RETI SAPERI LINGUAGGI

The bodily self

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1. Minimal Self and Bodily Self: Looking for the Minimalist Experience of One's Own Body.

"Self" is a complex, multileveled and multifaceted notion. From a phenomenological perspective (Parnas 2000; 2003) three levels of selfhood have been identified. First, there is the implicit awareness that this is 'my' experience. Such pre-reflective level of selfhood is sometimes referred to as the 'basic' or 'minimal' self or as 'ipseity'. Second, there is the more explicit awareness of self as an invariant subject of experience and action. Such reflective level of self-awareness presupposes the 'minimal' self. Finally, there is the social or narrative self, which refers to personality, habits, style and other characteristics of an individual.

The concept of minimal, pre-reflective, or "core self" (Rochat 2004) is currently under debate in cognitive science, developmental psychology and philosophy of mind. However, it is not clear which empirical features such a self is presumed to possess and which kind of experience concurs in shaping this implicit sense of being oneself. In particular, in the ongoing debate about the definition of the notion of self, as the minimalist level of subjective experience, one of the central issues is the contribution of bodily experience to its constitution. For instance, some aspects of the minimal self proposed by contemporary philosophical and empirical research are: the notion of perspective and first-person perspective, the 'mineness' of the phenomenal field, the question of transparency, embodiment of point of view, and the issues of agency and ownership (Cermolacce et al. 2007). What is important to note here is that, on the philosophical side, phenomenology emphasizes the necessity of embodiment of the self for all the above cited aspects of self experience. Furthermore, as argued by Cermolacce and colleagues (2007), in phenomenology "the field of experience is not yet considered to be *subjective* because this predicate already implies that there is a subject. For phenomenology, the very idea of the *subject* articulates itself in experience. In this sense, the manifestation and appearing of experience are the *conditions for* the experience of the subject in question". This philosophical standpoint should have important implications for the empirical studies, especially for those investigating the neural correlates of self-consciousness or self-representations. Rather than searching for the neural correlates of a pre-defined, explicit and reflective self-knowledge, the first aim of empirical research should be to investigate which kind of experience (and how) allows an implicit and pre-reflective self-knowledge to emerge. For example, reminding the importance of embodiment of the self for self-experience, an interesting question to be answered would be: "What is the basic experience of ourselves as bodily selves? What enables us to implicitly distinguish ourselves, as bodily selves, from other human bodies?" Contemporary research answers this question by focusing mostly on the notions of body ownership, sense of agency and first person perspective.

Body ownership refers to "the perceptual status of one's own body, which makes bodily sensations seem unique to oneself" (Tsakiris et al. 2007a). Different studies on Rubber Hand Illusion (RHI, Botvinick and Cohen 1998) suggested that multisensory integration is the crucial mechanism leading to the experience of our body as our own. The RHI consists in watching a rubber hand being stroked together with one's own unseen hand. If the stroking of the rubber and real hands occurs synchronously, the position sense of the real hand shifts towards the location of the dummy hand. Participants report that they feel the dummy hand to be part of their body. However, as it has been recently argued (see Gallese and Sinigaglia 2010; Gallese and Sinigaglia 2011), there is a lot of evidence showing that the multisensory integration leading to the experience of our body as our own, far from being the outcome of a mere visual–proprioceptive perceptual association (Costantini and Haggard 2007), is conditioned by the possibility – or not – to perform actions with a given body part (Tsakiris and Haggard 2005; Tsakiris et al. 2006; Tsakiris et al. 2007b).

Sense of agency refers to the sense of being the one who generates an action. We recognize ourselves as agents on the basis of the congruence between self-generated movements and their expected consequences. This dominant role of action over other possible cues for self-identification is accounted for by the hypothesis of the Central Monitoring Theory of action recognition. In its simplest form, this model holds that each time the motor centers generate an outflow signal for producing a movement, a copy of this command (the "efference copy", Von Holst and Mittelstedt 1950) is retained and then compared with the reafferent inflow signals generated by the movement (e.g., visual, kinesthetic). A predictive component of the model anticipating the sensory consequences of the movement, is such that, in the case of a self-produced movement, the actual sensory feedback will match the prediction. Otherwise, sensory signals will be referred to an external event (Jeannerod 2007).

However, as argued by Marc Jeannerod (2007), the Central Monitoring Theory "cannot explain the fact that sense of agency also arises in many situations where action representation is formed, but no movement is executed". Because circumstances where actions remain covert are frequent in our daily life, "the existence of an overt behaviour should not be a prerequisite for self-identification". Such circumstances occurs, for example, in the case of motor imagery (Jeannerod 1995) or motor simulation, which is a functional mechanism taking place during the observation of others' actions and having the mirror neuron system as its neural counterpart (Gallese 2000; Gallese 2006; Gallese 2009; Gallese and Sinigaglia 2011). Starting from the concept of shared representations (Georgieff and

Jeannerod 1998), Jeannerod (2007) proposed "the model of self/other differentiation as a rotate/simulate model: I first rotate myself at the location of the person I observe in order to specify her location in space. Then, I simulate the action I observe from that person in order to understand what she is doing."

