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RESEARCH ARTICLE

Self-other bodily merging in the context of synchronous but arbitrary-related multisensory inputs

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Abstract A debated issue in the multisensory literature concerns the relative contribution of bottom-up sensory components versus top-down cognitive elaborations in contributing to the rise and persistency of bodily illusion. Previous studies, for instance, have shown that simultaneity of sensory inputs and plausibility of the stimulated object play an important role in the rubber hand phenomenon, whereas violation of tactile expectancy does not disrupt the illusory feeling to own a fake hand. The present research examined this issue in the context of the "enfacement" phenomenon (i.e., self-other face-perception modification), using entirely arbitrary and non-ecological pairs of visual and tactile events. Visual and tactile stimulation was matched in terms of spatial location, but not linked by any previously learned associations, making temporal synchrony a critical binding factor. Participants received electro-tactile stimulations on their cheek, while they watched the face of a stranger illuminated on the cheek with a dot of white light. Synchronous (vs. asynchronous) stimulations yielded the enfacement effect. In addition, the stranger stimulated in synchrony was judged as more similar, physically and in terms of personality, and as closer to the self. These findings suggest that synchronous multisensory stimulation on the face can produce both perceptual and social binding, even in the absence of any previously learned associations between the stimulations.

Keywords Rubber hand illusion · Face perception · Multisensory · Synchrony · Arbitrary stimulations

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Introduction

Our body representation is constantly updated starting from the integration of different sensory inputs (Holmes and Spence 2004; de Vignemont 2007). A paradigmatic example of this notion is the well-known rubber hand illusion (RHI) in which participants feel illusory ownership for a seen rubber hand. This illusion was first documented by Tastevin (1937) and later described in more detail by Botvinick and Cohen (1998).

Since these first reports, the RHI has been extensively investigated (for review see: Makin et al. 2008) and it is now considered a useful paradigm to investigate body ownership, self-identification, or self-other merging. A few recent examples illustrate well the broader implications of this bodily illusion. This type of illusion need not be restricted to the hand and can readily be adapted for stimulation on the entire body (e.g., Lenggenhager et al. 2007; Blanke and Metzinger 2009) or the face (Paladino et al. 2010; Sforza et al. 2010; Tsakiris 2008).

When the illusion is created for stimuli delivered to the face, the participant receives a tactile stimulation on the cheek, while she is watching a video depicting the face of another person being touched in exact spatio-temporal synchrony. This variation of the RHI paradigm creates in the participant the sensations of being in front of a mirror,

modifying the perception of self-other face. The phenomenon, called by Sforza et al. (2010) "enfacement effect," is characterized by the illusory sensation of being able to control the facial movements of the person in the video and perceive a resemblance between the face shown in the video and their own face (Paladino et al. 2010; Sforza et al. 2010; Tsakiris 2008). Similar to the classic RHI phenomenon, these effects emerge when comparing the synchronous and the asynchronous condition.

For this enfacement phenomenon, Paladino et al. (2010) recently showed that the perception of self-other similarity induced during synchronous stimulation of the participant's face and an actor face in a video can go beyond the physical body attributes, to affect also social perception and behavior toward the stranger in the video. Participants felt closer and expected more psychological similarity (i.e., personality traits and inner states) toward the stranger stimulated in synchrony compared with a different stranger stimulated asynchronously. This suggests that visuo–tactile interactions can also affect processing of social information and that phenomena, such as the RHI or the enfacement effect, may be informative on how we create social bonds with the others.

