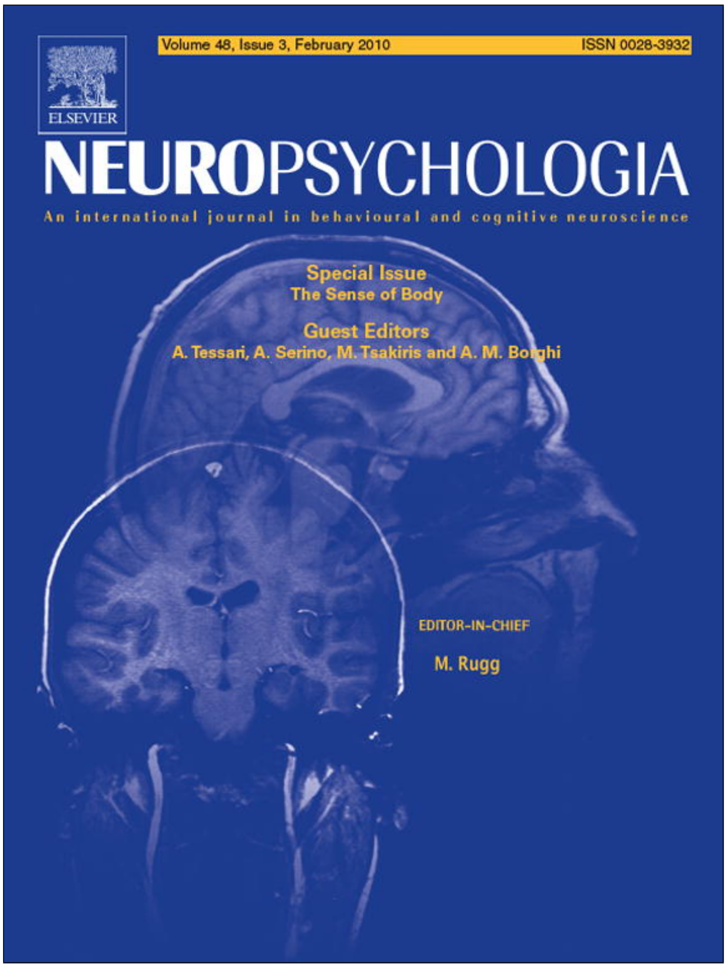
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The bodily self as power for action

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ABSTRACT

The aim of our paper is to show that there is a sense of body that is enactive in nature and that enables to capture the most primitive sense of self. We will argue that the body is primarily given to us as source or power for action, i.e., as the variety of motor potentialities that define the horizon of the world in which we live, by populating it with things at hand to which we can be directed and with other bodies we can interact with. We will show that this sense of body as bodily self is, on the one hand, antecedent the distinction between sense of agency and sense of ownership, and, on the other, it enables and refines such distinction, providing a conceptual framework for the coherent interpretation of a variety of behavioral and neuropsychological data. We will conclude by positing that the basic experiences we entertain of our selves as bodily selves are from the very beginning driven by our interactions with other bodies as they are underpinned by the mirror mechanism.

1. Introduction

To face the challenge of building adequate models of the self, philosophers, psychologists, and cognitive neuroscientists are used to distinguish between several senses and kinds of self-awareness and employ a variety of first- and third-person approaches to search for a core or "minimal" self, according to the intuition that "even if all the unessential features of self are stripped away", "there is a basic, immediate or primitive 'something' that we are willing to call a self" (Gallagher, 2000, p. 15). In order to escape the danger of being too abstract, most attempts to account for a minimal sense of self have recently claimed to be "closer to the ground" (Gallagher & Marcel, 1999, p. 5), focusing on the occurring and immersed consciousness of oneself as bodily subject of action. Indeed, the interpretation of the minimal self in terms of sense of agency (the sense of being the one who generates an action) and/or sense of ownership (the sense of being the one who undergoes any experience, no matter if internally or externally generated), as well as the investigation of the different types and levels of agency and/or ownership and their relative impairments are some of the most fruitful trends in contemporary research (see Metzinger, 2003, 2009).