Finally, first-person perspective may be referred to the phenomenological idea that the world *appears* as constrained by a mobile bodily self, that is, by the spatially located point of view, the orientation and the attitudes relative to the subject's sensorimotor background capacities (Cermolacce et al. 2007).

In sum, all the notions adopted by contemporary research to answer the question of how we distinguish ourselves, as bodily selves, from other human bodies refer to a crucial role of the motor system.

In the same vein, and more radically, it has been recently proposed (Gallese and Sinigaglia 2010; Gallese and Sinigaglia 2011) that there is a sense of body that is enactive in nature and that enables to capture the most primitive sense of self as bodily self. According to this perspective, "the body is primarily given to us as "source" or "power" for action, that is, as the variety of motor potentialities that define the horizon of how we can interact with the world we live in" (Gallese and Sinigaglia 2010). Such primitive sense of self as bodily self is conceived of as being antecedent the distinction between sense of agency and sense of ownership. Accordingly, Smith (2007) explained the concept of bodily self as follows: "The bodily self is a physical agent. Knowledge of oneself as bodily is fundamentally knowledge of oneself as agentive; such knowledge is grounded in both experience of oneself as instantiating a bodily structure that affords a limited range of actions, and experience of oneself as a physical agent that tries to perform a limited range of actions over time" (Smith 2007).

The existence of such motor experience-based representation of the bodily self has been empirically investigated in the behavioural study described below (section 3).

2. Bodily Self-Advantage Effect.

Neuropsychological and neuroimaging studies show that the body is a "unique" object. Indeed, specific brain structures are involved in the visual processing of the human body (Downing et al. 2001; Peelen and Downing 2007; Moro et al. 2008). Viewing non-facial body parts selectively activates a lateral occipito-temporal cortex (OTC), called extrastriate body area (EBA), and an area located in the fusiform gyrus, known as fusiform body area (FBA; Peelen and Downing 2005; Schwarzlose et al. 2005; Peelen and Downing 2007). Moreover, a topographically organized body part map has been described within the OTC, with distinct clusters of voxels showing clear preference for different visually presented body parts (Orlov et al. 2010). In line with this evidence, a hand-selective region has been recently revealed in the left lateral occipital sulcus, partially overlapping with EBA, which could be functionally and anatomically dissociated from it (Bracci et al. 2010).

Studies using different methods (behavioral, fMRI, TMS studies) have shown that the recognition of one's own body is independent from the recognition of other people's bodies. Recent evidence suggests that a specific neural network is dedicated to "self-body" recognition. This brain network seems to be, at least partially, distinct from that responsible for general body-related information processing (Sugiura et al. 2006; Myers and Sowden 2008; Hodzic et al. 2009). As argued by Myers and Sowden (2008), from our own body, we combine visual information with, at least, somatosensory, proprioceptive, and motor information, in order to guide our interpretation of sensory events and our actions upon the world. For others' bodies, we have mostly visual information available to us.

According to this remark, previous behavioural studies (Frassinetti et al. 2008; Frassinetti et al. 2009; Frassinetti et al. 2010) have demonstrated the human ability to implicitly recognize one's own body. When submitted to a visual matching task, participants showed the so-called *self-advantage effect*, that is, a better performance with one's own rather than others' body-parts (Frassinetti et al. 2008; Frassinetti et al. 2009; Frassinetti et al. 2010). Moreover, it has been shown that such self-advantage effect is stronger for dynamic than for static stimuli (Frassinetti et al. 2009). Indeed, participants performed better with dynamic than with static images depicting self than others' body-parts, even if the dynamic condition was more difficult than the static one. Although the mechanism supporting the bodily self-advantage effect has still to be clarified, this evidence holds for the hypothesis that bodily self recognition is based on a sensorimotor representation (for a review, see Tsakiris 2010).

In a first behavioural study from our group (Frassinetti et al. 2011), we specifically tested the hypotheses that the bodily self-advantage i) is the expression of an implicit, rather than explicit knowledge, and i) is a body-specific effect. We started from the assumption that such implicit bodily self-knowledge is based mainly on the sensorimotor representation of one's own body-effectors. Alternatively, the bodily self-advantage could rely on visual recognition of pictorial cues. According to the first hypothesis, the bodily self-advantage should emerge only when self-body recognition is implicitly required and should be specific for body-effectors and not for inanimate objects. In contrast, if the self-advantage is due to a mere visual-perceptual facilitation, it should be independent of the implicit or explicit request (and could be extended also to objects).

