It *feels* like it’s me: interpersonal multisensory stimulation enhances visual remapping of touch from other to self.

Flavia Cardini [a]*, Ana Tajadura-Jiménez [a], Andrea Serino [b,c]** and Manos Tsakiris[a]*

Published as: Cardini F, Tajadura-Jiménez A, Serino A, Tsakiris M. (2013) It Feels Like It's Me: Interpersonal Multisensory Stimulation Enhances Visual Remapping of Touch From Other to Self. *J Exp Psychol Hum Percept Perform*. 2012 Dec 31. [Epub ahead of print]

[a] Lab of Action & Body, Department of Psychology, Royal Holloway, University of London, Egham, Surrey, TW20 0EX, UK.

[b] Dipartimento di Psicologia, Universita di Bologna, via Riccardo Brusi 20, 47023, Cesena, Italy.

[c] Centro studi e ricerche in Neuroscienze Cognitive, Polo Scientifico-Didattico di Cesena, Università di Bologna, via Riccardo Brusi 20, 47023, Cesena, Italy.

*To whom correspondence should be addressed: Dr Flavia Cardini, Department of Psychology, Royal Holloway, University of London, Egham, Surrey, TW20 0EX, UK. Tel. +44(0)1784276551, Fax. +44(0)1784434347, E-mail: flavia.cardini@rhul.ac.uk or manos.tsakiris@rhul.ac.uk

** now at: Laboratory of Cognitive Neuroscience & Center for Neuroprosthetics, School of Life Sciences, École Polytechnique Fédérale de Lausanne.

Abstract

Understanding other people’s feelings in social interactions depends on the ability to map onto our body the sensory experiences we observed on other people’s bodies. It has been shown that the perception of tactile stimuli on the face is improved when concurrently viewing a face being touched. This Visual Remapping of Touch (VRT) is enhanced the more similar others are perceived to be to the self, and is strongest when viewing one’s face. Here, we ask whether altering self-other boundaries can in turn change the VRT effect. We used the enfacement illusion, which relies on synchronous interpersonal multisensory stimulation (IMS), to manipulate self-other boundaries. Following synchronous, but not asynchronous, IMS, the self-related enhancement of the VRT extended to the other individual. These findings suggest that shared multisensory experiences represent one key way to overcome the boundaries between self and others, as evidenced by changes in somatosensory processing of tactile stimuli on one’s own face when concurrently viewing another person’s face being touched.

Keywords: Multisensory Interaction; Visual Remapping of Touch; Interpersonal Multisensory Stimulation; Self-recognition; Enfacement illusion

Introduction

We constantly feel, see and move our body, and have no doubt that it is our own. The distinction between one’s body and that of other people may rely on processes that monitor whether sensations, events and objects should be attributed to oneself or not, in order to form a mental representation of the bodily self as distinct from the other. Such self representations has been shown to be continuously updated by the interaction between body-related sensory (Blanke & Metzinger, 2009; Ehrsson, Holmes, & Passingham, 2005; Tsakiris, 2010), semantic (D'Argembeau et al., 2007) and social information (Meltzoff, 2007). At the same time, the representation of the bodily self is necessary for interacting with other, as it is currently accepted that understanding other people’s feelings, sensations and emotions depends on the ability to refer to one’s body the sensory experiences observed onto the others’ bodies (de Vignemont & Singer, 2006; Gallese, Keysers, & Rizzolatti, 2004).

Among the different senses, touch is peculiar as it is often conceptualized as a private sense, and hence tactile experience is thought as limited to the subject who experiences touch. However, recent findings have challenged this assumption by showing that viewing touch on the body of others automatically activates one’s own somatosensory system (Blakemore, Bristow, Bird, Frith, & Ward, 2005; Cardini et al., 2011; Ebisch et al., 2008; Keysers et al., 2004), and also affects somatosensory perception, when perceptual thresholds are experimentally manipulated. For example, viewing a face being touched by fingers enhances the perception of near-threshold tactile stimuli on the face compared to viewing the same face being just approached. This Visual Remapping of Touch (Ladavas & Serino, 2010) is specific for viewing touch on a body-part and does not generalize to non-bodily stimuli. Moreover, the amount of enhancement is maximum when observing one’s own face as compared to when observing the face of another person (Serino, Pizzoferrato, & Ladavas, 2008). Interestingly, VRT is also stronger when the other is perceived as belonging to the same group as oneself (Serino, Giovagnoli, & Ladavas, 2009). The evidence for the existence and modulation of the VRT mechanism points to its key role in self-other representations and social interactions; in order to understand other peoples’ feelings, observers implicitly refer what they see experienced on other bodies onto their own body. This remapping mechanism is facilitated by the perceived similarity between self and others.

However, recent findings suggest that the perceived similarity between the self and others, in other words the boundary between self and others, is not fixed but malleable. For example, several studies have suggested that embodied interactions, and especially synchronized interactions, between individuals can change the cooperation, likeness and affiliation ratings (Hove & Risen, 2009; Sebanz, Bekkering, & Knoblich, 2006; Wiltermuth & Heath, 2009) between these individuals, and even result in a blurring between self and other. Beyond social psychology studies, recent experiments on multisensory integration have shown how synchronous visuo-tactile stimulation between one’s own body and a foreign body can induce changes in the sense of body-ownership. From the classic Rubber Hand Illusion (Botvinick & Cohen, 1998) to the more recent Body-Swap Illusion (Petkova & Ehrsson, 2008), consistent results show that synchronous multisensory stimulation results in changes in self-representations.

Recent studies using multisensory stimulation on the face between individuals have shown that such changes in self-representations in fact alter the self-other boundaries. By creating a situation that resembles the experience of looking at oneself into the mirror, albeit the “mirror reflection” of one’s face was replaced by another person's face (Sforza, Bufalari, Haggard, & Aglioti, 2010; Tajadura-Jiménez, Grehl, & Tsakiris, 2012; Tsakiris, 2008), produces a measurable bias in the ability of distinguishing between one's own face and the face of the other. Following synchronous but not asynchronous visuo-tactile stimulation, participants accepted as self-stimuli faces that contained a significantly higher percentage of the other's face (Tajadura-Jiménez et al., 2012; Tsakiris, 2008). Interestingly, following this "enfacement illusion" that relies on interpersonal multisensory stimulation (IMS), participants also showed marked differences in a range of social cognition processes such as conformity behaviour and self-other fusion (Mazzurega, Pavani, Paladino, & Schubert, 2011; Paladino, Mazzurega, Pavani, & Schubert, 2010). These findings suggest that we can use shared multisensory experiences to alter the self-other boundaries and therefore change the perceived similarity between self and other in a controlled way. In the present study, we therefore used this paradigm of IMS to change self-other boundaries and investigate the effect of this change on the ability to remap somatosensory stimuli seen on the face of the other into one's own somatosensory system, as measured by a VRT task.