However, most if not all current attempts to provide an account of the different forms of self-awareness and a definition of a minimal notion of self, although meritorious, end up being still too abstract, falling short of taking into adequate account both what kinds of body experience are critical in shaping and/or modeling various senses of self, starting from a minimal one, and also how the body shapes and/or model itself as bodily self by living in a world shared with other self-modeling bodies.

In the present paper we will posit that there is a sense of body that is enactive in nature and that enables to capture the most primitive sense of self. We will show that the body is not only something that is always already given to us, but it is primarily given to us as "source" or "power" for action, i.e., as the variety of motor potentialities that define the horizon of the world in which we live. The primitive sense of self we will be dealing with is, on the one hand, antecedent the distinction between sense of agency and sense of ownership, and, on the other, it enables and refine such distinction, providing a conceptual framework for the coherent interpretation of a variety of behavioral and neuropsychological data. Finally, we will emphasize that any serious attempt to account for a minimal sense of self must consider that this primitive sense of self as bodily self constitutes itself not only through its attunement with the world of inanimate things, but first and foremost through a practical attunement with a world inhabited by other living and self-modeling bodies.

In the next sections we will first argue that in order to understand how the sense of body can be intrinsic part of a minimal sense of self, it is necessary to rethink the classical notion of body schema, pointing out its dynamic relationship with peri-personal

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space conceived as the horizon of the motor potentialities our body instantiates. We will then show how this sense of bodily self can provide a unitary and coherent account of the intentional binding underlying the sensory–motor integration typical of our experience of action. In addition, we will show that many of the different and more or less explicit forms of self-recognition we entertain of our body rely upon a sense of bodily self as power for action even when the actual execution of action is not requested or physically impossible because of brain lesions. Last but not least, we will posit that the basic experiences we entertain of ourselves as bodily selves are from the very beginning driven by our interactions with other bodies, with such interactions being underpinned by the mirror mechanism.

2. Sense of body

What do we mean by sense of body? Is there something like a sense of body? And to what extent does such sense of body play a role in shaping a minimal sense of self?

When speaking of the "sense of body" we do not refer to any particular sensory channel specifically conveying information about the body, like proprioception. We believe there are at least two reasons to reject such equivalence. The first reason is that the content of proprioception is never purely and exclusively related to the body, because proprioception is neither the only sensory modality conveying information about the body, nor it exclusively implies the body in isolation from the world it constantly interacts with (Eilan, Marcel, & Bermudez, 1995; Marcel, 2003). When we touch (or are touched by) any object we do not exclusively make experience of our own body, and, similarly, we do not exclusively make experience of our own body by touching and being touched. The second reason is that by defining the experience we make of our body in such a way it follows that the sense of the body is reduced to the experience of body as an experienced body. A quick look at how we experience ourselves in relation to the world will show that the body's mode of being in experience is more than being experienced, because the body as experiencing body is always in 'excess' of the body that is experienced (Gallagher, 2003). We see *with* our eyes as well as we touch *with* our fingers. However, we have a visual or tactile experience of objects just because we do not perceive our seeing eyes or touching fingers. Indeed, our visual or tactile perception of an object is not accomplished through our perceptual awareness of the changing spatial properties of our eyes and/or our fingers, the latter being not equivalent to the former.

It has been recently argued at length for the phenomenological significance of this bodily excess as well as of the distinction between a pre-reflective bodily self-consciousness and the consciousness of the body that happens to be one's own (see Gallagher, 2005; Legrand, 2006, 2007; Thompson, 2005). Although the consciousness of body-as-subject and consciousness of body-as-object are not mutually exclusive, only the former can be defined as a genuine bodily self-consciousness, i.e., as "consciousness of oneself as a *bodily subject*" (Legrand, 2006, p. 96). The distinction between these different kinds of bodily consciousness is critical because it enables to disentangle two different aspects of the body experience quite often confused with each other.