To disentangle these hypotheses, healthy participants were implicitly (visual matching task) or explicitly (self/other discrimination task) required to recognize either their own body-effectors or inanimate-objects. They showed the bodily self-advantage effect in the implicit task, but not in the explicit task. Such data gave support to our hypothesis that bodily self-advantage is the expression of an implicit, rather than explicit, knowledge. Moreover, the absence of both self/other and implicit/explicit effects, when processing inanimate-objects, underlined the differences between the body and other objects.

The idea of a dissociation between implicit and explicit self body processing is in agreement with the large amount of neuropsychological studies showing that brain damaged patients can be impaired in explicit while sparing implicit processing. Typical clinical conditions in which implicit and explicit processes are dissociated are, for example, neglect (Berti and Rizzolatti 1992; Berti et al. 1994) and the blindsight phenomenon (Tamietto et al. 2010). Regarding the bodily self, such dissociation is in agreement with the independence of implicit from explicit self-body processing reported by infancy research. Indeed, during development an implicit sense of self and the ability to discriminate self from others appears to emerge earlier than the ability to explicitly self-recognize (Rochat 2003; 2010).

3. Motor simulation and the bodily self: a behavioral study

The self-advantage effect I discussed in the previous section suggests that a critical distinction can be made between processing one's own body and processing the body of others (see also Sugiura et al. 2006; Devue et al. 2007).

The main aim of the behavioral study I am going to describe in details in this section was to shed light on the role of the sensorimotor experience of one's body for the implicit bodily self-advantage. To this purpose, participants in the study were required to perform two different tasks. In a first experiment (Experiment 1) they were submitted to a laterality judgment task with either self or others' hands as body stimuli. In a second experiment (Experiment 2) we employed the same stimuli as in Experiment 1, but asked participants to explicitly recognize their own hand. Finally, in a third control experiment (Experiment 3) we ruled out the possibility that the results of the first experiment were simply driven by any sort of familiarity of "priming" effects.

In the laterality judgment task (Experiments 1 and 3) participants were requested to report the laterality (left or right) of depicted body parts presented in different angular orientations. We adopted this task because it is well known that in order to perform it participants simulate a motor rotation of *their own body parts* so as to match that of the *observed stimulus* (Parsons 1994; Ionta et al. 2007). Mental motor rotation of body parts shares the same temporal and kinematic properties with actual body rotation in space (Decety et al. 1991; Decety et al. 1994; Parsons 1994; Porro et al. 1996; Parsons et al. 1998; Jeannerod 2004). This idea is further corroborated by evidence showing that longer mental rotation times are needed for stimuli orientations corresponding to body part positions difficult to be maintained (Parsons 1994; Thayer et al. 2001; Petit et al. 2003). Since previous studies (Cooper and Shepard 1975; Parsons 1987) suggest that the left-right judgment of body parts relies upon the visuo-motor representation of one's own body, we hypothesized that the laterality judgment in Experiments 1 and 3 should be easier when the displayed stimulus is one's own hand. Indeed, only in this case, the displayed stimulus matches with the mentally rotated hand (self-advantage). If this is true, the visuo-motor representation of one's own body is crucial for the self-advantage.

Interestingly, the self-advantage described in previous studies (Frassinetti et al. 2008; Frassinetti et al. 2009; Frassinetti et al. 2010) has been found without requiring an explicit self body recognition, as it emerged on the basis of a mere implicit self-body recognition. As a consequence, the explicit recognition of one's own body does not seem to be necessary for the emergence of the self-advantage. To address the question of whether the requirement of explicitly recognizing one's own body is a sufficient condition for the emergence of the self-advantage, we ran a second experiment using the very same stimuli of the Experiment 1. Here (Experiment 2), participants were asked to explicitly recognize the identity of the displayed hand, that could be either the participants' or other people's hands. If the requirement of explicit self recognition is a sufficient condition for the self-advantage, this should be found also in the Experiment 2. Alternatively, a dissociation between implicit and explicit self body processing should be found.

3.1 Methods

Participants. Twenty-four right-handed healthy participants (mean age = 37,5 years; range 20-55), naive as to the purpose of the study, participated in each experiment. The same participants (12 men and 12 women) took part in Experiment 1 and Experiment 2. A different group of participants (14 men and 10 women) took part in Experiment 3. Participants had no history of neurological diseases as self reported. All participants gave their written informed consent for participation in the study. The experimental protocol was approved by the Ethics Committee of the University of Parma.

Stimuli and Procedure. The experimental stimuli consisted of grey-scale pictures of the dorsal view of right and left hands (see Figure 1). The hands of each participant were photographed with a digital camera in a session prior to the experiments (1 week before). This session took place in a controlled environment with constant artificial light and a fixed distance between the camera lens and the hands (40 cm), which were always photographed in the same position. Subsequently, photographs were modified with Adobe Photoshop software: they were cut from the original picture, pasted on a white background, and reoriented into the different rotated positions. Other people's hands were selected from this database as the best match for size, skin color, age, and gender, in comparison with each participant's hands. The sizes of the hands were compared in the pictures, in order to minimize the differences between matched hands both in length and in width. In addition, the ages of the people whose hands were matched with the participants' hands varied within 0 to 3 years of the participants' ages.