One of the debated issues in the multisensory literature concerns the relative contribution of bottom-up sensory components versus top-down cognitive elaborations in contributing to the rise and persistency of bodily illusion. Armel and Ramachandran (2003) argued that the statistical correlation between visual and tactile inputs that characterizes the synchronous stimulation condition is *necessary and sufficient* to induce the RHI. In support of this account, they showed that even a non-corporeal object, such as the table in front of the participant, could be incorporated by participants in their own bodily representation, when touched in synchrony with the participant's hand hidden from the view. This purely bottom-up view, however, has been challenged in a number of studies, showing that the simultaneous and correlated presence of sensory inputs is *necessary but not sufficient* to induce the illusion. This claim is supported by the observation that changes in the position (aligned vs. misaligned; Tsakiris and Haggard 2005; Costantini and Haggard 2007; Pavani et al. 2000), size (Pavani and Zampini 2007), or identity (hand/body part vs. object; Tsakiris et al. 2010) of the external object stimulated in synchrony can change substantially the extent of the illusion. For example, when the rubber hand occupies a posture, which is largely incongruent with respect to the body (e.g., it is rotated by 90° with respect to the participant's real hand), the RHI fades even if visuo-tactile stimulation is completely synchronous (e.g., Pavani et al. 2000; Tsakiris and Haggard 2005). Similarly, no reliable proprioceptive drift (i.e., one of the effects of the RHI) has been measured when the visible object stimulated in synchrony was a wooden stick (Tsakiris and Haggard 2005; see also Haans et al. 2008), unlike the original observation of Armel and Ramachandran (2003). These findings suggest that the illusory merging of a rubber hand into the person's body representation can be disrupted either by stimulation asynchrony or by plausibility mismatches between the stimulated object and the body.

In most studies, adopting the RHI paradigm, visual and tactile stimuli are delivered using the same ecological stimulus: a paintbrush. Thus, in the synchronous condition, two concurrent factors can contribute to multisensory binding: first, the co-occurrence of multisensory events; second, the expectation about tactile sensations resulting from a paintbrush on the skin. Tactile expectancy can thus be considered as an additional top-down factor (i.e., to what extent we expect a specific tactile sensation, given a specific visual stimulus approaching the fake hand). A few studies have recently examined whether changes in tactile expectancy can modulate the RHI. These studies violated tactile expectations by changing orientation congruency of the strokes on the participant's hand and on the fake hand (Costantini and Haggard 2007) or by creating a mismatch between the tactile properties of the stimulus administered to the fake hand and that of the stimulus delivered to the participant's own hand (White et al. 2010; Schütz-Bosbach et al. 2009; Ehrsson et al. 2005). The overall finding is that changing orientation congruency did interfere with the RHI, whereas creating a mismatched between previously experienced visuo-tactile pairings did not. The latter finding appears to falsify some anecdotal reports about the RHI becoming weaker when a mismatch between expected and perceived touch existed (e.g., "the illusion was ruined when [my] hand was touched in an area of high hair density", Armel and Ramachandran 2003, p. 1,504). Note that these approaches to top-down factors are very dissimilar to those adopted in earlier studies (e.g., Tsakiris and Haggard 2005; Pavani and Zampini 2007), in which top-down components were manipulated by changing some attribute of the stimulated object (e.g., size, orientation, or identity).

Violations of tactile expectation in the rubber hand illusion always entailed ecologically plausible pairs of stimuli, such as fingers, paintbrushes, or fabrics. Thus, it remains an open question whether administering entirely arbitrary and non-ecological pairs of visual and tactile events could also result in a conflict that can diminish the bodily illusions to a larger extent. Durgin et al. (2007) used non-ecological visual stimulation, a laser light projected on to the rubber hand, and showed that it is possible to create a tactile feeling on participants' hand, even for this atypical event. In that study, however, the visual stimulus was not paired to any actual tactile stimulation, leaving the open issue of whether a non-ecological tactile stimulus can be arbitrarily paired with a non-ecological visual stimulus. In

addition, the role of top-down stimulation binding has so far been examined exclusively for stimulation delivered to hands (fake and real), raising the issue of whether applying this manipulation to other body parts, such as the face or the entire body, could have a different effect.

The present study aims to address these two issues, by replicating the experimental paradigm in which Paladino et al. (2010) documented bodily as well as social consequences of the enfacement effect, but using visuo-tactile stimuli that have no previous multisensory association: an electrical stimulation on the participant's cheek and a dot of white light appearing on exactly the same location on a stranger's face. The electrical stimulation (i.e., the tactile stimulus) and the dot of light (i.e., the visual stimulus) were either synchronous or asynchronous. In both conditions, the rhythm of presentation of the inputs was non-cadenced and entirely unpredictable. We investigated the effect of this procedure on body perception, asking participants to rate their illusory perception of "enfacement" on three components (ownership, location and agency) and to judge self-other face similarity. With an exploratory purpose, we tested also the effect on social perception (closeness, attraction, and personality similarity) and behavior (tendency to conform) toward the partner of the stimulation, to assess the consequence of arbitrary-related stimuli on social and bodily effects of the illusion.