However, such distinction by itself is not yet sufficient to clarify and explain how bodily awareness can be part of the sense of self. Indeed, the sole eccentricity of the body experience in virtue of which the experiencing body exceeds the experienced body falls short of explaining the whole body experience–because the experiencing body reveals such an eccentricity even in relation with anything else that can be object of a bodily experience (Dokic, 2003). A further step is required, consisting in the investigation of the way in which the experiencing body unfolds its "excess" in the very making of experience, playing a constitutive role both in the consciousness of the body-as-object and also in the consciousness of the surrounding things, the bodies of other people included (Zahavi, 2005).

One way of doing it is by retrieving the classical distinction introduced by Head and Holmes (1911) between a *body schema* considered as a coherent and dynamically updated model enabling and monitoring the execution of bodily movement, and a *body image* considered as a conscious representation of perceptual features of the body. At first glance it might seem bizarre to connect the understanding of the self-relatedness of body experience with the notion of body schema, a notion not only rich in ambiguity (see Gallese, 2005), but also commonly conceived of as being "prior to or outside of intentional awareness" and functioning "in a subpersonal, unowned and anonymous way" (Gallagher, 1998, pp. 228, 229).

Things, though, look very different as soon as one tries to more clearly define the varying ranges of the body schema as well as the binding principle presiding over the multimodal integration of different sensory information enabling the constant updating of postural adjustments during movement execution.

Head and Holmes (1911) themselves acknowledged that the body schema is not only sensory–motor but also action-oriented in nature: it is in virtue of its action-orientedness that the body schema provides us with the power going beyond the limits of our own bodies, extending the localization of our movements to the end of some tool held in the hand. More recent findings indicate that tools can shape one's own body schema, extending the reaching space. Iriki and colleagues (Iriki, Tanaka, & Iwamure, 1996; Ishibashi, Hihara, & Iriki, 2000) showed that the visual receptive fields (vRFs) of monkey's bimodal visuo-tactile parietal neurons were modified by tool actions. Indeed, after few minutes of tool-using the vRFs anchored to the paw extended to encompass the tool, as if the latter were incorporated into the former. When the monkey stopped using the tool the vRFs returned to their previous extension, even if the animal continued to hold it.

Analogous results have been found in healthy and brain damaged humans. It has been shown that reaching a visual stimulus with the hand or with a tool produced similar interference effects: in the latter case these effects depended on the tool but not on the hand posture, and they increased with extensive tool use (Maravita, Spence, Kennet, & Driver, 2002). Moreover, several line-bisection studies on patients with selective neglect for the hemispace close to (or far from) their body indicated that tool use might reduce or increase the neglect according to the status of the line to be bisected (reachable or out-of-reach) in relation to tool use, being such dynamical remapping modulated both by the planned motor act and tactile and visual feedbacks received during the execution of that act (Ackroyd, Riddoch, Humphreys, Nightingale, & Townsend, 2002; Berti & Frassinetti, 2000; Neppi-Mòdona et al., 2007; Pegna et al., 2001). Finally, studies on patients with visuo-tactile extinction selectively confined to the space close to the hand showed that the severity of the extinction can be modified by tool use extending the reach of hand actions (Farné & Làdavas, 2000; Maravita, Husain, Clarke, & Driver, 2001), where this extension has been demonstrated to be tightly related to the functionally effective length of the tool (Farné, Iriki, & Làdavas, 2005).

Taken together, these findings indicate that the body schema is characterized both by multi-sensory integration and dynamic plasticity (Maravita & Iriki, 2004). The construal of the body schema in terms of a set of sensory–motor laws working at a mere kinematical level, with the only function to control the postural adjustments required by movement execution does not fully account for the two above-mentioned properties. This is not to deny that the body schema plays a critical role in monitoring various body parts, thus enabling action and perception. Rather, the point is that the relationship between body schema and action is way much stronger and deeper than that. It is not exclusively confined to the kinematical constraints enabling action execution, but it encompasses the level of motor goal-relatedness characterizing each basic action as such and as being different from every other basic action.