Given that the modulation of somatosensory processing due to viewing touch depends on the perceived similarity between the body of the observer and that of the observed (Cardini et al., 2011; Serino et al., 2009; Serino et al., 2008), we hypothesized that synchronous IMS - as used in the "enfacement illusion" - which eases the boundaries between self and other, would enhance the ability of embodying other people's sensations into one's somatosensory system, and therefore facilitate the remapping of touch from other to self. The possibility of using shared multisensory stimulation to reduce perceived physical distance between self and other might be a key way to change the perception and understanding of others' observed physical experiences during face-to-face interactions. This might be particular relevant for social cognition processes such as empathy that have been shown to depend partly on the perceived physical similarity between individuals, such as the lower empathy for pain for individuals belonging to an outgroup (Avenanti, Sirigu, & Aglioti, 2010; Xu, Zuo, Wang, & Han, 2009). To that end, we measured the self-related modulation of VRT when observing one’s own face or the face of another person (as in Serino et al., 2008) before and after participants were exposed to synchronous or asynchronous IMS sessions in which they viewed touch on the face of the other person (as in Tsakiris, 2008). We predicted that if the other face is experienced as self-face, as a result of synchronous IMS, the self-specific modulation of the VRT effect should consequently extend to the other’s face. Conversely, asynchronous IMS would preserve the self-specific modulation in the VRT effect.

Methods

Participants

Twenty-five healthy female volunteers (M = 21.36; range = 18-31, 22 right-handed) gave their informed consent to participate in this study, approved by the local ethics committee. All had normal or corrected-to-normal vision and reported normal touch.

Stimuli Preparation

In a session prior to the experiment, videos of each participant’s face and of six female models - who were unfamiliar to the participants and were used as stimuli in this experiment - were prepared. Two sets of videos were recorded, one for the IMS session and one for the VRT session. For the IMS session, we recorded for each of the models a two-minute video depicting her face being touched on the cheek by a cotton bud (every 2 seconds). For the VRT session, we prepared six videos for each of the models, depicting the model’s face being touched or just approached, bilaterally or unilaterally by human fingers. Six similar videos depicting the participant’s face being touched or just approached bilaterally or unilaterally by human fingers were prepared for each participant.

Design

The design of the experiment was a 2x2x2x2 Factorial design. The first factor was the identity of the person that participants saw during the VRT session, i.e. self-face or other-face. The second factor was the fingers’ trajectory, i.e. touching or no-touching the seen face. The third factor was the timing of the VRT, i.e. before or after Interpersonal Multisensory Stimulation (IMS). The fourth factor was the type of IMS, i.e. synchronous or asynchronous visuo-tactile stimulation between the face of the model and the face of the participant. To independently assess whether participants experienced the enfacement illusion, we included a questionnaire session that followed after two additional blocks, one of synchronous IMS and one of asynchronous IMS. Previously, subjective reports on the experience of the enfacement illusion have provided evidence of changes in the perceived physical similarity between the two faces (Tajadura-Jiménez et al., 2012). The statements in the questionnaire were adapted from previous studies on the effects of IMS on the experience of self-identification across several dimensions, such as identification with and ownership of the other’s face, mirror-like exposure, feelings of control over the other’s face and affect towards the other’s person (Paladino et al., 2010; Sforza et al., 2010; Tajadura-Jiménez et al., 2012).

Each of these two questionnaire blocks was performed one after each of the post-IMS VRT sessions. Therefore after the completion of each post-IMS VRT sessions, participants were exposed to one block of either synchronous or asynchronous IMS and were then asked to rate their level of agreement with a set of ten statements related to their subjective experience during IMS (Figure 1). In order to avoid any familiarity effect with the shown face, we used a different model face for each block of IMS stimulation.

------------- PLEASE INSERT Figure 1 ABOUT HERE-------------

Procedure

Each subject performed two experimental sessions. Each session consisted of a pre-stimulation VRT block, an IMS block, a post-stimulation VRT block, followed by another IMS block and the administering of the questionnaire. The difference between the two experimental sessions was the type of IMS, being either synchronous or asynchronous visuo-tactile stimulation, run in counter-balanced between subjects order.

First, participants performed a VRT block to establish a baseline measure of how much their tactile sensation was affected by viewing touch on their own face or on another person’s face (pre-stimulation VRT). Tactile stimuli were delivered by two constant current electrical stimulators (DS7A, Digitimer), via two couples of surface electrodes placed on the participants’ cheeks. The sides of the strong/weak stimuli were counterbalanced across participants. Through a staircase procedure the tactile stimulus on one cheek was set to be more intense (threshold detection rate of ≈100%)

than that on the other cheek (≈60%). The staircase procedure was as follows: for the weak stimulus, participants were asked to report the presence or absence of the electrical stimulus delivered to the cheek by verbal ‘yes’ or ‘no’ responses. Shock intensity began at 0 mA increasing in steps of 10 mA until the participant reported the presence of the stimulus. If the participant responded ‘yes’ three times consecutively, the shock intensity was reduced by 5 mA. If they responded ‘no’, intensity was increased. Progressively smaller changes were made until the participant was able to detect between 55% and 60% of shocks delivered to the cheek. For the strong stimulus, the same procedure was followed. Once the perceptual threshold was found, the intensity for the strong stimulus was set to be 1.4 times stronger than the threshold in order to allow the participants to feel a clear, but not painful stimulation. During the pre-stimulation VRT block, participants were asked to watch pre-recorded videos on a monitor placed in front of them. The videos depicted a face in the middle of the screen that was, in different trials, the participant’s face or another person’s face (i.e. Model 1). The videos showed one or two fingers moving towards the image of the face and then backwards to their starting position. In different trials the fingers touched the cheeks of the shown face (Touch), or stopped about 5 cm beside it (No-Touch) (Figure 1). Both Touch and No-Touch videos had the same duration because in the no-touch condition, as in the touch condition, the distance that the fingers had to travel was identical. Visual stimuli approaching or touching the observed face and tactile stimuli delivered to the participant’s face were simultaneous so that when the fingers reached the end point (i.e. the observed face in Touch videos or the area beside the observed face in No-touch videos) a unilateral or bilateral tactile stimulation was delivered to the participant’s face. Participants were asked to indicate by unspeeded key-presses the side on their face in which they felt the tactile stimulation (left, right or bilateral), regardless of the visual stimulation. A PC running NI LabVIEW 2011 software was used to present the stimuli and record responses.