If the exposure to temporally correlated signals can induce an extension of the bodily borders, even for totally arbitrary and non-ecological stimuli, we expected to replicate the enfacement effect and possibly extend this effect to the social dimension as well. By contrast, if temporal synchrony is not enough for binding arbitrary and not previously associated stimuli, we should not observe any of these modifications in self-other perception.

Methods

Participants

Nineteen students of the University of Trento took part in the study in exchange of course credits. One participant was excluded from the analysis because she was not able to fully understand the administrated questionnaires, being a non-native Italian speaker. Analyses were thus conducted on 18 participants (mean age 21.28, SD = 2.54; 16 females).

Apparatus and materials

Visual stimuli consisted of two movies of 4 min each. In each video, the photograph of a young woman's face appeared, with a sequence of white dots with blurred edges appearing on her left cheek. Dots were 1 cm in diameter and located 1 cm under the more external left-eye border. The women's hair and the entire background were covered by a white rectangular mask and were not visible. Two different woman's portraits were used in the two videos. They were both entirely unfamiliar faces to the participants: they were not students at the University of Trento and lived in another Italian region. In a pretest, external raters judged the two faces as equally attractive among a set of photos of female portraits ($M = 5.01$, SD = .99 and $M = 5.11$, SD = .86; $t < 1$). Tactile stimuli consisted of high-voltage pulses of brief duration, delivered using neurogical electrodes (Neuroline 700, AMBU) on participants' right cheek connected to a constant current stimulator devised for clinical use (DS7A, Digitimer®). For each participant, intensity of the electro-tactile stimuli was adjusted to a clear supra-threshold level, while also making sure that the stimulus was not perceived as painful. Tactile stimulation was always administered on the same hemispace as the visual stimulation on the face in the video. In other words, the spatial correspondence between visual and tactile stimulation mimicked what people normally see when they touch their face in front of mirror.

Visual and tactile stimulation was controlled using the E-Prime® software. In the synchronous condition, tactile stimulation on participants' cheek was delivered in the exact temporal synchrony with the dot of light that appeared on the cheek of the person in the movie. In the asynchronous condition, the tactile stimulation was designed to be unrelated to the visual one. Stimulation sequences were generated using a maximum length sequence (MLS) algorithm, with a linear feedback shift register method (Brown 2002). This resulted in binary pseudo-random sequences, in which 1 corresponded to stimulation present and 0 corresponded to stimulation absent. Sequences were 255 bits long, with each bit lasting 1,000 ms. The MLS algorithm produces a balanced proportion of 1 and 0 bits in each sequence and low correlation between successive output sequences. In the synchronous condition, exactly the same stimulation sequence was used for visual and electro-tactile stimulation. In the asynchronous condition, tactile and visual stimulation was based on independently generated sequences, with an intersequence correlation ranging between .40 and .60. Note that zero correlation between the sequences would have meant having the two sequences in anti-phase (e.g., whenever a 0 was present in the visual sequence, a 1 was present in the tactile sequence). Thus, both the synchronous and asynchronous stimulations followed a non-regular and unpredictable rhythm.

Procedure

Similarly to the study by Paladino et al. (2010), participants performed two experimental blocks. In each block,

they saw a 4 min movie while they received synchronous or asynchronous visuo-tactile stimulation. Order of targets and their combination with synchronous versus asynchronous stimulation were counterbalanced between participants. Immediately after each stimulation block, participants filled a questionnaire and performed a conformity task. The questionnaire concerned the different aspects of the bodily illusion of merging with the stranger shown in the movie, the perceived physical resemblance with her, and the feeling of relational closeness and attraction. In the conformity task, they were asked to provide an estimate about a large number of "a" letters randomly distributed on the screen, while also seeing the estimate supposedly provided for the same set by either stranger. At the end of the two experimental blocks, participants completed also an inference task and answered manipulation check questions. Finally, participants were debriefed and thanked for their participation. None of the participants was suspicious about the real goal of the study or had met the women shown in the movies before.