The body schema and its function as key dynamic binding principle enabling the integration of multiple sensory modalities cannot be fully understood without emphasizing their motor intentional features. It is, obviously, a very particular type of intentionality, a "pre-noetic" intentionality, operating in a "pre-objective space" (Gallagher, 1998) and that, according to Merleau-Ponty (1962), "provides us with a way of access to the world and the object, with a *praktognosia*, which has to be recognized as original and perhaps as primary" (p. 140).

Merleau-Ponty, probably better than anyone else, has pinpointed the specific motor intentional nature of the body schema, characterizing it as a "potential source" of action, so that it would be "neither the mere copy nor even the global awareness of the existing parts of the body, but its active integration of these latter only in proportion of their value to the organism's projects. Psychologists often say that the body schema is *dynamic*. Brought down to a precise sense, this term means that 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 or like that of 'spatial sensations', a *spatiality of position*, but a *spatiality of situation*" (Merleau-Ponty, 1962, p.100).

This *spatiality of situation* sheds new light on the following two points: First, the intrinsic and tight link between the notions of body schema and peri-personal space as the expression of motor potentiality (Gallese, 2005, 2007). Second, the specific bodily experience that concurs in defining a genuine sense of body as bodily self.

Concerning the first point, there is a great deal of studies on monkeys and humans showing that the peri-personal space, usually defined as the surrounding space encompassing objects within reach, is multi-sensory, body-centered and motor in nature (Rizzolatti, Fadiga, Fogassi, & Gallese, 1997). Peri-personal space is characterized by a dynamic plasticity that, like in the case of body schema, depends on the varying range of our motor goals and actions (see Rizzolatti & Sinigaglia, 2008, Chap. 3).

The distinction between the notion of body schema and that of peri-personal space seems to become sometimes utterly blurred, when not completely vanishing (Cardinali, Brozzoli, & Farné, 2009). However, the question arises as to whether the intimate link between the two notions also implies their identity. It must be added that even the interpretation of the consequences of tool use is controversial (Holmes & Spence, 2004; Serino, Bassolino, Farné, & Làdavas, 2007). Does tool use result in an extension of the cortical body representation, i.e., in an extension of the body schema per se? Or, more parsimoniously, does it simply imply a spatial remapping, transforming far space into near space, and near space into far space? Farné, Serino, and Làdavas (2007) demonstrated that a right brain damaged patient showed worse cross-modal extinction after tool use not only at the tip of the employed rake, but also at its middle location. This finding demonstrates that action (tool use) genuinely extends the peri-hand space. Nevertheless, even if one hypothesizes that tool use does not imply the effective embodiment of the used tool, this does not undermine the link between peri-personal space and the body schema to which that space is anchored (Legrand, Brozzoli, Rossetti, & Farné, 2007).

In that respect one should not only acknowledge that "When single neurons can respond both to tactile stimulation of an arm and to visual stimulation of the space immediately surrounding that arm, it may not even make neural sense to try to discriminate between the body and peri-personal space, at least at the level at which these particular neuronal populations are operating" (Holmes & Spence, 2004, p. 13). Rather, one should have clear in mind that just because of the nature of peri-personal space, and especially of its body centeredness, it is not possible to attribute to the sole peri-personal space the multisensory integration and dynamic plasticity required by action, while ascribing to the body schema just the mere control of postural constraints. Indeed such a move would end up in downplaying the specificity of both body schema and peri-personal space, the former embodying the "power for action" defining the horizon of every possible experience of the body, while the latter identifying surrounding space as a "collection of possible points" upon which this power of action may operate (Merleau-Ponty, 1962, p. 105).

Coming now to the second, and for us crucial point, by characterizing the body schema in terms of power for action we can understand how its recognized "anonymity" does not imply total transparency, but rather reflects the bodily pre-reflective self-awareness that is specific to the experience of oneself as a bodily subject.

This sense of the body as an experiencing body is at the basis of our practical attunement with the surrounding world. This sense of body is irreducible to the experience of the body as of one physical object among others. The experience of the body as an experiencing body not only reveals its intentional character as the source of or power for action, but also implies a *pre-reflective consciousness of the body as one's own body*. These two aspects are necessarily correlated because the experience of the body as an experiencing body pertains to the practical possibilities for action that constitute that body not as a body among others but as *one's own body*. This sense of body not only precedes, but, as we will show in the coming pages, also makes the attribution of sense of agency and/or sense of ownership possible.