Images of hands were presented one at a time at the centre of the computer screen in six different clockwise orientations from the upright (0°, 60°, 120°, 180°, 240°, 300°). The upright orientation was defined as fingers pointing upwards (figure 1).

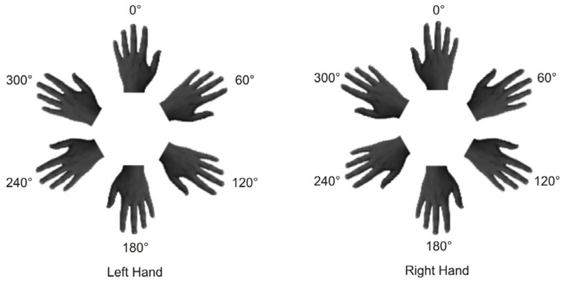

Figure 1- Stimuli. Experimental stimuli consisted of pictures depicting the dorsal view of right and left hands in six different clockwise orientations. Images of participant's hands or of three other people's hands were presented one at a time in 'self' trials and 'other' trials, respectively.

Stimuli depicted the participant's own left or right hand in half of the trials ('self' trials). In the other half of the trials, stimuli depicted the right or left hand of other three people ('other' trials, Experiments 1 and 2). In Experiment 3 stimuli presented in the 'other' trials depicted the right or left hand of only one other individual. This methodological change was done to control for "priming" or familiarity effects that might occur in the laterality judgment task.

Participants sat in front of a PC screen, at a distance of about 30 cm. Stimuli presentation was controlled by E-Prime (Psychology Software Tools Inc., (Schneider et al. 2002b); (Schneider et al. 2002a). Each trial started with a central fixation cross (500 ms duration), followed by stimulus presentation. The trial was timed-out as soon as participants responded (up to 4000 ms).

In Experiment 1 and 3 participants were required to judge the laterality (left or right) of observed digital images of hands by pressing as accurately as possible and within the allowed time interval, a left or a right response key, with their left and right index fingers, respectively.

In Experiment 2, participants were required to explicitly judge whether the displayed hand corresponded or not to their own hand by pressing as accurately as possible and within the allowed time interval, a left or a right previously assigned response key, with their left and right index fingers, respectively. The response keys were counterbalanced between subjects.

Each Experiment consisted of 288 trials, 72 trials for each of the four conditions: self-right, self-left, other-right, other-left. In particular, in Experiment 1 and 2 the self right and left hand stimuli were shown to participants 72 times each; others' right and left hand stimuli were shown only 24 times. To rule out the possibility that higher repetition rates of self, compared to others' stimuli led to a "priming" effect during the laterality judgment task, a control Experiment 3 was performed. In this experiment others' right and left hands belonged to only one "other" individual. Thus, self and others' right and left hands were shown 72 times each. In all the three experiments, each orientation was randomly depicted 12 times per condition. Experiments were always preceded by a task-specific practice block.

Since Experiment 1 investigated the implicit and Experiment 2 the explicit self-bodily recognition, Experiment 1 was always conducted before Experiment 2. The same group of participants performed both Experiments in one single session. Experiment 3 was administered in a separate session to a different group of participants.

3.2 Results

Results of Experiment 1. Data are shown in Figure 2. To test the presence of self-advantage with the laterality judgment task, an ANOVA was conducted on participants' reaction times (RTs), with Owner (one's own and other people's stimuli), Laterality (left and right), and Orientation (0°, 60°, 120°, 180°, 240° and 300°) as within-subject factors. The Newman-Keuls test was used for all post-hoc comparisons.

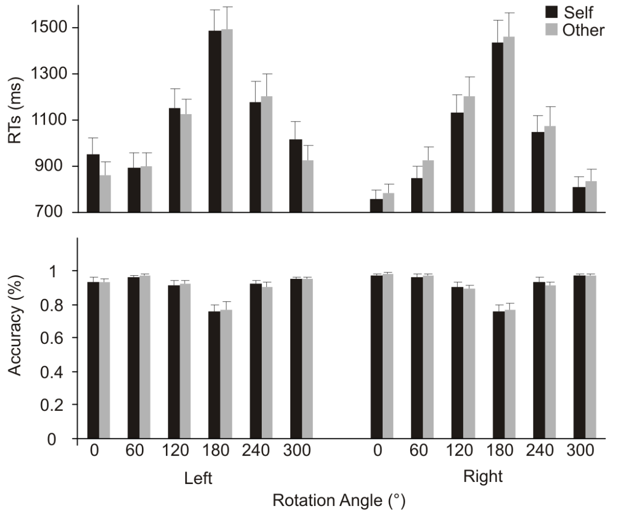

Figure 2- Experiment 1. Mean response times (upper panel) and accuracy (bottom panel) at the different self' and others' hands stimuli orientations in the Implicit task. Error bars depict the standard error of the mean.

