

This article was downloaded by: [Università Studi di Padova]

On: 8 October 2009

Access details: Access Details: [subscription number 909168547]

Publisher Psychology Press

Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



## Social Neuroscience

Publication details, including instructions for authors and subscription information:

<http://www.informaworld.com/smpp/title-content=t741771143>

### My face in yours: Visuo-tactile facial stimulation influences sense of identity

Anna Sforza <sup>a</sup>; Ilaria Bufalari <sup>a</sup>; Patrick Haggard <sup>b</sup>; Salvatore M. Aglioti <sup>a</sup>

<sup>a</sup> Sapienza University of Rome and Fondazione Santa Lucia IRCCS, Rome, Italy <sup>b</sup> University College London, London, UK

First Published on: 07 October 2009

**To cite this Article** Sforza, Anna, Bufalari, Ilaria, Haggard, Patrick and Aglioti, Salvatore M.(2009)'My face in yours: Visuo-tactile facial stimulation influences sense of identity',*Social Neuroscience*,99999:1,

**To link to this Article:** DOI: 10.1080/17470910903205503

**URL:** <http://dx.doi.org/10.1080/17470910903205503>

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: <http://www.informaworld.com/terms-and-conditions-of-access.pdf>

This article may be used for research, teaching and private study purposes. Any substantial or systematic reproduction, re-distribution, re-selling, loan or sub-licensing, systematic supply or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

# My face in yours: Visuo-tactile facial stimulation influences sense of identity

Anna Sforza and Ilaria Bufalari

*Sapienza University of Rome and Fondazione Santa Lucia IRCCS, Rome, Italy*

Patrick Haggard

*University College London, London, UK*

Salvatore M. Aglioti

*Sapienza University of Rome and Fondazione Santa Lucia IRCCS, Rome, Italy*

Self-face recognition is crucial for sense of identity and self-awareness. Finding self-face recognition disorders mainly in neurological and psychiatric diseases suggests that modifying sense of identity in a simple, rapid way remains a “holy grail” for cognitive neuroscience. By touching the face of subjects who were viewing simultaneous touches on a partner’s face, we induced a novel illusion of personal identity that we call “enfacement”: The partner’s facial features became incorporated into the representation of the participant’s own face. Subjects reported that morphed images of themselves and their partner contained more self than other only after synchronous, but not asynchronous, stroking. Therefore, we modified self-face recognition by means of a simple psychophysical manipulation. While accommodating gradual change in one’s own face is an important form of representational plasticity that may help maintaining identity over time, the surprisingly rapid changes induced by our procedure suggest that sense of facial identity may be more malleable than previously believed. “Enfacement” correlated positively with the participant’s empathic traits and with the physical attractiveness the participants attributed to their partners. Thus, personality variables modulate enfacement, which may represent a marker of the tendency to be social and may be absent in subjects with defective empathy.

**Keywords:** Self face recognition; Illusory perceptions; Multisensory integration; Social neuroscience; Psychiatric diseases.

## INTRODUCTION

Although we typically see our face only in mirrors, facial self-recognition is a key component of personal identity, and thus of self-consciousness. The ability to self-recognize in the mirror has been demonstrated only in a limited number of species including humans, apes, and perhaps dolphins, elephants, and magpies (Keenan,

Gallup, & Falk, 2003; Plotnik, de Waal, & Reiss, 2006; Prior, Schwarz, & Güntürkün, 2008). Moreover, in humans this ability is thought to correlate with higher forms of empathy and altruistic behaviour and it appears around the age of two years (Keenan et al., 2003).

Acquired and congenital forms of prosopagnosia, i.e. the altered ability to visually recognize famous and familiar faces, have long been

---

Correspondence should be addressed to: Salvatore Maria Aglioti or Anna Sforza, Department of Psychology, Sapienza University of Rome, Via dei Marsi, 78, 00155 Rome, Italy. E-mail: salvatoremaria.aglioti@uniroma1.it; anna.sforza@uniroma1.it

This work was supported by: the Ministero Istruzione Università e Ricerca (PRIN) and the Italian Ministry of Health (to SMA), a Leverhulme Trust Research Fellowship (to PH); a BBSRC ISIS collaboration grant (to PH and SMA).

described (Barton, 2003; Behrmann & Avidan, 2005). Thus, deficits in visual face recognition stand as conspicuous clinical disorders. In contrast, deficits of visual recognition of the form and the action of nonfacial body-parts have been demonstrated only in a recent lesion mapping study using subtle discrimination tasks (Moro et al., 2008). This study documented a behavioral and neural double dissociation with deficits in visual face recognition associated to lesions in the fusiform and occipital face areas, and deficits in body processing associated to extrastriate body area and fusiform body area (Moro et al., 2008). Even if transient difficulties in recognizing one's own face have been reported by normal subjects (as for example when looking at old pictures; Brédart & Young, 2004), genuine deficits in one's own face recognition have been reported very rarely and almost exclusively in patients with severe neurological (Breen, Caine, & Coltheart 2001; Phillips, Howard, & David, 1996) or psychiatric disorders (Frith, 1992; Irani et al., 2006; Kircher, Seiferth, Plewnia, Baar, & Schwabe, 2007). That facial sense of identity cannot be easily challenged stands in striking contrast with several studies reporting denial or misattribution of hands or feet following brain damage (Berlucchi & Aglioti, 1997; Giummarra, Gibson, Georgiou-Karistianis, & Bradshaw, 2008) and with psychophysical studies showing that healthy individuals experience an artificial limb as if it were part of their own body as a consequence of a congruent (synchronous) stimulation of both the real and the fake hand (rubber hand illusion, RHI; Botvinick & Cohen, 1998; Slater, Pérez-Marcos, Ehrsson, & Sanchez-Vives, 2008; Tsakiris & Haggard, 2005). Even more striking are the results of two recent studies employing virtual reality and a paradigm derived from RHI studies based on delivering temporally congruent visual-somatosensory inputs, which were apparently able to entirely transpose the self into a virtual body, in an analog of out-of-body experiences (Lenggenhager, Tadi, Metzinger, & Blanke, 2007; Ehrsson, 2007). In a similar vein, by using a simple method based on the use of two mirrors, it has been possible to induce in healthy subjects the subjective experience of being out of their body (Altschuler & Ramachandran, 2007). Thus, current knowledge would indicate that while it may be comparatively easy to induce illusory percepts concerning ownership of nonfacial body parts and even out-of-body experience, no similar effects can be found for faces.

One may think that, given its role in preserving identity, self-face recognition has to be largely impenetrable to changes in body and external world inputs at least in the absence of any neurological or psychiatric disorder. Recently, however, two studies suggested that self-face identity recognition may be more malleable than previously believed. Barnier et al. (2008) suggested to highly hypnotizable healthy subjects in a deep hypnosis state that their mirror-reflected face belonged to a stranger. Importantly, the procedure induced face-specific misidentification reports (e.g., the participants who did not recognize their reflection in the mirror described the person in the mirror as having different physical characteristics to themselves). This result indicates that self-face recognition can be influenced by higher-order cognitive variables, at least under specific circumstances. Even more relevant to our research is a study showing in healthy subjects that multisensory integration of visuo-tactile facial stimuli influences the ability to distinguish one's own face from the face of a stranger model (Tsakiris, 2008).

Here we used a psychophysics paradigm to examine the received linkage between stable personal identity and self-face recognition. We extended to faces a paradigm originally used for inducing illusions of non-facial body part incorporation (Botvinick & Cohen, 1998; Ehrsson, 2007; Lenggenhager et al., 2007; Slater et al., 2008; Tsakiris & Haggard, 2005). Thus, by using identical paintbrushes, we stimulated pairs of same-sex individuals on their cheek in a synchronous or asynchronous way in epochs of 2 min. Immediately after each epoch, we presented morphed face pictures and asked one of the pair subject to rate the extent to which each picture reproduced himself/herself or his/her partner. As previously shown for hands (Botvinick & Cohen, 1998; Slater et al., 2008; Tsakiris & Haggard, 2005), full bodies (Ehrsson, 2007; Lenggenhager et al., 2007) and face (Tsakiris, 2008), this minor difference in multisensory correlation may fundamentally alter self-recognition. Indeed the visuo-tactile integration derived from seeing touch on the other face while feeling touch on one's own (on which the fake hand and virtual body illusions seem to be based) should occur in the synchronous but not in the asynchronous condition.

Using this paradigm we have been able to explore whether: (1) the temporal congruency between tactile stimuli delivered to an onlooker's face and visual stimuli seen on the face of a

familiar model may modify the onlooker's self-face recognition ability; (2) any change in self-face recognition may be influenced by the onlookers' interpersonal reactivity, which likely plays a major role in self-other interactions, and by the onlookers' rating of the model familiarity, physical attractiveness, and inner beauty.