All measures used in the study are explained in detail in the next two paragraphs.

Bodily perception measures

Enfacement effect

As in previous studies (Paladino et al. 2010; Sforza et al. 2010; see also Longo et al. 2008), we administered a questionnaire to assess the main components of the experience, i.e., the feeling of becoming the person in the movie (*ownership*, 4 items), the confusion in the source of the stimulation (*location*, 3 items), and the sensation of controlling the face in the movie (*agency*, 2 items[1]) (see Fig. 1a). Three additional items assessed the pleasantness of the experience (*affect*). The responses were given on a bipolar scale of 100 mm (−50 mm totally disagree, +50 mm totally agree).

Physical resemblance

Participants judged the resemblance they felt with the stranger on different facial areas. We computed an index for core (e.g., eyes, nose) and peripheral regions (e.g., cheeks, chin). Moreover, they answered also about the general physical resemblance. All responses were given on a 7-point scale (1 = not at all; 7 = completely).

Social perception measures

Self-other closeness

Participants rated the degree of closeness felt with the stranger seen in the movie on the Schubert and Otten (2002)'s version of the Inclusion of the Other in the Self scale (IOS, Aron et al. 1992). This graphic 7-point scale consists of a series of pictures of two circles representing the self and the other person with different degree of overlap, from two distant (1) to a completely overlapping circles (7) (see Fig. 1c).

Attraction

Three items investigated the attraction toward the strangers in the movies. Responses were given on a 7-point scale (1 = not at all; 7 = completely).

Conformity behavior

An implicit measure of conformity (Castelli et al. 2001; Vaes et al. 2003) was used. This task was presented as a numeric estimation task. Fourteen pages with different letters "a" agglomerates were presented, each one for few seconds. The number of the letters was always 200 but the different layouts on the page make them looking different numbers. On the top of the page, we showed the estimations of the person participants just seen in the movie and who supposedly participated in the same task. Although participants were instructed to ignore this evaluation, it could work in fact as an anchor for their judgments. Conformity was operationalised as the absolute difference between the participants' estimates and the anchors that were given in each trial.

Self-projection

At the end of the whole procedure, after participants saw both the movies and received the two types of stimulations, an inference task was presented (Mitchell et al. 2006). Participants answered (yes/no) to 51 questions presented in a booklet, in a random order, about their habits and characteristics and about the synchronous and asynchronous stimulated others' same habits and characteristics. Therefore, the same questions were repeated three times. To enhance the participants' feeling of being entitled to judge the actor, we told them that during the

[1] In this study, questions about the possibility to control the person shown in the photo, turned out to be inappropriate, if not constructed in a hypothetical way. Therefore, differently from Paladino et al. (2010)'s study, here we dropped the item "It seemed that the face in the video had my same facial expressions". Moreover, deleting it a larger internal consistency was reached: $\alpha = .67$ and $\alpha = .93$ in the synchronous and in the asynchronous stimulation condition. Here only 2 of the 3 items used in Paladino et al. (2010)'s study to assess the illusory perception of agency were retained (see Fig. 1a).