The ANOVA revealed the significance of the main effect of Laterality [F(1,23) =9.28, p< .006, η_p^2=.29], since RTs to right stimuli were faster than RTs to left stimuli (1028 ms vs 1100 ms). The factor Orientation was also significant [F(5,115) =57.74, p< .001, η_p^2 =.72]. This effect was accounted for by faster RTs at 0°, 60° and 300° (839, 893, 898 ms, respectively) compared to RTs at 120°, 180°, 240° (1155, 1472, 1128 ms, respectively; p<.001 in all cases). The Laterality by Orientation interaction was also significant [F(5,115) =4.01, p< .002, η_p^2 =.15], because of the faster performance with right than left stimuli at 0° (771 ms vs. 908 ms), 240° (1064 ms vs.1192 ms), and 300° (822 ms vs. 974 ms, p<.01 for all comparisons). Relevant to the main goal of the study, the interaction Owner by Laterality was also significant [F(1,23) =5.82, p< .02, η_p^2=.20]. The interaction was explained by faster RTs to right self stimuli compared to right others' stimuli (1007 ms vs. 1048 ms, p<.05, see Figure 2). No significant difference was observed for left hands between self and others' stimuli (1114 ms vs. 1087 ms, p=.19). Moreover, RTs to self-right stimuli were faster than RTs to self-left ones (and other-left; p<.002 for all comparisons), whereas only a trend to significance was found between other-right and other-left stimuli (p=.07).

When the same analysis was conducted on accuracy (percentage of correct responses), only the factor Orientation was significant F[(5,115) =20.2, p< .0003, η_p^2=.47], being subjects less accurate at 180° (76%) than at all other orientations (0°=96%, 60°=97%, 120°=91%, 240°=92%, 300°=96%, p<.0001 for all comparisons). The other orientations were not significantly different.

Results of Experiment 2. Data are shown in Figure 3. An ANOVA similar to that of Experiment 1 and 2 was conducted on participants' reaction times (RTs), with Owner, Laterality and Orientation as within-subject factors.

The factor Owner was significant F[(1,23) =18.66, p< .001, η_p^2 =.45], since participants responded faster to others' than to self stimuli (814 vs 997 ms, see Figure 3). No other significant effects were found.

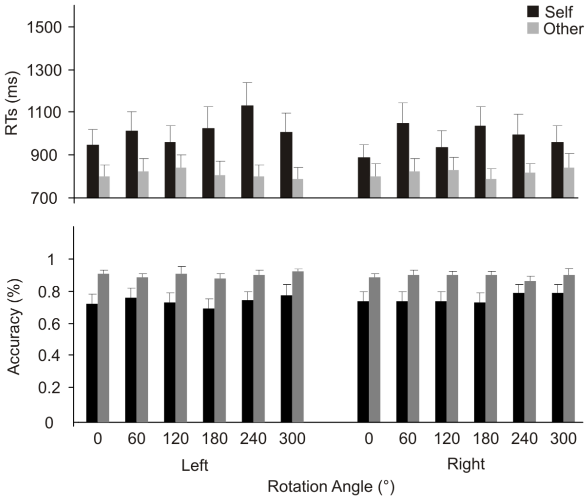

Figure 3- Experiment 2. Mean response times (upper panel) and accuracy (bottom panel) at the different self' and others' hands stimuli orientations in the Explicit task. Error bars depict the standard error of the mean.

The same analysis conducted on accuracy (percentage of correct responses) confirmed a worse performance with self than with others' stimuli (76% vs 91%, F[(1,23) =11.29, p< .001, η_p^2=.33]).

Results of Experiment 3. To rule out the possibility that the presence of the self-advantage for right hands with the laterality judgment task was due to any sort of familiarity or "priming" effect, we asked a new group of participants to perform the same task in the control Experiment 3. In this experiment, each self and other's stimulus was shown the same number of times. An ANOVA was conducted on participants' reaction times (RTs), with Owner (one's own and other people's stimuli), Laterality (left and right), and Orientation (0°, 60°, 120°, 180°, 240° and 300°) as within-subject factors. The Newman-Keuls test was used for all post-hoc comparisons.