Stimuli comprised a combination of the two different faces (Self and Other), two types of tactile stimulation (Unilateral and Bilateral), two types of visual stimulation (Unilateral and Bilateral), and two fingers’ trajectories (Touch and No-Touch). To maximize the number of critical trials and ensure the unpredictable nature of the task, stimuli were presented with different frequencies and only some of these combinations were used as experimental trials, whereas the other ones were used as catch trials. In particular, the combinations of the two images being touched bilaterally while participants received a bilateral tactile stimulation were repeated 10 times each; the combinations of the two images being just approached bilaterally while participants received a bilateral tactile stimulation were repeated 8 times each; all the other combinations using either unilateral visual, unilateral tactile or unilateral visual and tactile stimulation were used as catch trials, thus repeated only 2 times each. A total of 100 trials per session were presented randomly ordered. Each block lasted approximately 5 minutes (Figure 1A).

Next, participants were exposed to the IMS block, lasting 2 minutes. Participants were touched by a cotton bud on the cheek every 2 seconds while watching a pre-recorded video showing a face of a model (i.e. Model 2, that was different from that shown in the pre-stimulation block) being touched with a cotton bud on a specularly congruent location, either in synchrony or asynchrony with respect to the touch delivered on the participants’ face (Figure 1B).

Next, a new VRT block was run (post-stimulation VRT). Now the “other’s face” was the face seen during the previous IMS block (i.e. Model 2, see Figure 1C).

Finally, to assess independently whether IMS results in changes in the mental representation of the self-face, we quantified these changes with a structured questionnaire. After each post-stimulation VRT block, participants underwent a further two-minute IMS with a different face (i.e. Model 3), changing the synchrony (either synchronous or asynchronous) of the visuo-tactile stimulation used in the previous IMS block. Participants were asked to rate their agreement on statements (see Table 1) presented in a random order, using a Visual Analogue Scale (Figure 1D).

In the second experimental session, this combination of VRT/IMS/VRT/IMS + questionnaire was repeated using different faces (i.e. Model 4 for the pre-stimulation-VRT, Model 5 for the IMS and for the post-stimulation-VRT, and Model 6 for the IMS/questionnaire block) and changing the synchrony of the visuo-tactile stimulations during the IMS.

At the beginning of each VRT block, detection thresholds were recalibrated in order to keep the threshold detection rate for the stronger tactile stimulus at ≈100% and for the weaker one at ≈60%. During the IMS session, the stroking to the participant’s face was always delivered on the cheek where the stronger tactile stimulus was delivered during the VRT blocks.

Overall, a different face was used in each VRT block and the assignment of each face to the different experimental block was counterbalanced across participants. We decided to use a different face in each VRT block in order to avoid any familiarity effect across the blocks. The familiarity effect on VRT has not hitherto been investigated, since in previous VRT studies the “other’s face” was unfamiliar to the participant (Cardini, Bertini, Serino, & Ladavas, 2012; Cardini et al., 2011; Serino et al., 2008). Finally, to avoid any confounds due to aesthetical, perceptual or idiosyncratic features of the six models, the faces shown in the two experimental sessions were counterbalanced between participants for the synchronous and asynchronous experimental sessions.

Results

To study the effect of IMS on VRT, we compared participants’ tactile accuracy during bilateral tactile stimulation delivered on their face while viewing self and other faces being touched or just approached by two fingers, before and after IMS. The remaining conditions with unilateral visual and tactile stimulations were used as catch trials and hence not included in statistical analysis (as in Cardini et al., 2012; Cardini et al., 2011). A 2x2x2x2 ANOVA was conducted on the percentage of correct responses with the within-subjects factors of Face (Self vs. Other), Fingers’ Trajectory (Touch vs. No-Touch), Stimulation (Synchronous vs. Asynchronous IMS) and Time (Pre- vs. Post-stimulation). The Face x Fingers’ Trajectory x Stimulation x Time was significant [$F_{(1,24)} = 6.91$, $p < 0.05$]. To further investigate the source of this four-way interaction, we first split the analysis in two separate ANOVAs for Touch and No-Touch conditions with the within subjects factors of Face (Self vs. Other), Stimulation (Synchronous vs. Asynchronous IMS) and Time (Pre- vs. Post-stimulation). No differences across conditions were observed in the No-Touch condition, since neither main effects nor interactions were significant (all $p > 0.08$; see Figure 2). Conversely, in the Touch condition, the main effect of Face [$F_{(1,24)} = 19.17$, $p < 0.01$] and the interaction Face x Stimulation x Time [$F_{(1,24)} = 4.83$, $p < 0.05$] were significant (see Figure 3).

-------------- PLEASE INSERT Figure 2 ABOUT HERE-------------

Then, we used Holm-Bonferroni corrected *t-tests* comparisons to study single effects in the Touch condition. We used the Holm-Bonferroni because it is less susceptible to false negatives and therefore more powerful to detect true differences than the Bonferroni method (Holm, 1979). The three-way interaction was driven by the fact that accuracy was higher when viewing the self-face (M = 82%, s.e.m. = 3%) as opposed to the other face (M = 70%, s.e.m. = 3%) before synchronous IMS [$t_{(24)} = 3.26$, $p < 0.01$], before asynchronous IMS (Self, M = 78%, s.e.m. = 4%; Other, M = 70%, s.e.m. = 4%), [$t_{(24)} = 2.46$, $p < 0.05$] and after asynchronous IMS (Self, M = 80%, s.e.m. = 3%; Other, M = 68%, s.e.m. = 4%), [$t_{(24)} = 3.57$, $p < 0.005$], while only after synchronous IMS, the difference in accuracy between viewing the self-face (Self, M = 80%, s.e.m. = 4%) as compared to the other face (Other, M = 82%, s.e.m. = 3%) was not significant [$t_{(24)} = -0.59$, $p = 0.56$]. This pattern of results shows that synchronous IMS successfully abolished the self-specific preference in the VRT. In order to demonstrate that this effect was due to a change in VRT when viewing the other face following synchronous IMS, we compared accuracy when observing the other face in the synchronous post-IMS condition (Other, M = 82%, s.e.m. = 3%), with the accuracy when observing the other face in the synchronous pre-IMS (M = 70%, s.e.m. = 3%), [$t_{(24)} = -2.80$, $p < 0.05$] and in the asynchronous post-IMS (M = 68%, s.e.m. = 4%), [$t_{(24)} = 2.93$, $p < 0.01$].