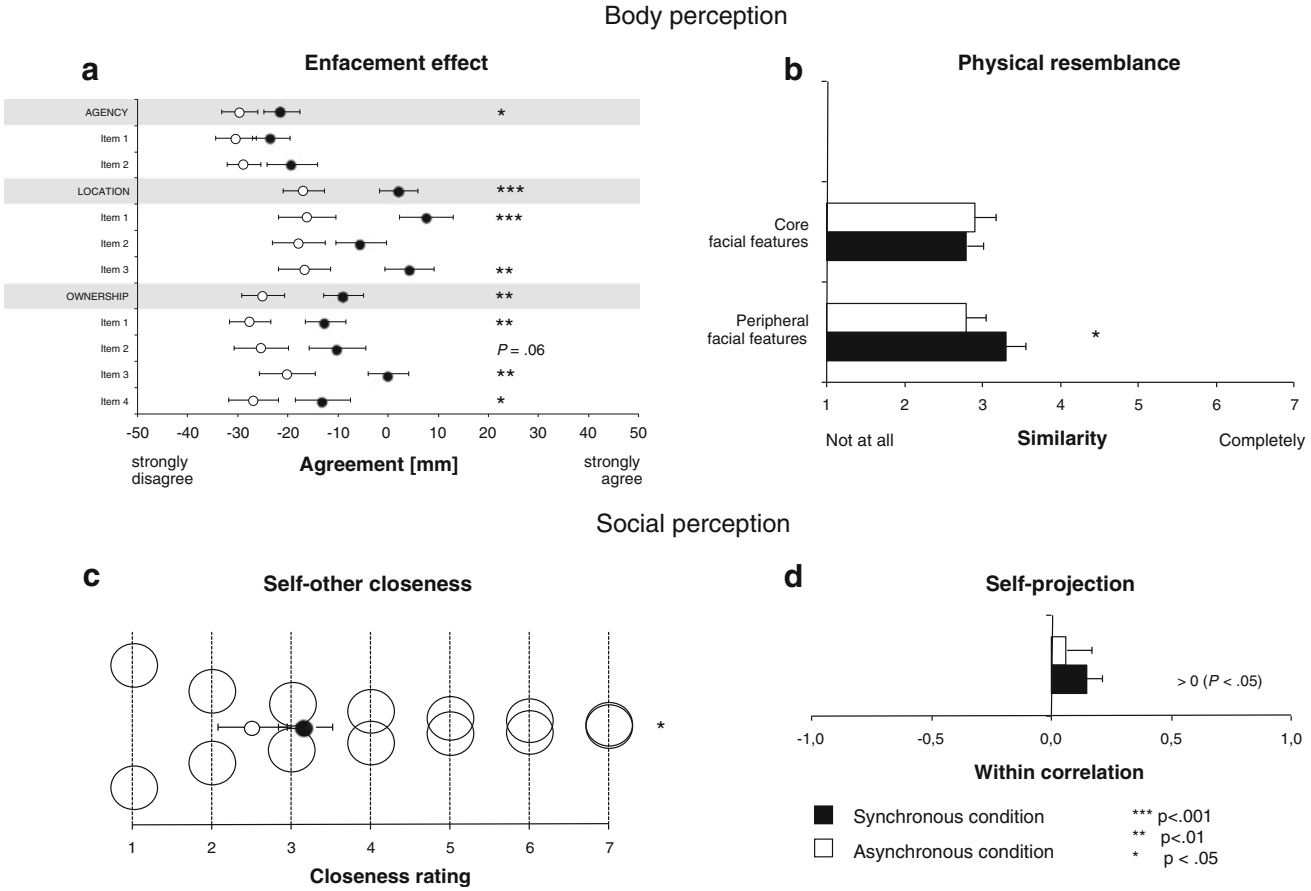

Fig. 1 Effects of a visuo-tactile synchronous (*black*) versus asynchronous (*white*) stimulations on **a** the different components of the enfacement effect and the single items (*Ownership 1* I had the impression to see myself in a mirror, *2* It felt as if my face was turning into the face in the video, *3* sometimes, I had the impression that the face in the movie started resembling to me, *4* sometimes, I had the impression to see my own face in the video; *Location 1* it seemed as if the touch I felt was caused by the light on the face in the movie, *2* sometimes, I did not know whether the stimulation was happening on my face or the face in the video, *3* it seemed as if I were feeling the stimulation on the face in the video; *Agency 1* sometimes, I had the impression that if I had moved my eyes, the eyes of the person in the video would have moved too, *2* it had the sensation that if I had moved my own face, I would have seen movements of the face in the video); **b** physical resemblance on the core and peripheral facial features; **c** closeness with stranger, rated on the inclusion of other in the Self (IOS) scale; **d** self-projection, operationalized as within correlation between the self and the synchronous stimulated other and the self and the asynchronous stimulated other. Means and standard error of the mean (error bar) are reported. ***$P \leq .001$, **$P \leq .01$ and *$P \leq .05$

video they received some subliminal information about the actor (Yzerbyt et al. 1994). Obviously, no subliminal information was given. Within-participant correlations were computed between the self and the synchronous stimulated other ratings and between the self and the asynchronous stimulated other ratings. The *z*-transformed correlations formed an indirect index of self-projection onto the other.