## METHODS

### Participants

Twelve pairs of healthy volunteers (14 females) aged between 21 and 35 years (mean 25.5 years) participated in the experiment. Since we wanted to explore the effect of interpersonal knowledge on self-other face merging illusory effects, we chose to involve in the study pairs of same-sex subjects who were familiar to each other. This choice allowed us to avoid any potential confound of greater familiarity with one's own face with respect to the face of a stranger.

All participants had normal or contact corrected vision; none wore glasses. They were unaware of the specific aim of the study. All participants provided their written consent. The study was approved by the local Ethics Committee and was in accordance with the ethical standards of the 1964 Declaration of Helsinki.

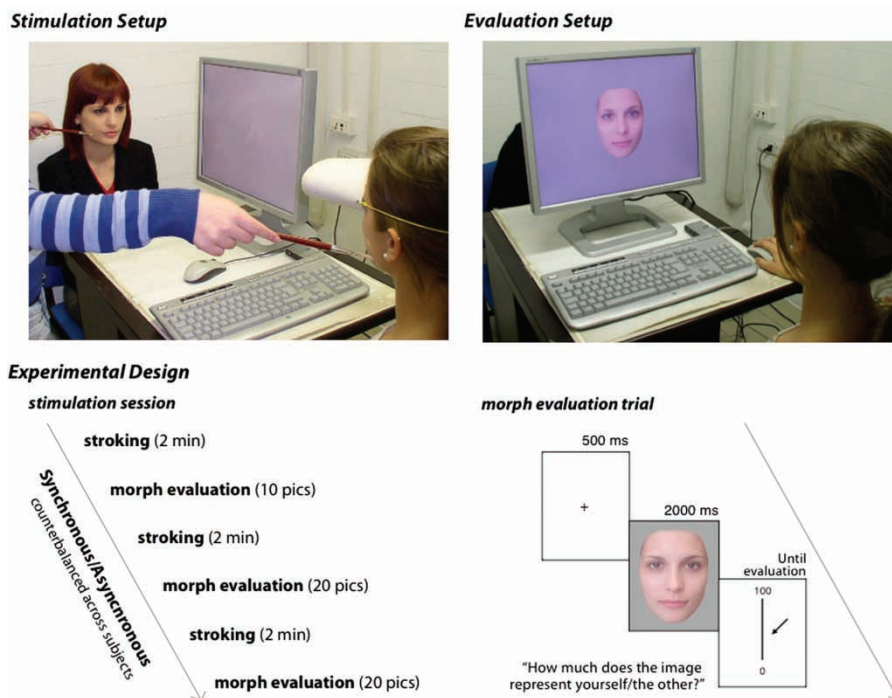
### Experimental set-up and visuo-tactile stimulation

Each subject was seated at a table facing his or her partner; their faces were about 140 cm apart. For each pair, two separate stimulation sessions were performed. Thus, each member of the pair rated the morphs in either the first or the second stimulation session, which meant that he/she was alternately an active rater or a passive model. The active rater subject wore a rigid white-paper funnel around the eyes that prevented the lateral view of the experimenter who was stimulating his/her own face but allowed the vision of the partner seated in front of him/her (Figure 1, upper left). Subjects were instructed to maintain the fixation on their partner's face. The experimenter stood between the two participants and repeatedly touched the subjects' cheeks with two identical paintbrushes. Multisensory perceptual correlations strongly modulate the sense of body ownership and induce the experience of rubber

hand and virtual body illusions. As we typically see our faces and events occurring to them only through mirror reflections, the experimental subjects were tactually stimulated in a mirror-like fashion. Thus, for each subject there was a specular correspondence between the touch felt on the self and the paintbrush seen on the other. The paintbrushes were moved either synchronously (illusion condition) or asynchronously (no illusion condition). The tactile stimulation was delivered manually by a trained experimenter (AS). No automatic procedures for controlling a/synchrony were used. In a preliminary phase, the experimenter learned to introduce an about 1 s asynchrony through a metronome. The two different stimulation conditions were administered in counterbalanced order. The only difference between the two was the mode of stroking, which in one case was synchronous (the paintbrush strokes were simultaneously delivered to the two subjects, experimental condition) and in the other was asynchronous (about 1 s delay between the two paintbrush strokes was introduced so that the temporal congruency between the stimulus felt on one's own face and the identical stimulus seen on the other's face was broken). Each condition consisted of three stimulation blocks, each lasting 2 min. The directional pattern of the tactile stimulation varied between the blocks to avoid habituation. However, this pattern was kept constant across subjects. In particular, in all subjects upward-downward stimulation was used in the first block, left-to-right stimulation was used in the second block and downward-upward in the third block.

### Visual stimuli and experimental task

Visual stimuli were individually tailored to each participant and consisted of static colour images obtained by taking pictures of the face of each participant using a digital camera (Sony Cyber-shot 4.1 M). These pictures were edited using Adobe Photoshop 6.0 to remove external features (hair, ears) and create a uniform grey background. Then, for each pair, different degrees of digital morphing between the two picture faces were created using Abrosoft Fantamorph 3.0 (from 0% to 100% in steps of 2%, for a total of 48 morphs, plus the two original pictures; Figure 2A). Along the morphing continuum, 2% steps were contemplated except for two specific points



**Figure 1.** Schematic representation of the experimental setup and design. The upper left panel displays the two subjects sitting in front of each other while the experimenter touches their cheeks with two identical paintbrushes. The rating subject wears a rigid white-paper funnel around the eyes. The upper right panel displays the rating subject during the evaluation of the morphed pictures (which was performed immediately after the stimulation phase). The lower part shows the timeline of a typical stimulation session (left panel) and of a typical evaluation trial (right panel). Subjects underwent two visuo-tactile stimulation sessions performed on the same day (synchronous and asynchronous conditions). Each stimulation session consisted of three 2-min stimulation blocks followed by the evaluation of 10, 20, and 20 pictures. Each evaluation trial started with the presentation of a cross on a white display followed by the morphed picture. VAS ratings of the different morphs were requested also in a no-stimulation, control session performed at least one week after the stimulation sessions.

where the step was 3% (from 24% to 27% and from 73% to 76%). This procedure was adopted to avoid having a 50% image balance between self and other and to have morphs with predominance of Self or Other physical features.

We decided to split the evaluation of the 50 morphed images in three blocks (each performed after 2 min of stroking) to minimize the risk that the ratings were outside any supposedly effective after-stroking window. Ten, 20, and 20 images were evaluated after the first, second, and third block respectively. A schematic timeline of the stimulation design is reported in the lower left panel of Figure 1. The order of presentation of the 50 images was randomized across the three blocks.

Each image subtended  $11.42^\circ \times 17.06^\circ$  of visual angle, and was positioned about 70 cm from the observing subject. The face image remained on the screen for 2 s and it was followed by a 20 cm vertical line, the extremities of which were labeled with 0 and 100. After each stimulation block the subjects were asked to rate, along this 0–100 visual-

analog scale (VAS), the extent to which different face pictures reproduced themselves or the other person. These responses were provided by moving a cursor along the VAS line and clicking the mouse at the estimated position. The position of the pixel marked on the screen was converted into a numerical value through an automated procedure (a typical evaluation trial is reported in Figure 1, right lower panel). The average time to complete one rating block was about 40 s in the first (10 images' ratings) and about 80 s in the second and third block (20 images' ratings in each).

To rule out that any illusory effects were due to a bias induced by the type of required response, half of the subjects were instructed to mark the point corresponding to the quantity of self-features in a given face picture (“How much does the image represent yourself?” 0 = Other, 100 = Self) and the other half to the quantity of other-features in a given face picture (“How much does the image represent the other person?” 0 = Self, 100 = Other).

To exclude the possible contribution of visuo-tactile stimulation *per se* on basic subjective self-other distinction, VAS ratings of the 50 images (48 morphs and the two pair partners' faces) were also acquired in a further experimental control session, in which the self-other morphs rating phase was not preceded by the face stimulation phase and the pair partner was not in the testing room (no stimulation condition).