An interesting question arising from these results is whether the present effect is specifically related to the face seen during the stimulation or if it is a generic effect observed also for faces other than the one that participants saw during the visuo-tactile stimulation. In order to answer this question, we first split our sample depending on the order of their experimental sessions. Twelve participants received the Synchronous IMS in the last block of the first session. Thirteen participants received the Asynchronous IMS. If the Synchronous IMS had a generic effect, we would expect that participants who received the Synchronous IMS in the last block of the first session (see Fig. 1D) show an enhancement of tactile perception when viewing another face in the following pre-stimulation-VRT block of the second session, thus showing a "Self-like VRT effect". On the contrary, if the present results are driven by a face-specific effect of the IMS, we should expect no VRT enhancement for the other face in the pre-stimulation-VRT block in the second session (and concurrent enhancement in the post- stimulation-VRT block).

Accordingly, we compared participants' tactile accuracy during bilateral tactile stimulation while viewing self and other faces being touched in the pre-stimulation VRT block of the second session using a mixed-ANOVA with Order (Synchronous first, Asynchronous first) as between subject factor and Image (Self face, Other face) as within subjects factor. As expected, the main effect of Image was significant [$F_{(1,23)} = 17.27$, $p < 0.01$] with an overall higher accuracy when viewing self-face (M=81%) compared to the other face (M=68%). Importantly, no significant interaction of Image x Order was found [$F_{(1,23)} = 0.28$, $p = 0.87$]. These results support the hypothesis that sharing a multisensory experience with another person (through the Synchronous IMS) does not generically enhance tactile perception when viewing touch towards any other face. Instead, synchronous IMS exerts a face-specific enfacement effect for tactile stimuli viewed on the face that has been incorporated into the mental representation of one's own face.

We replicated the main VRT findings (Serino et al., 2008), showing an enhancement of tactile perception when viewing one's face compared to another person's face in the Touch condition, whereas no modulation was observed in the No-Touch condition. Second and more importantly, the significant differences observed in the Touch condition demonstrate that synchronous IMS specifically enhanced somatosensory remapping of observed tactile stimuli delivered on someone else’s face, and abolished the self-specific effect of VRT (see Figure 3). Finally, the extension of the VRT to a face other than the self-face was specific to the face that participants saw during the IMS session and was not generalized to other faces. These results support the hypothesis that IMS facilitates embodiment of the other into one’s own body representation, thus enhancing the other-related VRT effect.

------------- PLEASE INSERT Figure 3 ABOUT HERE-------------

Although the present experimental design is not optimum for signal detection theory analysis - given the few unilateral trials we used - we tried to investigate whether the observed effects when perceiving bilateral touch were related to changes in sensitivity or in response criterion.

We, therefore, calculated *d’* and C scores, by considering as a hit a “bilateral” response to bilateral stimulation, as an omission a unilateral (left or right) response to a bilateral stimulation, as a correct rejection a left response to a left stimulation or a right response to a right stimulation, and as a false alarm a bilateral response to unilateral (left or right) stimulation. Two separate ANOVAs, one for *d’* and one for C scores, on VRT indices obtained in the Touch trials, with factors Face (Self, Other), Stimulation (Synchronous, Asynchronous) and Time (Pre, Post IMS) were performed.

For *d’*, we did not find any significant main effects or interactions, suggesting no changes in sensitivity.

As far as C scores are concerned, we found a significant three-way interaction [$F_{(1,24)} = 4.18$, $p = 0.052$].

Planned comparisons show that before synchronous IMS, C-scores were lower when viewing the self-face (M = 0.14, s.e.m. = 0.06) as opposed to the other face (M = 0.28, s.e.m. = 0.07) [$t_{(24)} = 1.77$, $p = 0.044$, 1-tailed], but this difference vanished after synchronous IMS (Self, M = 0.17 , s.e.m. = 0.06; Other, M = .15, s.e.m. = 0.07), [$t_{(24)} = -0.41$, $p > 0.6$]. Given that lower C scores indicate more frequent ‘hits’ and ‘hits’ in our case refer to bilateral responses to double stimuli, the results suggest that participants were more confident in feeling double stimulation when looking the other’s face after than before synchronous IMS stimulation. Although our experimental design was not optimized to run analyses in terms of signal detection theory, the present analyses suggest that the enfacement effect induced by IMS made subjects to rely more on tactile stimulation seeing on the face they have embodied when making perceptual judgements for stimuli on their own face.

Finally, to confirm that our IMS manipulation was effective, we compared the answers to each of the statements of the questionnaire for the synchronous and asynchronous conditions. First, we tested whether the distributions of the obtained data were normal using the Shaphiro-Wilk test. Some of the factors did not pass the normality test, therefore we used non-parametrical statistical tests to analyze the data (Wilcoxon Signed Ranks Test). Planned paired comparisons assessed the differences in the answers to each of the statements for the synchronous and asynchronous conditions (alpha level at 0.05, 2-tailed, unless otherwise specified). Synchronous visuo-tactile stimulation produced changes in self-face representation across different dimensions (Table 1), such as identification with and ownership of the other’s face (Q1: $z = -2.83$; $p = 0.005$; Q2: $z = -2.45$; $p = 0.014$; Q3: $z = -3.32$; $p = 0.001$), changes in the perceived physical similarity between own and other face (Q5: $z = -1.81$; $p = 0.035$ 1-tailed) and changes in the feelings of being imitating the other person (Q10: z

= -2.29; *p* = 0.022). Overall, synchronous IMS consistently produced significant changes in the way participants experienced the other face, indicating that viewing touch on the face of the other and feeling touch on one’s own face in the synchronous condition felt closer to the experience of looking at one’s face in a mirror and evoked changes in the perceived physical similarity between the two faces and in the feelings of being imitating the other person, as compared to the asynchronous condition.