The ANOVA revealed the significance of the main effect of Laterality [F(1,23) =6.1, p<.05, η_p^2=.21], since RTs to right stimuli were faster than RTs to left stimuli (838 ms vs 867 ms). The factor Orientation was also significant [F(5,115) =23.9, p<.001, η_p^2=.86]. This effect was accounted for by faster RTs at 0°, 60° and 300° (704, 755, 732 ms, respectively) compared to RTs at 120°, 180°, 240° (888, 1165, 870 ms, respectively; p<.001 in all cases). Most interestingly, the significance of the interaction Owner by Laterality, found in Experiment 1, was confirmed in the present control experiment [F(1,23) =4.5, p< .05, η_p^2=.16]. Once again this interaction was explained by faster RTs to right self stimuli compared to right others' stimuli (831 ms vs. 844 ms, p<.05). No significant difference was observed for left hands between self and others' stimuli (868 ms vs. 865 ms, p=.55). Moreover, RTs to self-right stimuli were faster than RTs to self-left ones (and other-left; p<.0002 for all comparisons). Similarly, RTs to other-right stimuli were faster than RTs to other-left ones (and self-left; p<.002 for all comparisons).

When the same analysis was conducted on accuracy (percentage of correct responses), only the factor Orientation was significant F[(5,115) =14.8, p< .001, η_p^2 =.60], being participants less accurate at 180° (86%) than at all other orientations (0°=97%, 60°=97%, 120°=95%, 240°=96%, 300°=97%, p<.001 for all comparisons). The other orientations were not significantly different.

3.3 Discussion

We investigated whether and to what extent the so-called self-advantage (Frassinetti et al. 2008; Frassinetti et al. 2009; Frassinetti et al. 2010) is based on a motor simulation. To this aim healthy participants were submitted to a hand laterality judgment task. Crucially, the hand to be judged could be either the participants' own hand or other people's hand. Results showed an advantage when judging one's own right compared to others' hands. Such an advantage was reflected by faster reaction times when responding to the former stimulus compared to the latter ones (Experiment 1 and 3). It is worth noting that this advantage was present in a task in which explicit self recognition was not required. By contrast, the self-advantage was lacking in the second experiment where self-recognition was explicitly required. Indeed, a worse performance with self-related stimuli compared to other-related stimuli was observed.

Experiments 1 and 3 differed from Experiment 2 with respect to two main variables. The first one is the motor strategy required to solve the task, present in the laterality judgment task (Experiment 1 and 3), but not in the self-body recognition task (Experiment 2). In order to perform the laterality judgment task a mental motor rotation of body parts is required (Parsons 1987; Parsons 1994; Parsons et al. 1998; Ionta et al. 2007). Coherently, the classical bell-shaped function of RTs found for this task (see Figure 2) constitutes the behavioral signature of mental rotation. On the other hand, the absence of such a function in the RTs of the self-body recognition task (see Figure 3) shows that a motor simulation is not required to accomplish the explicit task. For these reasons the presence of the self-advantage in Experiment 1 and 3, and its absence in Experiment 2 suggest that the bodily self is ultimately linked to a motor representation.

The second variable is the requirement to explicitly recognize self stimuli, which characterizes the second, but not the first and the third experiments. Our data demonstrate that the request of an explicit recognition of one's own body does not lead to the emergence of the self-advantage. Thus, explicit body processing is *per se* neither necessary nor sufficient to grant the bodily self-advantage.

We are aware the two tasks required two different responses, thus they cannot be directly compared to each other. However, to the best of our knowledge, this is the first study investigating the implicit and explicit self bodily knowledge by means of the very same stimuli and the same experimental procedure. The idea of a dissociation between implicit and explicit self body processing is in agreement with the large amount of neuropsychological studies and infancy research (see section 2, pp. 6-7).

Taken together, data from Experiments 1 (confirmed by Experiment 3) and 2, although not directly comparable to each other, suggest that the crucial element for the self-advantage to emerge is the recruitment of a motor simulation. This interpretation is in agreement with and provides a coherent explanation to a variety of previous studies. Tsakiris et al. (Tsakiris et al. 2006) carried out a study in which participants had to decide whether they viewed their own right hand or someone else's right hand covered with identical gloves, while experiencing a passive displacement of their own right index finger, either generated by the experimenter or by participants' own left hand. The results showed that the performance was significantly better when the displacement of participants' right index finger was self-generated. As argued by Tsakiris, Schutz-Bosbach, & Gallagher (2007b), this shows that "Self recognition was significantly more accurate when subjects themselves were the authors of the action" (p. 654-655). Coherently, visual and motor related information converge within the OTC in a body part specific manner (Devue et al. 2007), and the feeling of ownership of the hand positively correlates with activity in the premotor cortex (Ehrsson et al. 2004).

In a behavioral study Loula, Prasad, Harber, & Shiffrar (2005) asked participants to perform a self identification task while observing sagittal displays of point-light depictions of themselves, their friends, and strangers while performing various actions. They found higher sensitivity to one's own motion. Since everyone has little experience of viewing her own body moving, such self-advantage can be easily explained by the activation of observers' own action motor representation. Similarly, a self-advantage was demonstrated by Casile & Giese (2006) in a behavioral task, in which only non-visual motor training was available to participants.