Previous studies tested the effect of rubber hand or full body illusions comparing the amount of spatial drifts (Armel & Ramachandran, 2003; Ehrsson, 2007; Ehrsson, Holmes, & Passingham, 2005; Ehrsson, Spence, & Passingham, 2004; Kammers et al., 2008; Lloyd, 2007; Schaefer, Flor, Heinze, & Rotte, 2006a; Schaefer, Noennig, Heinze, & Rotte, 2006b; full body illusions: Ehrsson, 2007), skin temperature (Moseley et al. 2008) and familiarity between the real and the fake hand (Longo, Schüür, Kammers, Tsakiris, & Haggard, 2009) in asynchronous vs synchronous stimulation conditions. Other RH studies used pre-stimulation baselines to compare ratings in asynchronous and synchronous stimulation conditions. Moreover, the effect of a virtual fake hand was examined performing synchronous and asynchronous stimulation in two different groups of subjects (Botvinick & Cohen, 1998; Slater et al., 2008). In this study, we used as baseline self-other discrimination ratings obtained in a no-stimulation condition performed at least one week after the stimulation session. This allowed us to minimize any carry-over and learning/practice effects across the different sessions and to reduce the duration of the crucial stimulation session.

Also in the baseline session the 50 pictures were presented in random order. For each subject, the rating instructions ("judge the self" or "judge the other") were identical to those in the previous two rating sessions.

For subsequent statistical analysis, individual ratings of five consecutive morphing steps were averaged to obtain 10 clusters (expressing % of other): 0–8%; 10–18%; 20–29%; 31–39%; 41–49%; 51–59%; 61–69%; 71–80%; 82–90%; 92–100%.

### Subjective reports in the synchronous and asynchronous stimulation conditions

In addition to ratings of self-other features in the morphed faces, at the end of each stroking

condition we obtained subjective reports about the perceived phenomenology of the illusion by asking participants to fill out a questionnaire that was adapted from the first, seminal study on the rubber hand illusion (Botvinick & Cohen, 1998). The questionnaire consisted of the following eight statements suggesting specific perceptual experiences:

*STATEMENT 1: It seemed as if I were feeling the touch of the paintbrush in the location where I saw the other's face touched.*

*STATEMENT 2: It seemed as though the touch I felt was caused by the paintbrush touching the other's face.*

*STATEMENT 3: I felt as if the other's face was my face.*

*STATEMENT 4: It felt as if my face were drifting towards the other's face.*

*STATEMENT 5: It seemed as if I might have more than one face.*

*STATEMENT 6: It seemed as if the touch I was feeling came from somewhere between my own face and the other's face.*

*STATEMENT 7: It appeared as if the other's face were drifting towards my own face.*

*STATEMENT 8: The other's face began to resemble my own face, in terms of shape, skin tone, or some other visual feature.*

The first three statements (in italics) were designed to capture the experience of the illusion in its two components of referred sensation (statements 1 and 2) and sense of facial ownership (statement 3). Subjects indicated their response on a seven-step VAS ranging from  $-3$  (completely false) to  $+3$  (completely true). For each statement, the scores obtained in the stroking conditions were compared using paired *t*-tests with Bonferroni correction.

### Personality traits of the raters

As faces play a crucial role in social interactions (Adolphs, 2008), we explored whether the hypothesized effect in self-other judgment due to synchronous visuo-tactile facial stimulation was related to measures of dispositional empathetic responding. To this end, after the two visuo-tactile stimulation sessions each participant was requested to complete the Italian version (Bonino, Lo Coco, & Tani, 1998; Albiro, Ingoglia, & Lo Coco, 2006) of Davis' Interpersonal Reactivity

Index (IRI) (Davis, 1983), a personality questionnaire comprising 28 items to be rated on a five-point Likert scale. The IRI consists of four subscales that measure different aspects of trait-reactivity to others. Three subscales, namely Fantasy Scale (FS), Perspective Taking (PT), and Empathic Concern (EC), measure other-oriented reactivity. In particular, FS assesses the tendency to project oneself into the place of fictional characters in books and movies, PT assesses the tendency to spontaneously imagine and assume the cognitive perspective of another person, and EC assesses the tendency to feel sympathy and compassion for others in need. The fourth subscale, namely Personal Distress (PD) measures self-oriented reactivity and provides an estimate of the extent to which an individual feels distress as a result of witnessing another's distress.

We planned to perform Pearson correlation analysis (with Bonferroni correction for multiple comparisons) between the four interpersonal reactivity index (IRI) scores and any possible effects of synchronous/asynchronous stimulation on subjective self-other judgements.

### Ratings of familiarity, physical attractiveness, and inner beauty of the pair partner

Based on the notion that self, familiar, and stranger faces are differentially processed at both behavioral and neural levels (Kircher & David, 2003; Platek et al., 2006), we tested whether familiarity between the rater and the pair partner could influence the hypothesized effect in self-other judgments due to synchronous visuo-tactile stimulation.

Thus, we obtained a measure of the degree of familiarity between the rater and the pair partner, asking the subjects (1) how deeply they thought they knew their pair partner (on a 1–5 Likert scale) and (2) the average days per month (from 1 to 30) they used to meet their pair partner.

Furthermore, given the close relationship between social perceptions and perceived attractiveness (the “what is beautiful is good” stereotype: Dion, Berscheid, & Walster, 1972; Johnson & Tassinari, 2007; Rhodes, 2006), we explored the possible relationship between the enfacement effect and subjective ratings concerning attractiveness of the partner. Subjects were asked to rate along five-point Likert scales (where 1 corresponds to “very low” and 5 to “very high”): (1)

the physical attractiveness (Swami, Furnham, Georgiades, & Pang, 2007) and (2) the inner beauty of the pair partner. It was emphasized that the partner would never have access to the subjective reports of the rater.

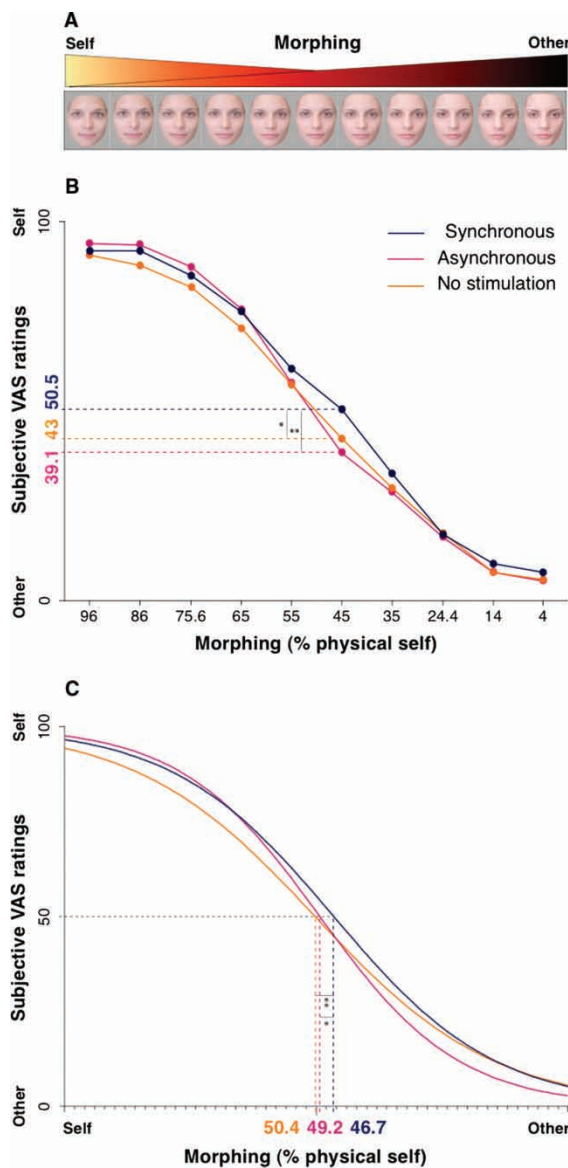
We planned to perform Pearson correlation analyses (with Bonferroni correction for multiple comparisons) between each partner's qualities (regarding familiarity and beauty ratings) and any effect concerning subjective self-other judgments.

## RESULTS

### Self-other judgments of morphed faces

To explore if synchronous visuo-tactile facial stimulation could result in altered self-face recognition, subjective self-other ratings collected after synchronous, asynchronous, and no stimulation condition were analyzed as a function of Morphing percentage (Morph%, 10 levels of self-other morphing, each corresponding to the average value of five consecutive images) and Mode of stroking (MOS, three levels) by means of a repeated measure ANOVA.