Manipulation check

Two questions for both synchronous and then asynchronous stimulations aimed to control if the participants perceived the type of synchrony ("I had the sensation that the tactile stimulation on my face and the light on the face of the person in the movie appeared at the same—synchronous- or at different moments—asynchronous-") and felt the electric stimulation ("I felt clearly the tactile stimulation on my face"). Responses were given on a 7-point scale (respectively 1 = totally asynchronous; 7 = totally synchronous and 1 = not at all; 7 = completely).

Results

All dependent variables were submitted to a repeated measure ANOVA, with stimulation timing (synchronous

or asynchronous) as variable. Results on self-other merging in bodily and social perception are summarized in Fig. 1. The manipulation check confirmed that participants perceived the differences in synchrony in the two experimental blocks, F (1, 17) = 114.90, $P < .001$, $\eta_p^2 = .87$ ($M = 6.56$, SD = .71 and $M = 1.89$, SD = 1.28 for the synchronous and asynchronous type of stimulation, respectively) and to have equally felt the tactile stimulation in both the conditions, F (1, 17) = 3.32, $P = .09$, $\eta_p^2 = .16$.

Enfacement effect

The synchronous condition led to stronger enfacement effect compared to asynchronous stimulation. In particular, the perception of *ownership*, that is the illusory sensation of being/becoming the face shown in the movie, was higher after synchronous ($M = -8.94$, SD = 16.85, $\alpha = .83$) than asynchronous stimulation ($M = -25.02$, SD = 17.96, $\alpha = .85$), F (1, 17) = 9.12, $P = .008$, $\eta_p^2 = .35$. The confusion between the *location* source of the seen and the felt stimulation was also stronger after synchronous ($M = 2.08$, SD = 16.35, $\alpha = .61$) than asynchronous stimulation ($M = -16.93$, SD = 17.70, $\alpha = .66$), F (1, 17) = 18.25, $P = .001$, $\eta_p^2 = .52$. Finally, the illusory sensation of *agency* was stronger in the synchronous ($M = -21.29$, SD = 15.21, $\alpha = .67$) compared with the asynchronous condition ($M = -29.61$, SD = 15.25, $\alpha = .93$), $F(1, 17) = 4.39$, $P = .05$, $\eta_p^2 = .21$. In brief, we replicated all the main aspects of the enfacement phenomenon (in Fig. 1a, the components and also all the single items results are reported). Instead, evaluations of the pleasantness (*affect*) of the stimulation and the overall experience were comparable for the synchronous and asynchronous conditions ($M = 5.44$, SD = 20.18, $\alpha = .85$ and $M = 3.74$, SD = 16.14, $\alpha = .82$, respectively), $F < 1$, and did not differ from the midpoint of the scale (t (17) = 1.14, n.s., and $t < 1$).

Physical resemblance

Participants judged the face of the person stimulated in synchrony (vs. asynchrony) as more resembling to the self-face on the peripheral, ($M = 3.78$, SD = 1.05 and $M = 3.41$, SD = 1.00, for the synchronous and the asynchronous stimulation condition, respectively), F (1, 17) = 4.30, $P = .05$, $\eta_p^2 = .20$, but not on the core facial features, $F < 1$ (Fig. 1b). However, this perceived resemblance on the peripheral features did not affect the general perception of physical similarity toward the partner of the stimulation, $F < 1$.

Self-other closeness

On *social perception*, the analysis of responses to the IOS scale showed that participants felt closer toward the person in the video when the visual stimulation (dots of light) was synchronous ($M = 3.17$, SD = 1.43) rather than asynchronous to the tactile stimulation ($M = 2.50$, SD = 1.82), F (1, 17) = 6.18, $P = .02$, $\eta_p^2 = .27$ (Fig. 1c).

Self-projection

Evidence for an overlap between the self and the synchronously stimulated other was found also in the responses to the self-projection task. The within-correlations between the self and the other were in fact positive and significantly different from zero only in the synchronous stimulation condition ($M = .14$, SD = .28), t (17) = 2.13, $P = .048$, but not in the asynchronous stimulated condition ($M = .06$, SD = .45), $t < 1$. This shows that when judging the personality and the inner states of the other, the self was only used for inferences when the stimulation was synchronous (Fig. 1d). However, the difference between the correlations in the two conditions was not significant, $F < 1$.