The last point to be addressed is the presence of the self-advantage only for participants' right hand. Such selectivity is a further argument in favor of our motor hypothesis of the self-advantage. The presence of the "self-advantage" only for the right hand can be explained by the greater lateralization in hand motor skills observed in right-handers compared to left-handers (e.g., Gentilucci et al. 1998). Neuroimaging studies have shown hemispheric asymmetries in cortical areas associated with body representation in right-handed people, but not in left-handed people. Indeed, right-handed individuals have a greater cortical surface area in the left sensory cortex and stronger activation in the left sensory-motor cortex while performing right hand movements than in the corresponding areas of the right hemisphere. In contrast, left-handed individuals seem to have near-symmetrical surface areas and activations (Amunts et al. 1996; Kawashima et al. 1997; Zilles et al. 1997). Similar results have been observed with electroencephalographic (EEG) studies (Buchner et al. 1995; Jung et al. 2003). Furthermore, it was recently shown that right-handers perceive their own right arm and hand as being longer than their left ones, whereas left-handers perceive both arms and hands accurately (Linkenauger et al. 2009). Thus, it appears that the conscious perception of the body is grounded on its motor potentialities (Gallese and Sinigaglia 2010).

Since according to our data the self-advantage relies upon a sensory-motor representation, the presence of the self-advantage only for self right hand stimuli is likely the consequence of the greater involvement of the left, rather than the right, sensory-motor areas in right-handers during a mental motor task. Given such a near-symmetrical cortical representation in left-handers, future studies on this population might help us to shed new light on this phenomenon. Recent data seem to support our hypothesis. Conson and colleagues (2010) asked right-handed and left-handed healthy participants to categorize full-colored pictures of hands, presented according to the egocentric or the allocentric perspective, as belonging to themselves or to other people. They found that both right- and left-handers were faster in recognizing dominant hands (right and left hand, respectively) in egocentric perspective, and others' non-dominant hands in allocentric perspective.

Possibly one may argue that the self advantage we found in Experiment 1 can be construed in terms of "priming" effect or any sort of visual familiarity. Indeed, in this experiment self stimuli were presented 72 times while each of the three others' stimuli was presented only 24 times. To deal with this possible concern, we run a third control experiment in which we used the hands of only one other individual, thus matching the number of occurrences of each stimulus in terms of identity. We found the same results as in Experiment 1. This rules out the possibility that the self-advantage is exclusively due to "priming" effects. Regarding visual familiarity, we believe something different might underpin our behavioral effect. Indeed, out of the total of self-related trials, one half involved the presentation of the right hand while the other half involved the presentation of the left hand. It follows that if perceptual familiarity could fully explain our results, it is not clear why our effect was visible only for right hand stimuli. Our idea is also corroborated by a recent study (Aranda et al. 2010) exploring whether symbolic cues, predicting the appearance of one's own or another person's hand could optimize the processing of these stimuli. Results showed a selective attentional effect with one's own hand, but not with someone else's hand. More relevant for the purpose of our study, in a control experiment the authors tested whether this selective attentional effect could be due to the higher perceptual familiarity. Results showed that participants could use the cues to anticipate the appearance of both stimuli, since a behavioral advantage was observed for all valid stimuli, regardless of their degree of familiarity.

In conclusion, our data demonstrate that implicit and explicit recognition of the bodily self dissociate and that, only when bodily self recognition is implicit, a self-advantage does emerge. Since the implicit mechanism recruits a motor simulation, it follows that the bodily self is primarily mapped in motor terms. Indeed, when explicit self recognition is required and different cognitive and/or perceptually-based mechanisms are likely involved, the self-advantage is lacking. The idea of the motor nature of the bodily self is in agreement with previous philosophical intuitions. Merleau-Ponty posited that our body appears to us as an attitude directed towards a certain existing or possible tasks. When referring to the spatiality of the body he claimed: "[...] my body appears to me as an attitude directed towards a certain existing or possible task. And indeed its spatiality is not, like that of external objects [...], a spatiality of position, but a spatiality of situation".