We found a predictable main effect of Morphing,  $F(9, 207) = 658.2$ ,  $MSE = 129$ ,  $p < .0000$ , that simply indicates subjects rated the ten morphing clusters differentially. The significance of the MOS main effect,  $F(2, 46) = 6.19$ ,  $MSE = 101$ ,  $p < .01$ , is explained by the highest “attribution to self” mean score in the synchronous ( $52.7\% \pm 1.06$ ) than in the other two control conditions (asynchronous:  $50.9\% \pm 1.33$ ,  $p < .05$ ; and no stimulation:  $49.5\% \pm 0.92$ ,  $p < .01$ ). Crucially, the significant interaction between  $MOS \times Morph\%$ ,  $F(18, 414) = 3.086$ ,  $MSE = 42$ ,  $p < .0001$ , indicates that the higher self-attribution was specific for a given morph percentage range. Indeed, the Bonferroni *post-hoc* test showed that the 51–59% morphed faces (which means more other- than self-face physical features, 55% other vs. 45% self on average) were rated as having higher percentage of Self following the synchronous, mean  $\pm MSE$ ,  $50.5\% \pm 1.79$ , with respect to asynchronous ( $39.1\% \pm 2.19$ ,  $p < .00001$ ) and no stroking conditions ( $43\% \pm 1.92$ ,  $p = .033$ ), which did not differ from each other (see Figure 2B). Therefore, in the range of morphing where faces begin to have more other than self percentage the synchrony of vision and touch induces a clear illusion of incorporation of other's face features in one's own face.



**Figure 2.** Enfacement effect: incorporating other’s facial features into the self-face representation. The stimuli used in the experiment and the results of statistical analyses conducted on self–other judgments after synchronous, asynchronous, and no stimulation conditions are shown. (A) Examples of morphed faces: The percentage of Self decreases while the percentage of Other increases. (B) Subjective ratings of the self–other features in the different morphs (y-axis) and physical percentage of self features in the ten clusters of face morphing (x-axis). Remarkably, only in the synchronous condition subjects rated as more similar to self morphs in the cluster with 2–9% more “other” features. (C) Subjective ratings of 2% morphs in the three experimental conditions fitted with a sigmoid statistical model:  $x_0$  values, i.e. an index of self-face bias, were significantly higher in synchronous than in asynchronous and no stimulation conditions.

Importantly, the self-face bias is found only when the morphs are ambiguous and self–other discrimination is complex, suggesting that it is a genuine

and specific perceptual effect. We call this new illusion “enfacement”.

### Order of VAS ratings does not influence the self-bias effect

Since each subject was active rater in the first or in the second visuo-tactile stimulation session, an additional control analysis was performed to exclude any possible difference in the self-face bias due to the different amount of visuo-tactile stimulation. Results of mixed ANOVA with Session (first or second) as between-subjects factor and Mode of stroking (MOS, synchronous, asynchronous, no stimulation) and Morphing (10 levels of self–other morphing) as within-subjects factors showed no difference. Neither the main effect of session nor the interactions between factors reached significance [main effect of Session:  $F(1, 22) = 0.28$ ,  $MSE = 720$ ,  $p = .59$ ; Session  $\times$  MOS:  $F(2, 44) = 0.37$ ,  $MSE = 103$ ,  $p = .69$ ; Session  $\times$  Morphing:  $F(9, 198) = 0.88$ ,  $MSE = 130$ ,  $p = .54$ ; Session  $\times$  MOS  $\times$  Morphing:  $F(18, 396) = .52$ ,  $MSE = 43$ ,  $p = .95$ ]. Therefore, no apparent difference was found in the self-bias effect depending on whether subjects rated the images in the first or the second session.

### Morph rating instructions did not influence the self-bias effect

Preliminary to analyzing the three experimental sessions (synchronous, asynchronous, no stimulation), we tested whether any illusory effect was influenced by the instructions to rate the percentage of self or other in each image. To make the two sets of data comparable, other group VAS scores (with scale ranging from 0 = self to 100 = other) were converted to the scale adopted by the self group (where 0 = other and 100 = self). Results of mixed ANOVA with rating Instruction (self, other) as between-subjects factor, and MOS (synchronous, asynchronous, and no stimulation) and Morphing (10 levels of self–other physical morphing in steps of 10%) as within-subjects factors showed no significant main effect or significant interaction [Instruction:  $F(1, 22) = 0.01$ ,  $MSE = 729$ ,  $p = .93$ ; Instruction  $\times$  MOS:  $F(2, 44) = 0.3$ ,  $MSE = 104$ ,  $p = .74$ ; Instruction  $\times$  Morphing:  $F(9, 198) = 0.54$ ,  $MSE = 132$ ,  $p = .84$ ; Instruction  $\times$  Morphing  $\times$  MOS:  $F(18, 396) = .65$ ,  $MSE = 43$ ,  $p = .86$ ]. As different rating instructions

did not affect the way subjects evaluated the morphed images, all subsequent analyses were conducted on the whole group of 24 subjects.

### Fine-grained transitions in the morphs

To provide a fine-grained analysis of the self-bias effect, the whole set of 2% rating values for each subject and for each of the three conditions (synchronous, asynchronous, and no stroking) were fitted into a four-parameter sigmoid statistical model which was based on the Boltzmann equation:  $y = A1 - A2/[1 + e^{(x-x0/dx)}] + A2$  where: A1 and A2 represent the upper (100) and lower (0) possible boundaries of the subjective self–other ratings,  $x0$  is the midpoint of the function, and  $dx$  parametrizes the width of the function. The appropriateness of the model was demonstrated for all three conditions at individual level [mean  $R_{adj}$  for synchronous:  $0.85 \pm 0.09$  (mean  $\pm$  SD), asynchronous:  $0.87 \pm 0.07$ , and no-stimulation condition:  $0.87 \pm 0.11$ ; all associated  $p$  values  $< .01$ ].

Particularly relevant is the analysis of the  $x0$  parameter, namely the midpoint of the function (corresponding to the physical percentage of self–other morph values on the abscissa when subjective ratings were 50% on the ordinate). Figure 2C shows higher  $x0$  values in the synchronous than in the asynchronous and no-stimulation sessions.

This pattern is confirmed by the repeated-measure one-way ANOVA with Mode of stroking (three levels: “synchronous”, “asynchronous”, “no stimulation”) as main effect performed on individual  $x0$  parameter values. The Mode of stroking was significant,  $F(2, 46) = 5.94$ ,  $MSE = 14.8$ ,  $p < .01$ . Newman-Keuls *post-hoc* comparisons demonstrated significantly higher  $x0$  values in the synchronous (mean  $\pm$   $MSE$ ,  $53.3 \pm 1.22$ ) with respect to the asynchronous ( $50.8 \pm 1.54$ ) and the no-stimulation conditions ( $49.6 \pm 1.13$ ) ( $p = .03$  and  $p = .004$  respectively), which in turn did not differ from one another ( $p = .27$ ). This result indicates that in the synchronous stimulation condition the subjective perception of perfect self–other equivalence was attributed to morphs in which the other percentage (53%) was higher than the self percentage (47%), whereas in the asynchronous and in the no stimulation conditions there was a large coincidence between subjective ratings and physical morphing. This is confirmed by a further analysis contrasting  $x0$  values with

50% by means of one-sample  $t$ -tests. We found a significant difference only in the synchronous condition (synchronous:  $p = .01$ ; asynchronous:  $p = .60$ ; no stimulation:  $p = .72$ ). Thus, the integration between the touch felt on the self and the visual stimulus seen on the other induced the illusion that features of the pair partner face were included in the rater’s face.

We also estimated the percentage of self assigned to a morph equally representing self and other in the three different sigmoidal curves by computing the  $y0$  value corresponding to the point on the  $y$ -axis where morphing values (on the  $x$ -axis) were equal to 50. Individual  $y0$  estimated values were entered in a repeated measure ANOVA with factor Stroking with three levels (synchronous, asynchronous, no stimulation). As predicted, the results of the ANOVA showed a significant main effect of the factor Stroking,  $F(2, 46) = 6.57$ ,  $MSE = 41.1$ ,  $p = .003$ , explained by the higher percentage of perceived self after the synchronous condition, (mean  $\pm$   $MSE$ ,  $55.9\% \pm 1.94$ ), with respect to the asynchronous ( $50.8\% \pm 2.55$ ,  $p = .008$ ) and the no stimulation conditions ( $49.7\% \pm 1.79$ ,  $p = .004$ ), which in turn did not differ from each other ( $p = .54$ ). To sum up, the fine-grain analysis of 2% step morphs (Figure 2C) on  $x0$  and  $y0$  parameters expands the 10% clusters analysis (Figure 2B) by estimating for each experimental condition the point of perceptual equivalence (the physical morph values at which subjects would rate an equal amount of self and other) and the percentage of self at the point of physical self–other equivalence in the morphs. Importantly, this more comprehensively formal approach also confirmed that the self-face bias effect was present only under synchronous visuo-tactile stimulation.