Attraction and conformity behavior

The analysis of the other social perception variables, attraction toward the other and conformity behavior, yielded no significant effect, for attraction (F (1, 17) = 1.27, n.s., $\eta_p^2 = .07$) and conformity behavior (F (1, 17) = 2.86, n.s., $\eta_p^2 = .14$).

Discussion

In the present study, we aimed to investigate whether previous learned associations between multisensory stimulations play a role in the enfacement phenomenon. Unlike previous studies that manipulated the congruency between seen and felt touches using ecological stimuli (e.g., a paintbrush touch paired with a finger touch; e.g., White et al. 2010), here we adopted entirely arbitrary and non-ecologic stimulations. Participants received a series of electro-tactile stimuli on the cheek, while watching a movie in which a discontinuous sequence of dot of white light appeared on the cheek of a stranger. These stimulations were either synchronous or asynchronous, resulting in a series of multisensory events that could be associated on the basis of temporal synchrony but not on the basis of previous experience.

The main result of the present study is that synchronous sensorial stimulations affected body perception leading to a blurring in self-other bodily boundaries, despite their arbitrary link. Compared to the asynchronous conditions, when the stimulation was synchronous participants tended to report touches in the location where they saw the visual stimulation. Furthermore, they experienced the illusory perception of being the person in the video and being able to control eye and facial movements of the person in the video. Consistent with these effects, participants also tended to see some resemblance between the peripheral facial features of the stimulated partner and their own ones. These findings suggest that a previously learned association between the visual and tactile stimulation delivered in the enfacement paradigm is not a necessary condition for experiencing the bodily aspects of the experience. This result supports and extends also recent work on the role of tactile expectancy on the RHI phenomenon (e.g., White et al. 2010; Schütz-Bosbach et al. 2009) by showing that even an extreme violation of tactile expectancy (such as the one evoked here by entirely arbitrary non-ecological stimuli) can induce self-other merging at the bodily level.

To what extent is the effect evoked here with arbitrary stimuli comparable with the body sensations evoked when the same paradigm is adopted using paintbrush stimulation? To answer this question, we conducted a meta-analytic comparison between the effect size of enfacement measures obtained in the present study and the average effect size found on the same measures in other studies ($N = 3$, in total 73 participants; average $N = 24$) we previously conducted (Paladino et al. 2010; Mazzurega et al. in preparation). In these comparison studies, participants were touched by a paintbrush on the cheek while watching a person being touched on a cheek by a paintbrush (either in synchrony or asynchrony). Thus, visual and tactile events were both temporally related and matched on the basis of previously learned tactile expectations (i.e., feeling associated with the bristles touch). Bodily illusion was measured along the ownership, agency, and location dimension, as well as in terms of perceived physical similarities on the facial features. In all these 3 studies, the effect of synchrony of stimulation was significant and in the same direction for the 3 facets of the enfacement effect and the resemblance on peripheral facial features. Following Rosenthal's (1991) indications, the effect sizes were combined into a single index. The results of the meta-analytic procedure indicated that the illusory perception of being the person in the video (i.e., ownership), controlling her facial movement (i.e., agency), and a sensation of confusion between the felt and the seen touch experience (i.e., location), as the perceived physical resemblance, were experienced equally strongly in the present and the comparison studies (all Z's < 1).[2] This suggests that the experience of enfacement and the perception of a certain physical similarity are not reduced when introducing an arbitrary link between the visual and the tactile stimulations.

Unlike these bodily aspects of the experience, in the present study, we only partially replicated Paladino et al. (2010)'s findings on social perception and behavior. Although the person stimulated in synchrony (vs. asynchrony) was judged as closer to the self (IOS scale; Aron et al. 1992; Schubert and Otten 2002) and more similar in terms of personality (projection of inner states), synchrony did not influence attraction toward the partner of the stimulation nor induced conformity behavior. Inclusion of the other in the self typically characterizes the relationship with a close other and the extent to which we rely on the self to infer personality traits of the other may precisely reflect this self-other merging. Attraction and conformity, instead, can be influenced by self-other merging but can also reflect other factors such as the sociability and the influenceability of the person. In this respect, synchronous pairing of arbitrary multisensory inputs appears sufficient to induce a blurring in self-other body boundaries, but insufficient to affect other socio-affective responses toward the partner of the stimulation.