-------------- PLEASE INSERT Table 1 ABOUT HERE-------------

Discussion

Recent studies have shown that shared multisensory experiences between self and other can influence the mental representation of one’s face as well as conceptual and social dimensions of self-other relations. These shared multisensory experiences may make people assimilate features of the other person’s face into the mental representation of their own face (Sforza et al., 2010; Tsakiris, 2008) and feel closer to the other person (Paladino et al., 2010). In the present study we demonstrated that when the boundaries between self and other are altered by synchronous shared sensory experiences, the multisensory interaction between somatosensory stimuli felt on one’s body and seen on the body of others is enhanced.

The VRT mechanism, that reflects the ability to remap a sensation seen on the body of other onto one’s own sensory system, seems important for social interactions. In order to understand other peoples’ feelings, observers might implicitly register the observed experiences against the representations used to perceive one’s body, re-experiencing the observed states through their own somatosensory system (Gallese et al., 2004; Keysers & Gazzola, 2009). This mechanism implies both remapping from one sensory modality to another (from vision to touch), as well as from one reference frame to another reference frame (the other’s and one’s own body). It has been shown that remapping of a sensation from vision to touch is more direct when the two modalities share a common reference system, i.e. the same physical (Cardini et al., 2011) or experienced (Ehrsson et al., 2005; Ehrsson, Spence, & Passingham, 2004) body, whereas the remapping requires a bigger effort when the seen touch is directed towards another body. Importantly, the more similar the other is perceived to the self, the stronger this mapping is (Serino et al., 2009; Serino et al., 2008). Those previous studies focused on *existing* similarities or differences between self and other (e.g. self versus other face, ingroup versus outgroup). Here, we first confirm that shared synchronous multisensory inputs are able to increase perceived physical similarity between self and other (Sforza et al., 2010; Tajadura-Jiménez et al., 2012; Tsakiris, 2008). Second, we show that experimentally *changing* the perceived physical similarity between self and other enhances processing of the observed touches to the other’s body within one’s somatosensory system.

Other studies have looked at how perceptual, conceptual and sensorimotor systems process bodies that are either similar or dissimilar to one’s own. For example, there have been reported consistent differences in the neural processing of one’s own face as compared to the face of another person in parietal (inferior parietal lobe) and frontal (inferior frontal gyrus) areas (Uddin, Iacoboni, Lange, & Keenan, 2007; Uddin, Kaplan, Molnar-Szakacs, & Iacoboni, 2005). Furthermore, functionally discrete subregions of medio-prefrontal cortex are differently activated when viewing faces of other individuals, depending on how similar their sociopolitical views are to one’s own (Jenkins, Macrae, & Mitchell, 2008; Mitchell, Macrae, & Banaji, 2006). Interestingly, similar differences have been observed not simply in the domain of face processing, but also in the domain of action observation and empathy, suggesting that self-other distinctions are also grounded within the sensorimotor system (de Vignemont & Haggard, 2008). For example, visually evoked activity within the motor cortex varies depending on whether participants observe actions attributed to the self or to another person (Schütz-Bosbach, Mancini, Aglioti, & Haggard, 2006) or gestures performed by an actor from one’s own or another ethnic group (Desy & Theoret, 2007; Molnar-Szakacs, Wu, Robles, & Iacoboni, 2007). Empathic, sensorimotor resonance evoked by viewing pain on the body of others is modulated as a function of whether the other does or does not belong to one’s own ethnic group (Avenanti et al., 2010). In the context of the VRT effect observing a face belonging to one’s own ethnic or political group being touched enhances detection of near-threshold tactile stimuli on the observer's face (Serino et al., 2009). Taken together these findings show that the self-other distinction is represented at several levels of information processing and that the perceived differences between self and others can indeed affect the degree of resonance induced within the sensorimotor system when observing others’ actions, sensations and emotions. The new insight provided by recent studies using multisensory integration to investigate the malleability of self-representations (Tsakiris, 2010) is that self-other distinctions are not fixed, but can be altered by experience, both at level of perceived physical (Longo, Cardozo, & Haggard, 2008) and of psychological (Paladino et al., 2010) distinction. Results from the present study provide direct evidence that sharing multisensory experience with others can alter self-representations across the self-other boundaries, thus enhancing the mechanism of remapping tactile stimuli seen on the body of others onto one’s somatosensory system.

In light of these results and based on previous literature, a possible neural mechanism underlying the IMS modulation of self-related VRT enhancement might be suggested. During the two-minutes of synchronous stroking, one might come to bind the observed touch – i.e. the touch seen on the other’s face - and the felt touch – i.e. the touch delivered on one’s own face - in an illusory fashion, through a Rubber Hand Illusion-style process (Botvinick & Cohen, 1998). In the RHI, synchronous visuo-tactile stimulation between a rubber hand and one’s own unseen hand generates the feeling that the rubber hand is part of one’s body. This phenomenon results from a touch referral mechanism, whereby after visuo-tactile recalibration, the seen touch comes to be associated to the felt touch, leading to a sense of ownership of the fake hand (Ehrsson et al., 2004; Makin, Holmes, & Ehrsson, 2008; Tsakiris, Carpenter, James, & Fotopoulou, 2010). Similarly, in the present study, multisensory correlated inputs during IMS - i.e. felt touch on one’s face and seen touch on someone else’s face - might be linked, generating a sense of identification with the seen face (Paladino et al., 2010; Sforza et al., 2010; Tsakiris, 2008). For this reason, the VRT effect, which is normally higher for viewing touch on the self face can be extended to the observed face. Cardini et al. (2011) have shown that viewing touch on one’s own face while feeling touch more easily recruits multisensory pre-motor areas than viewing touch on the face of others. Such pattern of activity spreads to somatosensory cortices so that tactile perception is more influenced by visual information, when the latter concerns one’s own face. We propose that a similar modulation of multisensory and somatosensory activity might generalize to visual information related to the face of the other, because synchronous IMS enhances the perceived physical similarity between self and other. Conversely, asynchronous IMS does not affect self-other distinction, and therefore, tactile information seen on the face of the other is less effectively integrated with tactile information felt on one's own face. As a consequence, tactile perception more strongly relies on unisensory tactile signals than on visual information.