Many have considered the self-attribution of agency and ownership to be crucial for a definition of a minimal notion of self. In contrast, on the basis of our refinement of the dichotomies between body-as-subject and body-as-object and between body schema and body image we will assert that agency and ownership are rooted in a more basic sense of one's own body as power for action.

3. The bodily self in action

The notion that bodily self-awareness is motor in nature is not entirely new. Legrand (2006) recently argued that to get "the very definition of the bodily self" one needs to come back to the body itself "as it is acting and perceiving", i.e., to "the body as the point of convergence of action and perception" (Legrand, 2006, p. 108). According to Legrand (2006), this means that bodily self-awareness can be reduced neither to the experience of a pure mental self-conceived as an entity at the same time detached from the body and responsible of its actions, nor to a mere sensory self-awareness rooted in proprioception alone. In the first case we would be dealing with an *embodied self*, i.e., a self that is not bodily in nature, but simply put into the body, while in the second case we would be dealing with a sense of body-as-object that – as such – cannot be identified with a genuine form of bodily self-awareness because the former presupposes the latter.

We fully agree with Legrand's proposal to link the pre-flective bodily sense of self to experiencing "action and perception as coherent", thus conceiving the bodily self as "an integrated system characterized by matching of sensory–motor information" (2006, pp. 108, 111). However, we do not quite agree with Legrand's attempt to base the account of bodily self-awareness exclusively upon the action monitoring mechanism. This does not imply we minimize the crucial role played by action monitoring in both motor control and perceptual discrimination between internally and externally generated stimulations and its contribution to the bodily sense of self. On the contrary, we wish to underline that the intimate relation existing between action and bodily self-awareness, as testified by the evidence reviewed in the present paper, is not confined to and goes beyond the control of action and the anticipation of its sensory consequences. Both aspects presuppose the sense of body as power for action, i.e., the experience of body as a dynamic binding principle operating at a pre-noetic level, i.e., at the level of motor intentionality. Motor intentionality identifies every bodily action as such and differentiates it from any other action before and below any prior and distinct pure (noetic) mental state supposedly at its origin (Rizzolatti & Sinigaglia, 2007; Gallese, 2007).

It is at the level of this motor intentionality that the body experiences itself as a bodily self defined by a given horizon of practical possibilities for action. And it is at the level of this motor intentionality that is possible to account for the "dynamical coherence" that characterizes the bodily self as "a sensory–motor unity anchored to its world" (Legrand, 2006, p. 113), highlighting the mechanisms underlying the bodily integration of motor and sensory components of action. To this regard, it is worth noting that this bodily integration cannot be construed just in terms of "sensory registrations of action–effect-couplings" based on more or less robust "action–effect associations", even at the level of the "minimal action-related self-awareness" that is considered to be the precondition of the sense of agency and the sense of ownership (Synofzik, Vosgerau, & Newen, 2008, p. 413).

Such a construal would neither account for the intentional features of this sensory–motor bodily integration, nor enlighten its role in bodily self-awareness. Both issues can be understood only on the basis of a notion of bodily self *really* grounded in action. A bodily self grounded in action shows that the minimal sense of self is at the same time a prerequisite and a core component of both the sense of agency and sense of ownership.

Many studies carried out during the last decade, investigating the intentional, motor and sensory components of action are consistent with our proposal. For example, by employing a modified version of the paradigm originally devised by Libet, Gleason, Wright, and Pearl (1983), Haggard and colleagues have shown that the intentional selection of a motor action determines a more pronounced experience of being in control of one's movements and of their effects than when the same movements are externally generated by a mechanical device or by a TMS-induced stimulation of the motor cortex (see Haggard, 2005, 2008).