Finally, results from the ANOVA on the  $dx$  parameter revealed a significant main effect of mode of stroking (synchronous, asynchronous, no stimulation),  $F(2, 46) = 3.97$ ,  $MSE = 23.27$ ,  $p = .03$ . The  $dx$  parameter expresses the steepness of the sigmoidal curve around the midpoint and hence how rapidly the subjects switch their judgments from self to other. Therefore, it can be used as a categorization measure for the morphed images. Newman-Keuls *post hoc* showed that the only significant difference was between asynchronous (mean  $\pm$   $MSE$ ,  $13.8 \pm 0.95$ ), and no stimulation conditions ( $17.7 \pm 1.77$ ,  $p = .02$ ). A possible explanation for this result is that the incongruence between the two different modalities may have strengthened the categorization

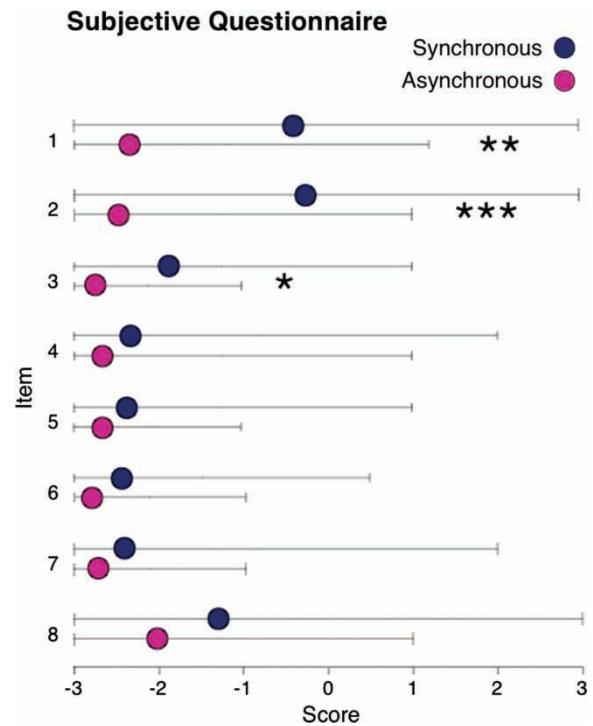
effect previously reported in the perception of morphed faces (Beale & Keil, 1995; Kircher et al., 2001).

### Subjective reports in the synchronous and asynchronous stimulation conditions

Subjective reports about the perceived phenomenology of the illusion confirmed that our visuotactile stimulation procedure was effective in manipulating sense of facial identity. Stronger agreement with the first three statements would indicate that subjects experienced a face-related illusion. Importantly, the questionnaire results showed that only for the three critical questions were the agreement ratings significantly higher in synchronous than asynchronous condition (paired *t*-test for statement 1:  $p < .001$ ; statement 2:  $p < .0001$ ; statement 3:  $p < .01$ ; significant values survived the Bonferroni correction) (Figure 3). The number of subjects who provided non-negative ratings to the first three statements designed to capture the face illusion were 13, 13, and 6 in the synchronous and 1, 2, and 0 in the asynchronous conditions. Unlike fake hand and full body illusions studies (Botvinick & Cohen, 1998; Ehrsson, 2007), questionnaire ratings were on average negative despite the significant differences between the synchronous and asynchronous conditions. This pattern of results indicates that sense of identity linked to the face is much more hard-wired and stable than that linked to hand or the full body. Thus, the compelling evidence that a clear “enfacement” effect can be obtained through our simple stimulation procedure is even more surprising.

### Correlation of enfacement effect with empathic traits of the raters

Correlational analyses between an index of the enfacement effect (expressed as self-other ratings difference between synchronous and asynchronous conditions divided by the ratings in the no stimulation condition) and the four interpersonal reactivity index (IRI) scores (Davis, 1983) revealed an influence of empathic traits of the raters on the strength of the illusion. A significant positive correlation was found with two out of four distinct IRI subscales, namely Perspective

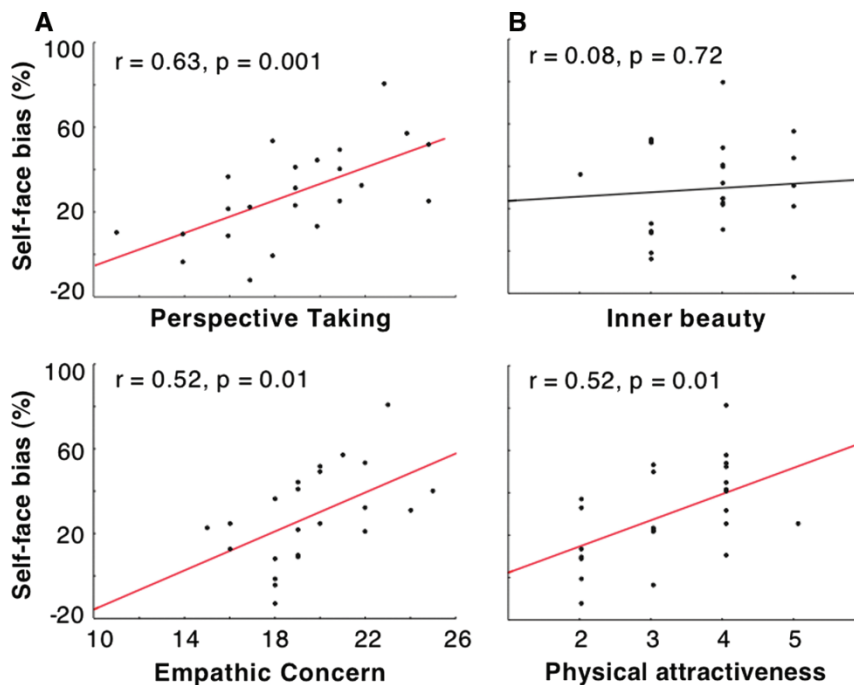


**Figure 3.** Questionnaire results. The questionnaire (adapted from Botvinick & Cohen, 1998), included the eight statements reported in the Methods section. Statements 1–3 describe the predicted phenomena. Subjects judged each statement on a seven-step visual-analog scale ranging from  $-3$  (“completely false”) to  $+3$  (“completely true”). Asterisks indicate significantly higher agreement with the suggested perceptual experiences (which are a subjective measure of face illusion) in synchronous than in asynchronous stimulation conditions.  $p < .001$  for statement 1 (\*\*),  $p < .0001$  for statement 2 (\*\*\*) and  $p < .01$  for statement 3 (\*). These significance values survived the conservative Bonferroni correction. Points indicate mean responses. Bars indicate response range.

Taking [(i.e., the ability and tendency to adopt the point of view of another individual; PT):  $r = .63$ ,  $p = .001$ , Figure 4A]; and Empathic Concern [(i.e., the tendency to share others’ emotions and feelings; EC):  $r = .52$ ,  $p = .011$ , Figure 4A]. All correlations survived the Bonferroni correction.

Note that analysis of standard residual values (greater than 2 sigma) and of Cook’s distances revealed one subject as an outlier. So, the correlation analyses were performed on 23 out of 24 participants.

This result indicates that the tendency to enface others, as indexed by the morphing experiment, is influenced by other-oriented empathy traits (e.g., PT and EC) but not by self-oriented interpersonal reactivity (e.g., personal distress).



**Figure 4.** Correlation between “enfacement” effect, interpersonal reactivity and physical attractiveness attributed to the pair partner. (A) Significant positive correlations between the self-face bias index (self–other ratings collected in the 51–59% interval of morphing, expressed as the difference between synchronous and asynchronous conditions divided by the ratings in the no stimulation condition) and perspective taking (upper part) and empathic concern (lower part) IRI subscales. The higher the self-reported empathic abilities, the higher the enfacement effect observed in the synchronous condition. (B) The enfacement effect did not correlate with the pair partner’s “inner beauty” but did correlate with the partner’s physical attractiveness ratings.

### Correlation of enfacement effect with ratings of familiarity and beauty of the partner

Results of correlation analysis with familiarity and beauty of the partner revealed that not only personality but also social variables could influence the strength of the enfacement effect.

No association between the index of self-face bias and any of the two indices of familiarity (index 1:  $r = .09$ ,  $p = .69$ ; index 2:  $r = -.15$ ,  $p = .49$ ) was found. Instead, the strength of illusory self-bias was related to the degree of physical but not inner attractiveness attributed to the pair partner ( $r = .52$ ,  $p = .01$ ; inner beauty:  $r = .08$ ,  $p = .72$ ; Figure 4B). The significance of the correlation between self-face bias and physical attractiveness of the pair partner survived the Bonferroni correction.