In conclusion, sharing multisensory experiences with someone else might engage the same neural structures that usually represent the sentient self, resulting in these structures processing also information related to the other person. This effect might boost the ability to map to one's body the observed experiences on the others' bodies, a mechanism which is considered important for empathetic responses and for the understanding of other people's feelings and emotions (Keysers & Gazzola, 2009; Paladino et al., 2010; Singer et al., 2004). The present study offers a direct demonstration of the interaction between self-other representations and integration of multisensory information between one's own body and the body of others, thus providing insight into the multisensory basis of social cognition and the plasticity of self-other representations.

Acknowledgments

ESRC First Grant RES-061-25-0233, European Platform for Life Sciences to MT, European Research Council (ERC-2010-StG-262853) to MT and by a Volkswagen Stiftung grant (the UnBoundBody project, 85 639) to AS and AT-J.

References

Avenanti, A., Sirigu, A., & Aglioti, S. M. (2010). Racial bias reduces empathic sensorimotor resonance with other-race pain. *Current Biology, 20*(11), 1018-1022.

Blakemore, S. J., Bristow, D., Bird, G., Frith, C., & Ward, J. (2005). Somatosensory activations during the observation of touch and a case of vision-touch synaesthesia. *Brain, 128*(Pt7), 1571-1583.

Blanke, O., & Metzinger, T. (2009). Full-body illusions and minimal phenomenal selfhood. *Trends in Cognitive Sciences, 13*(1), 7-13.

Botvinick, M., & Cohen, J. (1998). Rubber hands 'feel' touch that eyes see. *Nature, 391*, 756.

Cardini, F., Bertini, C., Serino, A., & Ladavas, E. (2012). Emotional Modulation of Visual Remapping of Touch. *Emotion*.

Cardini, F., Costantini, M., Galati, G., Romani, G. L., Ladavas, E., & Serino, A. (2011). Viewing one's own face being touched modulates tactile perception: an fMRI study. *Journal of Cognitive Neuroscience, 23*(3), 503-513.

D'Argembeau, A., Ruby, P., Collette, F., Degueldre, C., Balteau, E., Luxen, A., Maquet, P., & Salmon, E. (2007). Distinct regions of the medial prefrontal cortex are associated with self-referential processing and perspective taking. *Journal of Cognitive Neuroscience, 19*(6), 935-944.

de Vignemont, F., & Haggard, P. (2008). Action observation and execution: what is shared? *Social Neuroscience, 3*(3-4), 421-433.

de Vignemont, F., & Singer, T. (2006). The empathic brain: how, when and why? *Trends in Cognitive Sciences, 10*(10), 435-441.

Desy, M. C., & Theoret, H. (2007). Modulation of motor cortex excitability by physical similarity with an observed hand action. *PLoS ONE, 2*(10), e971.

Ebisch, S. J., Perrucci, M. G., Ferretti, A., Del Gratta, C., Romani, G. L., & Gallese, V. (2008). The sense of touch: embodied stimulation in a visuotactile mirroring mechanism for observed animate or inanimate touch. *Journal of Cognitive Neuroscience, 20*(9), 1611-1623.

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. *The Journal of Neuroscience, 25*(45), 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.

Gallese, V., Keysers, C., & Rizzolatti, G. (2004). A unifying view of the basis of social cognition. *Trends in Cognitive Sciences, 8*(9), 396-403.

Holm, S. (1979). A simple sequentially rejective multiple test procedure. *Scandinavian Journal of Statistics, 6*(2), 65-70.

Hove, M. J., & Risen, J. L. (2009). It's all in the timing: interpersonal synchrony increases affiliation. *Social Cognition, 27*(6), 949-961.

Jenkins, A. C., Macrae, C. N., & Mitchell, J. P. (2008). Repetition suppression of ventromedial prefrontal activity during judgments of self and others. *Proceedings of the National Academy of Sciences of the United States of America, 105*(11), 4507-4512.

Keysers, C., & Gazzola, V. (2009). Expanding the mirror: vicarious activity for actions, emotions, and sensations. *Current Opinion in Neurobiology, 19*(6), 666-671.

Keysers, C., Wicker, B., Gazzola, V., Anton, J. L., Fogassi, L., & Gallese, V. (2004). A touching sight: SII/PV activation during the observation and experience of touch. *Neuron, 42*(2), 335-346.

Ladavas, E., & Serino, A. (2010). How the Sense of Body Influences the Sense of Touch. In P. A. Reuter-Lorenz & K. Baynes & G. R. Mangun & E. A. Phelps (Eds.), *The Cognitive Neuroscience of Mind: A Tribute to Michael S. Gazzaniga*. Cambridge, MA (USA): MIT Press.

Longo, M. R., Cardozo, S., & Haggard, P. (2008). Visual enhancement of touch and the bodily self. *Consciousness and Cognition, 17*(4), 1181-1191.

Makin, T. R., Holmes, N. P., & Ehrsson, H. H. (2008). On the other hand: dummy hands and peripersonal space. *Behavioural Brain Research, 191*(1), 1-10.

Mazzurega, M., Pavani, F., Paladino, M. P., & Schubert, T. W. (2011). Self-other bodily merging in the context of synchronous but arbitrary-related multisensory inputs. *Experimental Brain Research, 213*(2-3), 213-221.

Meltzoff, A. N. (2007). 'Like me': a foundation for social cognition. *Developmental Science, 10*(1), 126-134.

Mitchell, J. P., Macrae, N. C., & Banaji, M. R. (2006). Dissociable medial prefrontal contributions to judgments of similar and dissimilar others. *Neuron, 50*(4), 655-663.

Molnar-Szakacs, I., Wu, A. D., Robles, F. J., & Iacoboni, M. (2007). Do you see what I mean? Corticospinal excitability during observation of culture-specific gestures. *PLoS ONE, 2*(7), e626.

Paladino, M. P., Mazzurega, M., Pavani, F., & Schubert, T. W. (2010). Synchronous multisensory stimulation blurs self-other boundaries. *Psychological Science, 21*(9), 1202-1207.

