces displayed by
22 untrustworthy partners might be perceived as less threatening because
23 unfair offers provided by untrustworthy partners were fewer than those
24 provided by unfair partners in the study by Hofman et al. (2012). Therefore,
25 it is possible that enhanced congruent facial reactions to angry faces
26 interpreted as emotional reactions depend on the intensity of non-affiliative
27 signals created by trustworthiness.

1 Interestingly, our finding indicates that zygomaticus major activity for
2 angry faces of the trustworthy partners was smaller than that for those of
3 the untrustworthy partners. This result suggests that incongruent facial
4 reactions to angry faces are inhibited when an expresser is trustworthy. It is
5 reasonable to inhibit positive expressions when those who has affiliative
6 relationship expresses anger. Thus, trustworthiness modulates not only
7 congruent facial reactions but also incongruent facial reactions.

8 For sadness, we did not find the effect of trustworthiness on facial
9 reactions. The result is not line with previous findings, in which emotional
10 mimicry of sad faces is modulate by emotional attitudes towards expressers
11 (Likowski et al., 2008) and group membership (Bourgeois & Hess, 2008).
12 One explanation for our results may be due to that emotional mimicry of
13 sadness less occurred even in the trustworthy condition. Our result showed
14 that corrugator supercilii activity for sad faces did not increase compared to
15 the initial period in which the neutral face was presented. In the trustworthy
16 condition, the partners tended to provide fair offers but not return more than
17 half the points to the participants who were the investor. Hence, affiliative
18 intent toward the trustworthy partners might be insufficient to induce
19 emotional mimicry of sadness. This can be explained by the notion that the
20 emotional mimicry of sadness incurs higher social cost than the emotional
21 mimicry of happiness (Bourgeois & Hess, 2008). Future studies should
22 investigate whether trustworthiness modulates emotional mimicry of
23 sadness under highly trustworthy conditions.

24 The present study demonstrated absence of congruent facial reactions to
25 happy faces of untrustworthy partners and decreased positive facial
26 reactions to angry faces exhibited by trustworthy partners relative to
27 untrustworthy partners. An alternative explanation for these findings is

1 affective divergence effect (Epstude & Mussweiler, 2009; Weisbuch &
2 Ambady, 2008), in which affective responses to outgroup emotional
3 expressions are diverged from emotional signal itself. Epstude and
4 Mussweiler (2009) and Weisbuch and Ambady (2008) demonstrated that
5 outgroup positive expressions elicit negative responses and outgroup
6 negative expressions elicit positive responses, relative to ingroup. Hence,
7 the modulation of facial reactions by trustworthiness that we found may be
8 partially a consequence of affective divergence.

9 Some limitation of this study should be acknowledged. First, the
10 participants and the models of our facial stimuli were only female. Because
11 we tried to eliminate influence of sex interaction between expressers (i.e.,
12 partners) and observers (i.e., participants) on facial reactions to emotional
13 faces. However, trustworthiness of others might depend on sex difference
14 between persons. Future studies should examine the effect of expresser's
15 sex on modulation of emotional mimicry due to trustworthiness. Second,
16 our finding that congruent facial reactions were enhanced in response to
17 happy faces of trustworthy partners are considered as not only emotional
18 mimicry to reciprocate affiliation but also emotional reactions to positive
19 stimuli (Moody, McIntosh, Mann, & Weisser, 2007). To disentangle this
20 issue, measuring another physiological activity in addition to zygomaticus
21 major and corrugator supercilii would be one of the tasks for the future.
22 Finally, we did not consider the effect of facial dynamics on perceived
23 trustworthiness because we uniformed the duration and dynamics of the
24 facial stimuli. A previous study has reported that smiles that have longer
25 onset duration and shorter apex durations were perceived as more
26 trustworthy (Krumhuber, Manstead, Cosker, et al., 2007; Krumhuber,
27 Manstead, & Kappas, 2007). It would be worthwhile to investigate how

trustworthiness of partners is constructed through social exchange in the interaction and dynamics of emotional faces and then modulates emotional mimicry.