Moreover, and even more relevantly to our thesis, the investigation of motor awareness of one's own bodily movements (key-presses) as well as of the physical effects (sounds) of the same movements has demonstrated that movements are perceived as shifted in time towards the sound effects they produce, and that the sounds are perceived as shifted earlier in time towards the movements causing them (Haggard, Clark, & Kalogeras, 2002). Self-produced bodily movements and their sensory effects are perceived as being closer in time. Haggard (2008) concludes that such temporal binding is 'intentional' because it is specific to the motor intentional components of action. Interestingly, temporal intentional binding occurs no matter if the motor action is completely internally generated or stimulus-driven, provided that the relationship between the motor and sensory components of that action is particularly consistent.

Altogether, the evidence here concisely reviewed clearly suggests that motor intentionality underlies the action-related bodily self-awareness, determining the way bodily movements are experienced together with their sensory effects and how they are bound in the temporal domain. In neural (subpersonal) terms, this implies that the parieto-premotor networks underpinning the planning and the execution of goal-related movements are also crucial in evoking the sense of body as power for action that characterizes the pre-reflective experience of one's body as bodily self. In addition, because this bodily sense of self is both prerequisite and core component of agency, this also implies that the brain mechanisms underlying the sense of agency are strictly related and partly overlap with the parieto-premotor networks subserving the bodily self in action.

By stating this we do not claim that the parieto-premotor networks underpinning the planning and execution of goal-related movements solely determine the experience of self as agent as well as the experience of actions as one's own actions. More simply (and modestly) we think that those cortical circuits constitute the prerequisite for the minimal experience of self we characterized in terms of bodily self that should not be confused with the full-fledged experiences of agency and ownership. To put it differently, some of the functional features of parieto-premotor cortical networks, first and foremost their capacity of coding bodily movements in terms of their goal-relatedness, are to be conceived as the basic components of the neural architecture underpinning different forms of self-awareness, among which are agency and ownership.

To this regard there is large and converging evidence showing that the premotor and the posterior parietal cortex are crucial in enabling the awareness not only of when we act but also of when we intend to act (for review, see Haggard, 2005, 2008). Haggard and Magno (1999) showed that transcranic magnetic stimulation (TMS) of the primary motor cortex delays reaction times of action performance, while TMS of the pre-supplementary motor area (pre-SMA) delays reaction times of the judgment on when the action occurred. In an fMRI study on healthy participants Lau, Rogers, Haggard, and Passingham (2004) showed increased activation of pre-SMA and of the cortex within the intraparietal sulcus when participants had to judge when they intended to act with respect to when they really performed the action.

For what pertains the relationship between our notion of bodily self and sense of agency, it is worth considering also two neuropsychological pathologies, classically thought to be expression of a deficit of agency: the anarchic hand syndrome and utilization behavior.

Patients affected by anarchic hand syndrome perform actions apparently against their will that may hinder the willed intentional actions they are executing with the unaffected hand (Della Sala, 2005; Della Sala, Marchetti, & Spinnler, 1994). Such disturbance of the phenomenal volition of action has been sometimes designated also as "alien hand syndrome". Marchetti and Della Sala (1998) quite appropriately proposed to call it 'anarchic hand syndrome' because the wayward hand is felt as belonging to the patients body, though not obeying his/her will. These patients often refer the unwilled behavior of their "anarchic" hand as due to a mind of its own. They experience a conflict between their conscious will and the effective performance of the contralesional hand, which carries out unintended goal-related motor acts. Thus, such pathology configures a disturbance of agency, leaving body ownership intact.

It is worth noting that sense of agency and sense of ownership are not symmetrical. It is indeed possible to observe patients who in spite of their lack of agency are still capable of conceiving of the unwilled actions they perform as *their* actions, while the converse is not true. This seems to be a further argument supporting our hypothesis that agency and ownership must be grounded on a more elementary notion that could account for their asymmetrical relationships, and the notion of the bodily self as power for action seems to be a good candidate for it.