Petkova, V. I., & Ehrsson, H. H. (2008). If I were you: perceptual illusion of body swapping. *PLoS ONE, 3*(12), e3832.

Schütz-Bosbach, S., Mancini, B., Aglioti, S. M., & Haggard, P. (2006). Self and other in the human motor system. *Current Biology, 16*, 1830-1834.

Sebanz, N., Bekkering, H., & Knoblich, G. (2006). Joint action: bodies and minds moving together. *Trends in Cognitive Sciences, 10*(2), 70-76.

Serino, A., Giovagnoli, G., & Ladavas, E. (2009). I feel what you feel if you are similar to me. *PLoS ONE, 4*(3), e4930.

Serino, A., Pizzoferrato, F., & Ladavas, E. (2008). Viewing a face (especially one's own face) being touched enhances tactile perception on the face. *Psychological Science, 19*(5), 434-438.

Sforza, A., Bufalari, I., Haggard, P., & Aglioti, S. M. (2010). My face in yours: Visuo-tactile facial stimulation influences sense of identity. *Social Neuroscience, 5*(2), 148-162.

Singer, T., Seymour, B., O'Doherty, J., Kaube, H., Dolan, R. J., & Frith, C. D. (2004). Empathy for pain involves the affective but not sensory components of pain. *Science, 303*, 1157-1162.

Tajadura-Jiménez, A., Grehl, S., & Tsakiris, M. (2012). The other in me: Interpersonal multisensory stimulation changes the mental representation of the self. *PLoS ONE*.

Tsakiris, M. (2008). Looking for myself: current multisensory input alters self-face recognition. *PLoS ONE, 3*(12), e4040.

Tsakiris, M. (2010). My body in the brain: a neurocognitive model of body-ownership. *Neuropsychologia, 48*(3), 703-712.

Tsakiris, M., Carpenter, L., James, D., & Fotopoulou, A. (2010). Hands only illusion: multisensory integration elicits sense of ownership for body parts but not for non-corporeal objects. *Experimental Brain Research, 204*(3), 343-352.

Uddin, L. Q., Iacoboni, M., Lange, C., & Keenan, P. (2007). The self and social cognition: the role of cortical midline structures and mirror neuron. *Trends in Cognitive Sciences, 11*(4), 153-157.

Uddin, L. Q., Kaplan, J. T., Molnar-Szakacs, I., & Iacoboni, M. (2005). Self-face recognition activates a fronto-parietal "mirror" network in the right hemisphere: an event-related fMRI study. *Neuroimage, 25*, 926-935.

Wiltermuth, S. S., & Heath, C. (2009). Synchrony and cooperation. *Psychological Science, 20*, 1-5.

Xu, X., Zuo, X., Wang, X., & Han, S. (2009). Do you feel my pain? Racial group membership mdulates empathic neural responses. *The Journal of Neuroscience, 29*(26), 8525-8529.

Table captions

Table 1. Scores for each of the 10 statements presented after both the synchronous and asynchronous Interpersonal Multisensory Stimulation (IMS). Participants had to agree or disagree with each of the statements using a Visual Analogue Scale (from -3, strongly disagree to +3, strongly agree). Wilcoxon Signed Ranks Test compared the answers to each of the statements after the synchronous and asynchronous IMS.

*1-tailed

Statements	**synchronous**	**asynchronous**	***p***
"I felt like the other's face was my face"	-0.184	-1.560	.005
"It seemed like the other's face belonged to me"	-0.504	-1.536	.014
"It seemed like I was looking at my own mirror reflection"	-0.544	-1.632	.001
"It seemed like the other's face began to resemble my own face"	-0.232	-0.904	.161
"It seemed like my own face began to resemble the other person's face"	-0.280	-1.272	.035*
"It seemed like my own face was out of my control"	-0.016	-0.592	.195
"It seemed like the experience of my face was less vivid than normal"	0.120	-0.288	.230
"It seemed like the person in the video was attractive"	0.424	0.368	.827
"It seemed like the person in the video was trustworthy"	0.272	0.112	.531
"I felt that I was imitating the other person"	0.440	-0.624	.022

Figures

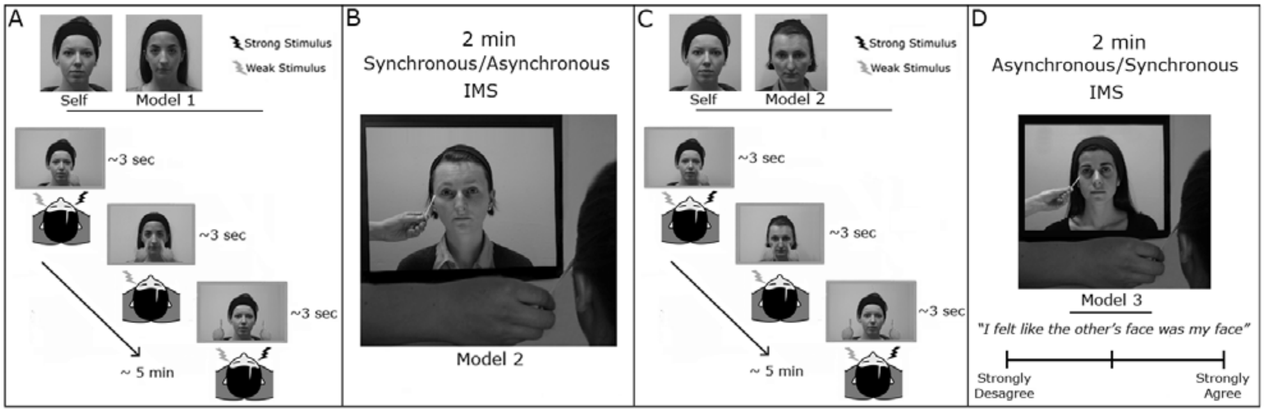

Figure 1. The experimental design comprised two experimental sessions, each comprising four consecutive blocks: *(a)* VRT measurement before IMS. Participants received either a unilateral or a bilateral tactile stimulation on their cheeks. Concurrently they were required to watch a video depicting either their own face or someone else’s face being touched, or just approached, unilaterally or bilaterally, by human fingers. Participants were asked to respond to the side of tactile stimulation, regardless of visual stimulation.