In summary, our findings revealed that the effect of trustworthiness on emotional mimicry was clearly observed in happy faces. Emotional mimicry of happiness occurred in the trustworthy condition, but not the untrustworthy condition. These results suggest that emotional mimicry of happiness is inhibited for those who are unfavorable for observers. Given that emotional mimicry functions to reciprocate affiliation with others, the absence of it in untrustworthy people is highly adaptive. This study provided a clue to understanding the functions of emotional mimicry in social communication by considering trustworthiness as an influential factor of affiliative relationships. In everyday life, we are not always smiling to everyone. We unconsciously inhibit our smiling to untrustworthy people to avoid reciprocal affiliation. Emotional mimicry might be useful as an index to quantify trustworthiness and the affiliation relationship between people.

References

- Berg, J., Dickhaut, J., & McCabe, K. (1995). Trust, reciprocity, and social history. *Games and Economic Behavior*, **10**, 122-142. doi: 10.1006/game.1995.1027
- Bourgeois, P., & Hess, U. (2008). The impact of social context on mimicry. *Biological Psychology*, **77**, 343-352. doi: 10.1016/j.biopsycho.2007.11.008
- Bradley, M. M., Codispoti, M., Cuthbert, B. N., & Lang, P. J. (2001).

- 1 Emotion and motivation I: defensive and appetitive reactions in
2 picture processing. *Emotion*, **1**, 276-298.
- 3 Cosmides, L., & Tooby, J. (1992). Cognitive adaptations for social
4 exchange. In J.H. Barkow, L. Cosmides & J. Tooby (Eds.), *The*
5 *adapted mind: Evolutionary psychology and the generation of*
6 *culture* (pp. 163–228). London: Oxford University Press.
- 7 De Wied, M., van Boxtel, A., Posthumus, J. A., Goudena, P. P., & Matthys,
8 W. (2009). Facial EMG and heart rate responses to emotion-inducing
9 film clips in boys with disruptive behavior disorders.
10 *Psychophysiology*, **46**, 996-1004. doi: 10.1111/j.1469-
11 8986.2009.00851.x
- 12 Dimberg, U. (1982). Facial reactions to facial expressions.
13 *Psychophysiology*, **19**, 643-647. doi: 10.1111/j.1469-
14 8986.1982.tb02516.x
- 15 Dimberg, U., & Lundquist, L. O. (1990). Gender differences in facial
16 reactions to facial expressions. *Biological Psychology*, **30**, 151-159.
17 doi: 10.1016/0301-0511(90)90024-Q
- 18 Dimberg, U., & Thunberg, M. (1998). Rapid facial reactions to emotional
19 facial expressions. *Scandinavian Journal of Psychology*, **39**, 39-45.
20 doi: 10.1111/1467-9450.00054
- 21 Dimberg, U., Thunberg, M., & Elmehed, K. (2000). Unconscious facial
22 reactions to emotional facial expressions. *Psychological Science*, **11**,
23 86-89. doi: 10.1111/1467-9280.00221
- 24 Epstude, K., & Mussweiler, T. (2009). What you feel is how you compare:
25 how comparisons influence the social induction of affect. *Emotion*, **9**,
26 1-14. doi: 10.1037/a0014148
- 27 Fischer, A., Becker, D., & Veenstra, L. (2012). Emotional mimicry in social

- 1 context: The case of disgust and pride. *Frontiers in Psychology*, **3**,
2 475. doi: 10.3389/fpsyg.2012.00475
- 3 Franzen, N., Hagenhoff, M., Baer, N., Schmidt, A., Mier, D., Sammer, G.,
4 Gallhofer, B., Kirsch, P., & Lis, S. (2011). Superior ‘theory of mind’
5 in borderline personality disorder: An analysis of interaction
6 behavior in a virtual trust game. *Psychiatry Research*, **187**, 224-233.
7 doi: 10.1016/j.psychres.2010.11.012
- 8 Freeman, J. B., Stolier, R. M., Ingbreetsen, Z. A., & Hehman, E. A. (2014).
9 Amygdala responsivity to high-level social information from unseen
10 faces. *The Journal of Neuroscience*, **34**, 10573-10581. doi:
11 10.1523/jneurosci.5063-13.2014
- 12 Fridlund, A. J., & Cacioppo, J. T. (1986). Guidelines for human
13 electromyographic research. *Psychophysiology*, **23**, 567-589. doi:
14 10.1111/j.1469-8986.1986.tb00676.x
- 15 Fujimura, T., Sato, W., & Suzuki, N. (2010). Facial expression arousal level
16 modulates facial mimicry. *International Journal of*
17 *Psychophysiology*, **76**, 88-92. doi: 10.1016/j.ijpsycho.2010.02.008
- 18 Fujimura, T., & Suzuki, N. (2007). Effects of temporal information and
19 configuration change on the recognition of emotional facial
20 expressions: based on dimensional perspective. *Journal of Japanese*
21 *Cognitive Psychology*, **5**, 53-61. doi: 10.5265/jcogpsy.5.53
- 22 Greenhouse, S. W., & Geisser, S. (1959). On methods in the analysis of
23 profile data. *Psychometrika*, **24**, 95-112. doi: 10.1007/bf02289823
- 24 Hess, U., & Blairy, S. (2001). Facial mimicry and emotional contagion to
25 dynamic emotional facial expressions and their influence on
26 decoding accuracy. *International Journal of Psychophysiology*, **40**,
27 129-141. doi: 10.1016/S0167-8760(00)00161-6