## DISCUSSION

Previous studies have demonstrated that sense of hand ownership or full body ownership can be

changed in healthy subjects through the induction of a visuo-tactile illusion. However, the objective measures used thus far provide only indirect evidence that the core sense of identity is altered by the experimental manipulations. Indeed, ownership changes have been inferred mainly from changes in the felt position of the hand or of the full body in illusory conditions (Botvinick & Cohen, 1998; Tsakiris & Haggard, 2005; Lenggenhager et al., 2007; Slater et al., 2008). Importantly, recent studies reported skin conductance and temperature changes during illusory ownership of artificial hands and bodies (Ehrsson, 2007; Moseley et al., 2008; Petkova & Ehrsson, 2008). However, the derivative notion of “me from where” and the implicit derivation of self–other distinction from autonomic indices are likely to be less directly linked to sense of identity than specific measures of self–other discrimination. As faces are inherently linked to self–other identification, our experimental paradigm was in principle best suited to provide measures directly concerning the fundamental question of whether “the person I am looking at is really me”. This is what we have found. In particular, we provide

evidence for a direct index of sense of identity through a face morphing test, which demonstrates the illusory perception of more self-features in faces that have more other-features instead. The enfacement illusion described in our study may be fundamentally important because it suggests that features of others' identity can be included in the notion of self. Indeed, we found that self-face recognition, which is thought to be a stable marker of self-awareness, can be challenged very rapidly at least in a self-other discrimination task (in which no conscious report about the illusory ownership of the other's face is required), even in the absence of brain diseases.

Our results expand a recent study where, using a somewhat different paradigm, changes in self-other facial morph discrimination after synchronous stimulation were reported (Tsakiris, 2008). Although both paradigms explored the effect of multisensory integration on self-other face discrimination, several differences between the two can be noticed. In our paradigm, the rating subject saw the face of a familiar partner and rated 50 images in each stimulation condition (100 in total). In the Tsakiris (2008) study the rating subject observed videos where a stranger individual was morphed with the subject's face. Four ratings per stimulation condition (eight in total) were provided. Moreover, during the stimulation phase the rating subject never observed the face of the other individual but only a morphed image of the two faces. Despite these differences, both studies report a self-face bias only during synchronous stimulation. However, unlike Tsakiris (2008), we collected systematic data on the phenomenological, subjective experience related to the visuo-tactile stimulation, in keeping with rubber hand and full body illusions studies (Botvinick & Cohen, 1998; Ehrsson, 2007; Lenggenhager et al., 2007; Slater et al., 2008; Tsakiris & Haggard, 2005). The analysis of the critical items of the questionnaire indicates that in statements 1 and 2 many more subjects reported non-negative scores in the synchronous than in the asynchronous stimulation conditions. Thus, although less vivid than what was reported for rubber hand and full body (Botvinick & Cohen, 1998; Ehrsson, 2007; Lenggenhager et al., 2007; Slater et al., 2008; Tsakiris & Haggard, 2005), the "referred sensation" component of the illusion was consistently found at the phenomenological level also with faces. Analysis of reports on statement 3 (which indexes conscious self-other

face merging) showed that non-negative scores were provided by six and zero subjects in the synchronous and asynchronous conditions respectively. Despite the statistical significant difference, the component of the illusion related to facial ownership was less reliable at the subjective, phenomenological level. This pattern indicates that changes of sense of facial identity contingent on visuo-tactile stimulation can be induced more easily when tested by means of a self-other morph rating task with respect to when tested by means of a task based on the report of subjective phenomenological experiences.

Thus, the questionnaire concerning the subjective experiences during synchronous and asynchronous stimulation suggests that while referred sensations are more strongly related to bottom-up multisensory integration processes, sense of facial ownership is highly influenced by top-down mechanisms relating the face to the core sense of identity. The processes at play in the enfacement effect are reminiscent of what was reported for full body and body part related illusions. In RH studies, for example, ownership and body part location are independent predictors of the proprioceptive bias induced by the synchronous visuo-tactile stimulation and are thus likely to play a different role in embodiment effects (Longo, Schüür, Kammers, Tsakiris, & Haggard, 2008).

However, it is worth noting that while visuo-tactile correlation can easily induce the clear phenomenological experience that the fake hand or the virtual body belong to the stimulated subject, the conscious experience of enfacement can hardly be obtained. This difference may speak in favor of the fact that, facial identity being at the core of sense of self, facial representations are less amenable to changes. This comparative impenetrability to conscious changes of self-face representation may constitute a defensive mechanism against assaults to the unity of the self, represented by the massive, ever-changing inputs from the inner and outer world. On the other hand, slow representational changes should be possible so as to allow one to deal with the passage of time (e.g., the appearance of wrinkles) without major psychological trauma. In this vein, inducing fast changes of facial representations could have induced feelings of strangeness and irritation even higher than those reported during induction of virtual body illusions (Lenggenhager et al., 2007).

The fact that subjects in our study did report little if any explicit ownership-related feelings during the enfacement indicates that the facial illusion indexed by the self–other judgment task occurred mainly at implicit, unconscious levels. Although the neural underpinnings of this novel enfacement effect are not known, our study provides an ideal model for testing whether face- and body-related illusions do rely on overlapping neural regions. Previous studies exploring brain activations during the experience of non-facial body-related illusions revealed a large neural network possibly related to body parts perception, cross-modal integration and conflict processing (Ehrsson et al., 2004, 2005; Tsakiris, Hesse, Boy, Haggard, & Fink, 2007). These studies revealed that the feeling of body ownership is mediated by neural activity in regions involved in the integration of multisensory signals, such as bilateral premotor cortices and cerebellum (Ehrsson et al., 2004, 2005), as well as in the right posterior insula (Tsakiris et al., 2007), a region consistently implicated in self-attribution (Farrer & Frith, 2002), self-processing (Fink et al., 1996; Vogeley et al., 2004), and representation of an egocentric reference frame (Fink et al., 2003). The left inferior, posterior parietal lobule seems to be involved in the recalibration of the perceived position of one's own limb toward the rubber hand. In fact, this region is activated during the induction phase of the RH (Ehrsson et al., 2004) and, if targeted by rTMS, causes a consistent reduction of the proprioceptive drift towards the RH (Kammers et al., 2008).

Importantly, a link between enfacement illusion and facial identity processing can be postulated. In this vein, the consequence of the self–other face merging illusion reported in our study may imply a modulation of activity in brain areas involved in self-face recognition such as those belonging to right-dominant (but largely bilaterally distributed) circuits involving frontal and parietal regions (Kircher et al., 2001; Platek et al., 2006; Platek, Keenan, Gallup, & Mohamed, 2004; Uddin, Kaplan, Molnar-Szakacs, Zaidel, & Iacoboni, 2005; Uddin, Molnar-Szakacs, Zaidel, & Iacoboni, 2006; for a meta-analysis of fMRI data see Platek, Wathne, Tierney, & Thomson, 2008). Right hemisphere dominance is also suggested by behavioural studies in healthy (Keenan, Ganis, Freund, & Pascual-Leone, 2000) and callosotomy patients (Preilowski, 1977; Keenan et al., 2003), by right

hemispheric temporary inactivation (WADA test) (Keenan, Nelson, O'Connor, & Pascual-Leone, 2001), and by reports of patients with mirror self-misidentification delusions (Breen et al., 2001). A crucial contribution of the right hemisphere is also suggested by studies investigating self-related cognition (Decety & Chaminade, 2003), one's own-body perception (Blanke, Ortigue, Landis, & Seeck 2002; Blanke et al., 2005) and self-awareness (Stuss, 1991; Andelman, Zuckerman-Feldhay, Hoffien, Fried, & Neufeld 2004; Barnacz, Johnson, Constantino, & Keenan, 2004).

An additional main point of novelty of our study is the exploration of how personality traits and specific relationships between the rating subject and the pair partner influence the enfacement effect. The choice to test pair partners familiar to one another allowed us to explore this important but so far unaddressed issue. We postulated that, although driven by a comparatively low-level cross-modal integration process, the enfacement effect could have been modulated by the rater's interpersonal trait reactivity as well as by the physical and inner positive qualities the rating subjects attributed to their pair partner. The results show that the enfacement effect was higher in individuals with high emotional and cognitive empathy, thus suggesting that empathic reactivity (Hein & Singer, 2008; Preston & de Waal, 2002) may modulate the tendency to incorporate the other, an issue that has never been addressed in fake hand and full body illusions studies. The link between empathy and the face illusion raises the fundamental question of whether or not the enfacement effect is present in clinical populations with altered interpersonal reactivity (e.g., in patients with autistic spectrum disorders). Therefore, our result may open potential avenues for testing the relationship between empathy and self–other distinction in healthy and disabled individuals.

We also found that the enfacement was modulated by the reported physical attractiveness but not by the inner beauty of the pair partner. While this result may hint at a more prominent role of external than internal variables, studies indicate that perception of physical attractiveness depends largely on complex, higher-order societal influences (Langlois et al., 2000). Therefore, far from being an entirely low-level variable, physical attractiveness creates differential responses in other people even at very complex emotional and cognitive levels (Langlois et al., 2000).