(b) Interpersonal Multisensory Stimulation. For two minutes, participants were touched by a cotton bud on the cheek every 2 seconds while watching a video showing an unknown face being touched with a cotton bud on a specularly congruent location in synchrony (in one session) or asynchrony (in the other session) with respect to the touch delivered on the participants’ face.

(c) VRT measurement after IMS. This session was similar to the one before IMS, but now the “other’s face” was the face seen during the IMS.

(d) A further two-minute IMS was delivered showing a different face and changing the synchrony (either synchronous or asynchronous) of the visuo-tactile stimulation used in the previous IMS block. Finally participants were asked to answer ten questions about their experience during IMS, using a Visual Analogue Scale.

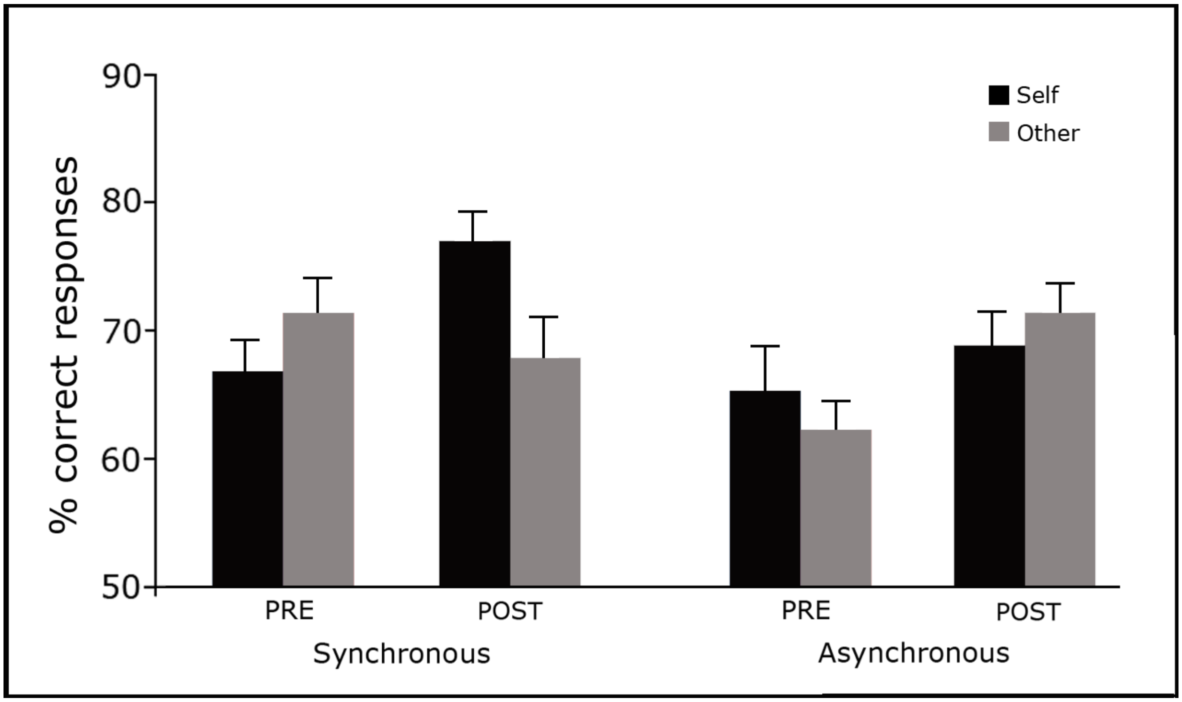

Figure 2. Results obtained for the No-Touch condition both before and after either synchronous or asynchronous IMS. Accuracy in detecting bilateral tactile stimulation while viewing videos showing either one’s face or the other’s face being approached but not touched by two human fingers. Error bars show standard error of the means across participants. Neither main effects nor interactions are significant.

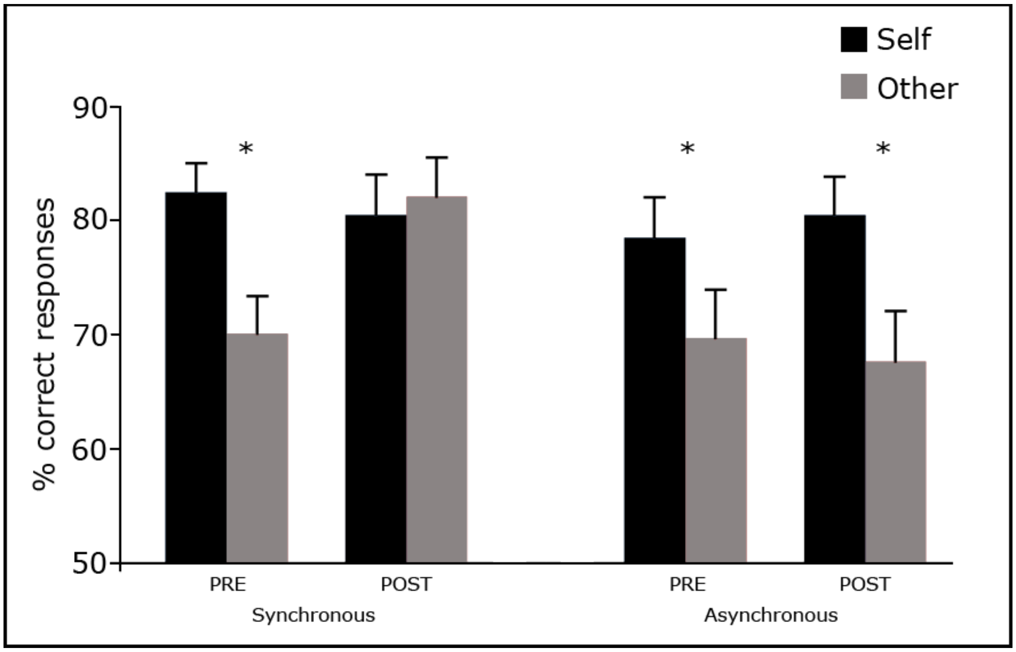

Figure 3. Results obtained for the Touch condition both before and after either synchronous or asynchronous IMS. Accuracy in detecting bilateral tactile stimulation while viewing videos showing either one’s face or the other’s face being touched by two human fingers. Error bars show standard error of the means across participants.