- 1 Hess, U., & Fischer, A. (2013). Emotional mimicry as social regulation.
2 *Personality and Social Psychology Review*, **17**, 142-157. doi:
3 10.1177/1088868312472607
- 4 Hess, U., & Fischer, A. (2014). Emotional mimicry: Why and when we
5 mimic emotions. *Social and Personality Psychology Compass*, **8**, 45-
6 57. doi: 10.1111/spc3.12083
- 7 Hofman, D., Bos, P. A., Schutter, D., & van Honk, J. (2012). Fairness
8 modulates non-conscious facial mimicry in women. *Proceedings of*
9 *the Royal Society B-Biological Sciences*, **279**, 3535-3539. doi:
10 10.1098/rspb.2012.0694
- 11 Kosfeld, M., Heinrichs, M., Zak, P. J., Fischbacher, U., & Fehr, E. (2005).
12 Oxytocin increases trust in humans. *Nature*, **435**, 673-676. doi:
13 10.1038/nature03701
- 14 Krumhuber, E., Manstead, A. S. R., Cosker, D., Marshall, D., Rosin, P.L.,
15 & Kappas, A. (2007). Facial dynamics as indicators of
16 trustworthiness and cooperative behavior. *Emotion*, **7**, 730-735. doi:
17 10.1037/1528-3542.7.4.730
- 18 Krumhuber, E., Manstead, A. S. R., & Kappas, A. (2007). Temporal
19 Aspects of facial displays in person and expression perception: The
20 effects of smile dynamics, head-tilt, and gender. *Journal of*
21 *Nonverbal Behavior*, **31**, 39-56. doi: 10.1007/s10919-006-0019-x
- 22 Lanzetta, J. T., & Englis, B. G. (1989). Expectations of cooperation and
23 competition and their effects on observers' vicarious emotional
24 responses. *Journal of Personality and Social Psychology*, **56**, 543-
25 554. doi: 10.1037//0022-3514.56.4.543
- 26 Likowski, K. U., Mühlberger, A., Seibt, B., Pauli, P., & Weyers, P. (2008).
27 Modulation of facial mimicry by attitudes. *Journal of Experimental*