Indeed, more attractive counselors (Vargas & Borkowski, 1982) and professors (Riniolo, Johnson, Sherman, & Misso, 2006) are perceived as more effective. Moreover, imaging studies indicate that viewing attractive faces activates in the onlooker brain regions related to reward (Aharon et al., 2001; Cloutier, Heatherton, Whalen, & Kelley, 2008; O'Doherty et al., 2003). Social psychology studies indicate that people may show a bias toward recognizing their own face as more attractive than actually is. This is typically explored by making the subject's face more or less attractive using a morphing procedure. People are more likely to recognize an attractively enhanced version of their own face (facial recognition enhancement effect). The same enhancement bias is found for both one's own face and a friend's face but not for a relative stranger's face (Epley & Whitchurch, 2008). In this vein, exploring the relationship between enfacement and physical attractiveness using pairs of individuals known to one another turned out to be crucial. Human beings are initially attracted to others who are more appealing to the eyes than to their emotions. However, inner beauty may become more relevant as intimacy progress. Therefore, albeit speculatively, we posit that correlation between enfacement and inner beauty may be found when the relationship between partners in a pair is stronger than in our study.

All in all, our novel method of transferring some aspects of "pure" personal identity between individuals may cast light on the fundamental mechanisms of self-other distinction and may have substantial implications not only for neuropsychiatry, psychology, and philosophy but also for the emerging field of the social neurosciences (Uddin, Iacoboni, Lange, & Keenan, 2007).

Manuscript received 17 December 2008

Manuscript accepted 22 July 2009

First published online day/month/year

## REFERENCES

- Adolphs, R. (2008). The social brain: Neural basis of social knowledge. *Annual Review of Psychology*, *60*, 693–716.
- Aharon, I., Etcoff, N., Ariely, D., Chabris, C. F., O'Connor, E., & Breiter, H. C. (2001). Beautiful faces have variable reward value: fMRI and behavioral evidence. *Neuron*, *32*, 537–551.
- Albiero, P., Ingoglia, S., & Lo Coco, A. (2006). Contributo all'adattamento italiano dell' interpersonal Reactivity Index. *TPM, Testing Psicometria e Metodologia*, *13*, 107–125.
- Altschuler, E. L., & Ramachandran, V. S. (2007). A simple method to stand outside oneself. *Perception*, *36*, 632–634.
- Andelman, F., Zuckerman-Feldhay, E., Hoffien, D., Fried, I., & Neufeld, M. Y. (2004). Lateralization of deficit in self-awareness of memory in patients with intractable epilepsy. *Epilepsia*, *45*, 826–833.
- Armell, K. C., & Ramachandran, V. S. (2003). Projecting sensations to external objects: Evidence from skin conductance response. *Proceedings of the Royal Society B: Biological Sciences*, *270*, 1499–1506.
- Barnacz, A. L., Johnson, A., Constantino, P., & Keenan, J. P. (2004). Schizotypal personality traits and deception: The role of self-awareness. *Schizophrenia Research*, *70*, 115–116.
- Barnier, A. J., Cox, R. E., O'Connor, A., Coltheart, M., Langdon, R., Breen, N., et al. (2008). Developing hypnotic analogues of clinical delusions: Mirrored-self misidentification. *Cognitive Neuropsychiatry*, *13*, 406–430.
- Barton, J. J. (2003). Disorders of face perception and recognition. *Clinical Neurology*, *21*, 521–548.
- Beale, J. M., & Keil, F. C. (1995). Categorical effects in the perception of faces. *Cognition*, *57*, 217.
- Behrmann, M., & Avidan, G. (2005). Congenital prosopagnosia: Face-blind from birth. *Trends in Cognitive Science*, *9*, 180–187.
- Berlucchi, G., & Aglioti, S. M. (1997). The body in the brain: Neural bases of corporeal awareness. *Trends in Neuroscience*, *20*, 560–564.
- Blanke, O., Ortigue, S., Landis, T., & Seeck, M. (2002). Stimulating illusory own-body perceptions. *Nature*, *419*, 269–270.
- Blanke, O., Mohr, C., Michel, C. M., Pascual-Leone, A., Brugger, P., Seeck, M., et al. (2005). Linking out-of-body experience and self processing to mental own-body imagery at the temporoparietal junction. *Journal of Neuroscience*, *25*, 550–557.
- Bonino, S., Lo Coco, A., & Tani, F. (1998). *Empatia. I processi di condivisione delle emozioni* [Empathy. Processes of emotional sharing]. Florence, Italy: Giunti.
- Botvinick, M., & Cohen, J. (1998). Rubber hands 'feel' touch that eyes see. *Nature*, *391*, 756.
- Brédart, S., & Young, A. W. (2004). Self-recognition in everyday life. *Cognitive Neuropsychiatry*, *9*, 183–197.
- Breen, N., Caine, D., & Coltheart, M. (2001). Mirrored-self misidentification: Two cases of focal onset dementia. *Neurocase*, *7*, 239–254.
- Cloutier, J., Heatherton, T. F., Whalen, P. J., & Kelley, W. M. (2008). Are attractive people rewarding? Sex differences in the neural substrates of facial attractiveness. *Journal of Cognitive Neuroscience*, *20*, 941–951.
- Davis, M. H. (1983). Measuring individual differences in empathy: Evidence for a multidimensional approach. *Journal of Personality and Social Psychology*, *44*, 113–126.
- Decety, J., & Chaminade, T. (2003). When the self represents the other: A new cognitive neuroscience view on psychological identification. *Consciousness and Cognition*, *12*, 577–596.