4. General discussion

Empirical evidence reported in this paper shed new light on the contribution of the motor experience of one's own body, as the minimalist level of bodily self experience, to our ability to implicitly differentiate between self and other. In particular, studies from our group started from the idea that the awareness of oneself, as bodily self, emerges from the experience of oneself as agentive. However, such knowledge is not limited to the "online" sense of being the one who generates action, which relies on the congruence between self-generated movements and their expected consequences (Central Monitoring Theory of action recognition), but rather it emerges also when actions remain covert (Jeannerod 2007), before and below the sense of agency. Indeed, as demonstrated by behavioural results described in section 3, self-body knowledge hinges on the implicit recruitment of motor simulation. In a recently published fMRI study, we provided neural data further supporting the pivotal role of the sensorimotor system in the implicit and pre-conscious self/other distinction during the laterality judgment task (Ferri et al., *in press*). Previous neuroimaging results associated with this task, showed activation in several dominant spatial-motor processing regions, including the posterior parietal (superior parietal and the intraparietal sulcus), premotor and primary motor cortices, the supplementary motor area and the cerebellum (Parsons et al. 1995; Cohen et al. 1996; Alivisatos and Petrides 1997; Kosslyn et al. 1998; Vingerhoets et al. 2002; Seurinck et al. 2004; Podzebenko et al. 2005). However, given the higher specificity of the premotor cortex for the mental rotation of body-related stimuli (Kosslyn et al. 1998; Arzy et al. 2006), than non corporeal stimuli, and considering its role in body awareness (Ehrsson et al. 2004; Berti et al. 2005; Arzy et al. 2006), we hypothesized that this brain area may represent one of the essential anatomical and functional basis for the motor aspect of bodily selfhood. Our fMRI study (Ferri et al., *in press*) besides revealing a neural network for the general representation of the bodily self encompassing the supplementary and pre-supplementary motor areas, the anterior insula and the occipital cortices, crucially, showed that the representation of one's own dominant hand is primarily confined to the left premotor cortex (figure 4).

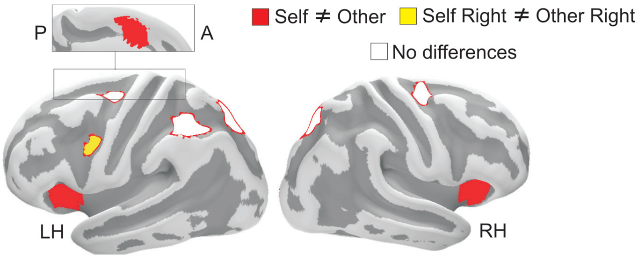

Figure 4- Regions involved in the mental rotation process (main effect of angular orientation), irrespectively of the variables owner and laterality. Group activation data are rendered on the cortical surface of a "canonical" brain (Mazziotta et al. 1995). Red clusters indentify areas differentiating between self and other conditions, regardless of the hand laterality. The yellow cluster identifies the cortical region differentiating between self right and other right hand stimuli. White clusters indentify areas not differentiating between self and other conditions.

These data clearly demonstrated that there is a sense of bodily self encased within the sensorimotor system. How much the representation of the body within this system, in terms of neural efficiency, articulates as "self", seems to depend upon participants' motor experience and motor skills, as demonstrated by the evidence that right-handed participants showed a self-advantage only for their right hand. However, despite engaging sensorimotor cortices, the condition for the self-advantage to emerge is not the motor nature of the task. Indeed, this effect was revealed for the first time by using a visual matching task of still pictures of body-parts (Frassinetti et al. 2008). In addition, that the sensorimotor system is involved during implicit self-processing, regardless of the motor nature of the task, is confirmed also by a recent study using a tactile detection task (Cardini et al. 2010).

It appears therefore that the necessary condition for the bodily self-advantage to come out is that the sensorimotor representation of oneself, as bodily self, is implicitly, rather than explicitly accessed. This evidence evokes a well-known effect described by Schooler and Engstler-Schooler (Schooler and Engstler-Schooler 1990) as the "verbal overshadowing" effect, which refers to the fact that verbalizing ineffable perceptual experiences impairs later retention. In other words, explicit verbalization creates a language-based representation that overshadows difficult-to-verbalize aspects of the perceptual memory. Verbal overshadowing has been observed in domains as diverse as taste, audition, map memory and insight problem solving, thus establishing that the effect is not limited to visual memories per se. More relevant for our purposes, the processes underlying this phenomenon contribute also to the tendency for conscious reflection to interfere with skilled action (Flegal and Anderson 2008).

In conclusion, my proposal is that the awareness of oneself, as bodily self, articulates from one's own motor experience. Such experience provides us with a pre-reflexive and pre-verbal knowledge of our potentialities for action, which is the basis of the sensorimotor representation of ourselves as bodily selves. Thus, when we look at the picture of a body-effector, the more we can implicitly associate our motor potentialities to it, the more we immediately recognize it as ours. Conversely, the more such implicit and pre-verbal knowledge is overshadowed by the recruitment of different cognitive and/or perceptually-based abilities, as required by the task, the less the self-advantage can emerge, even when one is required to make a self/other discrimination. This confirms that the self-advantage effect does not rely on an explicit and reflective self-knowledge. Conversely, an implicit bodily self-knowledge, which is fed by motor experience, facilitates the self-advantage effect. This evidence is in line with the above reported idea of Cermolacce and colleagues (Cermolacce et al. 2007) that "the field of experience is not yet considered to be *subjective* because this predicate already implies that there is a subject. For phenomenology, the very idea of the *subject* articulates itself in experience. In this sense, the manifestation and appearing of experience are the *conditions for* the experience of the subject in question".

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