- 1 *Social Psychology*, **44**, 1065-1072. doi: 10.1016/j.jesp.2007.10.007
- 2 Lundqvist, L. O. (1995). Facial EMG reactions to facial expressions: A case
- 3 of facial emotional contagion? *Scandinavian Journal of Psychology*,
- 4 **36**, 130-141. doi: 10.1111/j.1467-9450.1995.tb00974.x
- 5 Lundqvist, L. O., & Dimberg, U. (1995). Facial expressions are contagious.
- 6 *Journal of Psychophysiology*, **9**, 203-211.
- 7 McHugo, G. J., Lanzetta, J. T., Sullivan, D. G., Masters, R. D., & Englis, B.
- 8 G. (1985). Emotional reactions to a political leader's expressive
- 9 displays. *Journal of Personality and Social Psychology*, **49**, 1513-
- 10 1529. doi: 10.1037/0022-3514.49.6.1513
- 11 McIntosh, D. N. (2006). Spontaneous facial mimicry, liking and emotional
- 12 contagion. *Polish Psychological Bulltein*, **37**, 31-42.
- 13 Moody, E. J., McIntosh, D. N., Mann, L. J., & Weisser, K. R. (2007). More
- 14 than mere mimicry? The influence of emotion on rapid facial
- 15 reactions to faces. *Emotion*, **7**, 447-457. doi: 10.1037/1528-
- 16 3542.7.2.447
- 17 Suzuki, A., & Suga, S. (2010). Enhanced memory for the wolf in sheep's
- 18 clothing: Facial trustworthiness modulates face-trait associative
- 19 memory. *Cognition*, **117**, 224-229. doi:
- 20 10.1016/j.cognition.2010.08.004
- 21 Theodoridou, A., Rowe, A. C., Penton-Voak, I. S., & Rogers, P. J. (2009).
- 22 Oxytocin and social perception: Oxytocin increases perceived facial
- 23 trustworthiness and attractiveness. *Hormones and Behavior*, **56**, 128-
- 24 132. doi: 10.1016/j.yhbeh.2009.03.019
- 25 Todorov, A., Pakrashi, M., & Oosterhof, N. N. (2009). Evaluating faces on
- 26 trustworthiness after minimal time exposure. *Social Cognition*, **27**,
- 27 813-833. doi: 10.1521/soco.2009.27.6.813

- 1 Tukey, J. (1977). *Exploratory data analysis*. MA: Addison Wesley.
- 2 van Boxtel, A. (2001). Optimal signal bandwidth for the recording of
- 3 surface EMG activity of facial, jaw, oral, and neck muscles.
- 4 *Psychophysiology*, **38**, 22-34. doi: 10.1111/1469-8986.3810022
- 5 van der Schalk, J., Fischer, A., Doosje, B., Wigboldus, D., Hawk, S.,
- 6 Rotteveel, M., & Hess, U. (2011). Convergent and divergent
- 7 responses to emotional displays of ingroup and outgroup. *Emotion*,
- 8 **11**, 286-298. doi: 10.1037/a0022582
- 9 van't Wout, M., & Sanfey, A. G. (2008). Friend or foe: The effect of
- 10 implicit trustworthiness judgments in social decision-making.
- 11 *Cognition*, **108**, 796-803. doi: 10.1016/j.cognition.2008.07.002
- 12 Weisbuch, M., & Ambady, N. (2008). Affective divergence: Automatic
- 13 responses to others' emotions depend on group membership. *Journal*
- 14 *of Personality and Social Psychology*, **95**, 1063-1079. doi:
- 15 10.1037/a0011993
- 16 Winston, J. S., Strange, B. A., O'Doherty, J., & Dolan, R. J. (2002).
- 17 Automatic and intentional brain responses during evaluation of
- 18 trustworthiness of faces. *Nature Neuroscience*, **5**, 277-283. doi:
- 19 10.1038/nn816
- 20 Zak, P. J., Kurzban, R., & Matzner, W. T. (2005). Oxytocin is associated
- 21 with human trustworthiness. *Hormones and Behavior*, **48**, 522-527.
- 22 doi: 10.1016/j.yhbeh.2005.07.009

23

24 **Acknowledgements**

25

26 The authors thank Disa Sauter and Kentaro Katahira for constructive
27 comments on the manuscript. This work was supported by grants from

Okanoya Emotional Information Project, ERATO, Japan Science and Technology Agency, and JSPS KAKENHI (Grant Number 24730639).

Figures Captions

Figure 1. (a) Samples of facial stimuli. The emotional faces are the final images to create dynamic facial expressions using a morphing technique. The neutral face was used for creating dynamic facial expressions and presented in the trust game and the trustworthiness rating. (b) Single round in the trust game. In this round, a participant (i.e., investor) invested 2 points with a partner (i.e., trustee) and then the partner returned 2 points to the participant (i.e., “just return” allocation). Actual sentences in screens were written in Japanese.

Figure 2. Means and SEMs of EMG activity for each emotional face without manipulation of trustworthiness. (a) zygomaticus major activity (b) corrugator supercilii activity.

Figure 3. Means and SEMs of z -transformed zygomaticus major activity in response to emotional faces of trustworthy partners and untrustworthy partners.

Figure 4. Means and SEMs of z -transformed corrugator supercilii activity in response to emotional faces of trustworthy partners and untrustworthy partners.