Another potential explanation of the discrepancy in the social perception results should also be acknowledged. In addition to avoid a learned association between stimuli, we also made the stimulation rhythms entirely unpredictable, using carefully randomized sequence of stimuli. This differs from the stimulation conditions adopted in Paladino et al. (2010) and, to our knowledge, in most previous studies on the RHI and enfacement phenomena. We cannot exclude that this additional difference could have somehow

[2] Following Rosenthal's (1991) indication for each variable of interest, the combined effect size (z_1) was compared to the effect size obtained in the present (z_2) study using the following formula: $Z = \frac{z_1 - z_2}{\sqrt{\frac{1}{N_1-3}+\frac{1}{N_2-3}}}$ where $N_1 = 24$ (average sample) and $N_1 = 18$.

	z_1	z_2	Z
Ownership	.71	.68	.08
Location	.88	.91	−.09
Agency	.65	.49	.48
Similarity on peripheral feature	.49	.48	.00

interfered with social perception measures. In partial support of this account of the results on the social measures, moving in synchrony following an easy and predictable rhythm (e.g., Wilthermuth and Heath 2009) leads to a series of social and affective outcomes very similar to those showed by Paladino et al. (2010), whereas trying to tap in synchrony a not predictable rhythm does not lead to these effects (see Kurzban 2001).

Whatever the explanation for the absence of self-other merging in the social domain, the present findings demonstrate that enfacement can be elicited even when participants are exposed to stimuli that can be bound on the basis of temporal synchrony. This finding underlines the role of temporal synchrony in multisensory interactions and is consistent with the so-called unity assumption (Welch and Warren 1980). The unity assumption suggests that whenever two or more sensory inputs are highly consistent in one or more dimension (e.g., time as in the present study, but it could also be a semantic content), observers are likely to treat them as referring to the same underlying multisensory event and consequently bind them into a single unified percept. Interestingly, the present study suggests that time is more important than previously experienced links between visual and tactile inputs in inducing a modification of body representation. This account matches findings in the multisensory literature concerning, for instance, audio-visual integration and the ventriloquism effect. In a ventriloquist show, the auditory (ventriloquist's voice) and visual signals (the synchronous movement of the mouth of the puppet) come from different locations. The ventriloquist effect is the perceived shift of the auditory source toward the visual stimulus (Howard and Templeton 1966; Recanzone 2009). It has long been established that the ventriloquist effect emerges reliably with ecological connected stimuli (i.e., stimuli associated in our daily life experience) such as heard words and lip movements as in the actual ventriloquist show or a whistling sound and a puff of steam coming from a kettle. It is also clear that non-related stimuli, such as bells sounds and flashes of light, can also produce this audio-visual capture (Jackson 1953). In the latter case, however, the tolerance of spatial discrepancies between the auditory and visual signals that our perceptual system accepts before the ventriloquist illusion breaks down is smaller (e.g., Jackson 1953). Thus, prior knowledge about the multisensory link is not a prerequisite for the emergence of multisensory illusions, but may modulate their strength.

In the present study, the binding factor between the visual and the tactile stimulation was temporal synchrony. However, these stimulations involved the same body part (i.e., the face) and were spatially congruent (i.e. delivered on the cheek). To better establish the role of temporal synchrony per se, also these top-down aspects should be altered in future studies, changing, for instance, the stimulated side of the face (e.g., the same cheek for both the participant and the stranger). In conclusion, assessing the role of learned association between visual and tactile stimuli in the enfacement phenomenon, in the present experiment, we showed that correlated but arbitrary linked inputs delivered on the participant and a stranger's face did induce a modification in face perception and a certain physical similarity and connectedness. Moreover, comparisons of the effect size to previous studies suggest that it did not have a less strong effect than ecological and congruent shared stimulations (i.e., a paintbrush touch) in inducing a blurring in self-other bodily boundaries. This suggests that the enfacement effect, or the feeling of looking at another as if looking at the self in a mirror, can emerge also when arbitrary-related stimuli are used, provided that these are synchronous.

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