- Dion, K. K., Berscheid, E., & Walster, E. (1972). What is beautiful is good. *Journal of Personality and Social Psychology*, *24*, 285–290.
- Ehrsson, H. H. (2007). The experimental induction of out-of-body experiences. *Science*, *317*, 1048.
- Ehrsson, H. H., Holmes, N. P., & Passingham, R. E. (2005). Touching a rubber hand: Feeling of body ownership is associated with activity in multisensory brain areas. *Journal of Neuroscience*, *25*, 10564–10573.
- Ehrsson, H. H., Spence, C., & Passingham, R. E. (2004). That's my hand! Activity in premotor cortex reflects feeling of ownership of a limb. *Science*, *305*, 875–877.
- Epley, N., & Whitchurch, E. (2008). Mirror, mirror on the wall: Enhancement in self-recognition. *Personality and Social Psychology Bulletin*, *34*, 1159–1170.
- Farrer, C., & Frith, C. D. (2002). Experiencing oneself vs another person as being the cause of an action: The neural correlates of the experience of agency. *NeuroImage*, *15*, 596–603.
- Fink, G. R., Markowitsch, H. J., Reinkemeier, M., Bruckbauer, T., Kessler, J., & Heiss, W. D. (1996). Cerebral representation of one's own past: Neural networks involved in autobiographical memory. *Journal of Neuroscience*, *13*, 4275–4282.
- Fink, G. R., Marshall, J. C., Weiss, P. H., Stephan, T., Grefkes, C., Shah, N. J., et al. (2003). Performing allocentric visuospatial judgments with induced distortion of the egocentric reference frame: An fMRI study with clinical implications. *NeuroImage*, *20*, 1505–1517.
- Frith, C. D. (1992). *The cognitive neuropsychology of schizophrenia*. Hove, UK: Lawrence Erlbaum Associates.
- Giummarra, M. J., Gibson, S. J., Georgiou-Karistianis, N., & Bradshaw, J. L. (2008). Mechanisms underlying embodiment, disembodiment and loss of embodiment. *Neuroscience & Biobehavioral Reviews*, *32*, 143–160.
- Hein, G., & Singer, T. (2008). I feel how you feel but not always: The empathic brain and its modulation. *Current Opinion in Neurobiology*, *18*, 153–158.
- Irani, F., Platek, S. M., Panyavin, I. S., Calkins, M. E., Kohler, C., Siegel, S. J., et al. (2006). Self-face recognition and theory of mind in patients with schizophrenia and first-degree relatives. *Schizophrenia Research*, *88*, 151.
- Johnson, K. L., & Tassinary, L. G. (2007). Compatibility of basic social perceptions determines perceived attractiveness. *Proceedings of the National Academy of Sciences of the United States of America*, *104*, 5246–5251.
- Kammers, M. P., Verhagen, L., Dijkerman, H. C., Hogendoorn, H., De Vignemont, F., & Schutter, D. J. (2008). Is this hand for real? Attenuation of the rubber hand illusion by transcranial magnetic stimulation over the inferior parietal lobule. *Journal of Cognitive Neuroscience*, *10*, 1–10.
- Keenan, J. P., Gallup, G. G., & Falk, D., Jr. (2003). *The Face in the Mirror: The Search for the Origins of Consciousness*. New York: Harper Collins.
- Keenan, J. P., Ganis, G., Freund, S., & Pascual-Leone, A. (2000). Self-face identification is increased with left hand responses. *Laterality*, *5*, 259–268.
- Keenan, J. P., Nelson, A., O'Connor, M., & Pascual-Leone, A. (2001). Self-recognition and the right hemisphere. *Nature*, *409*, 305.
- Keenan, J. P., Wheeler, M., Platek, S. M., Lardi, G., & Lassonde, M. (2003). Self-face processing in a callosotomy patient. *European Journal of Neuroscience*, *18*, 2391–2395.
- Kircher, T., & David, A. S. (2003). Self-consciousness: An integrative approach from philosophy, psychopathology and the neurosciences. In T. Kircher & A. David (Eds.), *The self in neuroscience and psychiatry* (pp. 445–473). Cambridge, UK: Cambridge University Press.
- Kircher, T. T., Seiferth, N. Y., Plewnia, C., Baar, S., & Schwabe, R. (2007). Self-face recognition in schizophrenia. *Schizophrenia Research*, *94*, 264–272.
- Kircher, T. T., Senior, C., Phillips, M. L., Rabe-Hesketh, S., Benson, P. J., Bullmore, E. T., et al. (2001). Recognizing one's own face. *Cognition*, *78*, B1–B15.
- Langlois, J. H., Kalakanis, L., Rubenstein, A. J., Larson, A., Hallam, M., & Smoot, M. (2000). Maxims or myths of beauty? A meta-analytic and theoretical review. *Psychological Bulletin*, *126*, 390–423.
- Lenggenhager, B., Tadi, T., Metzinger, T., & Blanke, O. (2007). Video ergo sum: Manipulating bodily self-consciousness. *Science*, *317*, 1096–1099.
- Lloyd, D. M. (2007). Spatial limits on referred touch to an alien limb may reflect boundaries of visuo-tactile peripersonal space surrounding the hand. *Brain & Cognition*, *64*, 104–109.
- Longo, M. R., Schüür, F., Kammers, M. P., Tsakiris, M., & Haggard, P. (2008). What is embodiment? A psychometric approach. *Cognition*, *107*, 978–998.
- Longo, M. R., Schüür, F., Kammers, M. P., Tsakiris, M., & Haggard, P. (2009). Self awareness and the body image. *Acta Psychologica*, *14* March. doi: 10.1016/j.actpsy.2009.02.003.
- Moro, V., Urgesi, C., Pernigo, S., Lanteri, P., Pazzaglia, M., & Aglioti, S. M. (2008). The neural basis of body form and body action agnosia. *Neuron*, *60*, 235–246.
- Moseley, G. L., Olthof, N., Venema, A., Don, S., Wijers, M., Gallace, A., et al. (2008). Psychologically induced cooling of a specific body part caused by the illusory ownership of an artificial counterpart. *Proceedings of the National Academy of Sciences of the United States of America*, *105*, 3169–3173.
- O'Doherty, J., Winston, J., Critchley, H., Perrett, D., Burt, D. M., & Dolan, R. J. (2003). Beauty in a smile: The role of medial orbitofrontal cortex in facial attractiveness. *Neuropsychologia*, *41*, 147–155.
- Petkova, V. I., & Ehrsson, H. H. (2008). If I were you: Perceptual illusion of body swapping. *PLoS ONE*, *3*(12), 3832.
- Phillips, M. L., Howard, R., & David, A. S. (1996). Mirror, mirror on the wall, who...?: towards a model of visual self-recognition. *Cognitive Neuropsychiatry*, *1*, 153–164.
- Platek, S. M., Keenan, J. P., Gallup, G. G., Jr., & Mohamed, F. B. (2004). Where am I? The neurological correlates of self and other. *Cognitive Brain Research*, *19*, 114–122.

- Platek, S. M., Loughhead, J. W., Gur, R. C., Busch, S., Ruparel, K., Phend, N., et al. (2006). Neural substrates for functionally discriminating self-face from personally familiar faces. *Human Brain Mapping, 27*, 91–98.
- Platek, S. M., Wathne, K., Tierney, N. G., & Thomson, J. W. (2008). Neural correlates of self-face recognition: An effect-location meta-analysis. *Brain Research, 1232*, 173–184.
- Plotnik, J. M., de Waal, F. B., & Reiss, D. (2006). Self-recognition in an Asian elephant. *Proceedings of the National Academy of Sciences of the United States of America, 103*, 17053–17057.
- Preston, S. D., & de Waal, F. B. (2002). Empathy: Its ultimate and proximate bases. *Behavioural Brain Science, 25*, 1–20.
- Preilowski, B. (1977). Self-recognition as a test of consciousness in left and right hemisphere of “split-brain” patients. *Actas Nervosa Superior, 19*, 343–344.
- Prior, H., Schwarz, A., & Güntürkün, O. (2008). Mirror-induced behavior in the magpie (*Pica pica*): Evidence of self-recognition. *PLoS Biology, 6*, e202.
- Ramachandran, V. S. (1998). Consciousness and body image: Lessons from phantom limbs, Capgras syndrome and pain asymbolia. *Philosophical Transactions of the Royal Society B: Biological Sciences, 353*, 1851–1859.
- Rhodes, G. (2006). The evolutionary psychology of facial beauty. *Annual Reviews of Psychology, 57*, 199–226.
- Riniolo, T. C., Johnson, K. C., Sherman, T. R., & Misso, J. A. (2006). Hot or not: Do professors perceived as physically attractive receive higher student evaluations? *Journal of General Psychology, 133*, 19–35.
- Schaefer, M., Flor, H., Heinze, H. J., & Rotte, M. (2006a). Dynamic modulation of the primary somatosensory cortex during seeing and feeling a touched hand. *NeuroImage, 29*, 587–592.
- Schaefer, M., Noennig, N., Heinze, H. J., & Rotte, M. (2006b). Fooling your feelings: Artificially induced referred sensations are linked to a modulation of the primary somatosensory cortex. *NeuroImage, 29*, 67–73.
- Slater, M., Pérez-Marcos, D., Ehrsson, H. H., & Sanchez-Vives, M. V. (2008). Towards a digital body: The virtual arm illusion. *Frontiers in Human Neuroscience, 2*, 1–8.
- Stuss, D. T. (1991). Self, awareness, and the frontal lobes: A neuropsychological perspective. In J. Strauss & G. R. Goethals (Eds.), *The self: Interdisciplinary approaches* (pp. 255–278). New York: Springer-Verlag.
- Swami, V., Furnham, A., Georgiades, C., & Pang, L. (2007). Evaluating self and partner physical attractiveness. *Body Image, 4*, 97–101.
- Tsakiris, M. (2008). Looking for myself: Current multi-sensory input alters self-face recognition. *PLoS ONE, 3*, e4040.
- Tsakiris, M., & Haggard, P. (2005). The rubber hand illusion revisited: Visuotactile integration and self-attribution. *Journal of Experimental Psychology: Human Perception and Performance, 31*, 80–91.
- Tsakiris, M., Hesse, M. D., Boy, C., Haggard, P., & Fink, G. R. (2007). Neural signatures of body ownership: A sensory network for bodily self-consciousness. *Cerebral Cortex, 17*, 2235–2244.
- Uddin, L. Q., Iacoboni, M., Lange, C., & Keenan, J. P. (2007). The self and social cognition: The role of cortical midline structures and mirror neurons. *Trends in Cognitive Sciences, 11*, 153–157.
- Uddin, L. Q., Kaplan, J. T., Molnar-Szakacs, I., Zaidel, E., & Iacoboni, M. (2005). Self-face recognition activates a frontoparietal “mirror” network in the right hemisphere: An event-related fMRI study. *NeuroImage, 15*, 926–935.
- Uddin, L. Q., Molnar-Szakacs, I., Zaidel, E., & Iacoboni, M. (2006). rTMS to the right inferior parietal lobule disrupts self-other discrimination. *Social Cognitive and Affective Neuroscience, 1*, 65–71.
- Vargas, A. M., & Borkowski, J. G. (1982). Physical attractiveness and counseling skills. *Journal of Counseling Psychology, 29*, 246–255.
- Vogeley, K., May, M., Ritzl, A., Falkai, P., Zilles, K., & Fink, G. R. (2004). Neural correlates of first-person perspective as one constituent of human self-consciousness. *Journal of Cognitive Neuroscience, 16*, 817–827.