The conflict experienced by patients affected by anarchic hand syndrome reveals that the sense of agency is built upon the potentialities for action characterizing the body as bodily self, representing such potentialities the background against which the different motor intentions take shape. (Being "built upon" does not imply that the sense of agency fully overlaps with the bodily self. What we mean is that the power for action is a prerequisite of agency and ownership and as such is sufficient to define a notion of minimal self.) In the anarchic hand syndrome, the control mechanism regulating the potentialities for action within a coherent and stable motor pattern, i.e., within a motor intention, due to brain lesion does not work anymore. However, the anarchic hand is still felt as being part of the experiencing and acting body and its actions, even if occurring outside the agent's will, are still lived by the patient as potentialities of his/her body, i.e., as potentialities of his/her bodily self. The anarchic hand syndrome usually follows lesions of the anterior part of the corpus callosum and of the supplementary motor area (SMA). The "alien hand", in contrast, is usually produced by lesions of posterior corpus callosum and of the neighboring parietal cortex. In such syndrome the hand is felt as not belonging to the patient's body, thus Marchetti and Della Sala (1998) proposed to consider it as a mild or partial form of hemisomatoagnosia (see next section).

Brain lesions also impinging upon the mesial aspect of the frontal cortex, often bilateral lesions involving both the SMA and pre-SMA, may produce what has been defined utilization behavior (Archibald, Mateer, & Kerns, 2001; Lhermitte, 1983; Lhermitte, Pillon, & Serdaru, 1986). These patients compulsively grasp and use objects present in their immediate environment even when the object is not needed (Boccardi, Della Sala, Motto, & Spinnler, 2002). They perform such goal-related motor acts in an instrumentally correct way, although inappropriate given the context in which they occur. For example, they can grasp and put on a pair of spectacles, even if they already wear a pair of them. Curiously, at difference with the anarchic hand syndrome, patients suffering of utilization behavior do not perceive any conflict between their will and the actions they perform, thus they never show perplexity at their own behavior.

We posit that the correct instrumental goal-relatedness of these actions as they are performed enables the experience of ownership they evoke in these patients. The instrumental correctness of such goal-related motor acts, in spite of their lack of explicit sense of agency, is determined by the activation of the neural networks normally underpinning the visuo-motor transformation enabling visually-guided actions such as grasping and putting on spectacles. The visuo-motor transformation process taking place within the parieto-premotor networks is usually controlled by mesial frontal areas that can select intended actions and inhibit unintended ones. In the case of action inhibition, the motor acts evoked by the objects' affordances remain at the state of mere potential actions, and generate the pragmatic meaning of the surrounding things, thus enabling our practical attunement with the world even in the absence of any overt motor behavior (Rizzolatti & Gallese, 1997).

In the anarchic hand syndrome and in utilization behavior the potential motor acts become current and overt actions even when unintended, i.e., when not endogenously evoked. These syndromes show that the sense of body – characterized as we did as power for action – is the prerequisite upon which the sense of agency can be built. Both the anarchic hand syndrome and utilization behavior indicate that our body experiences itself as bodily self inasmuch it experiences itself as the source of potential actions that are owned by the body even before any explicit feeling of agency.

4. The "hidden side" of action

So far we have considered the bodily self in action. In this section we will show that many of the different and more or less explicit forms of self-recognition we entertain of our body rely upon the pre-reflective experience we make of the body as power for action, even when the actual execution of action is not required or physically impossible, because of a brain lesion. Thus, we will demonstrate that not only the sense of agency, but also the sense of ownership, and even the possibility to be aware of the existence of a given part of our body can be accounted for by a bodily self-characterized by its intrinsic potentiality for action.

Our body is probably what we usually trust the most among the things that populate the world in which we live. In normal conditions we never doubt that our hand is *our* hand, or that the feeling experienced by the contact produced when the same hand touches an object is *ours*. At the same time, we would normally find rather odd to attribute feelings to an object when we see it being touched, and even incredible to personally own its feelings.

However, all of the abovementioned certainties we entertain about our body can be easily fooled: it only takes a brush and a rubber hand. Furthermore, neuropsychology shows us that focal lesions damaging part of the parieto-premotor circuits mentioned in the previous section can distort the awareness of the body parts whose motor acts are controlled by the same circuits, so that patients deny the absence of or can even experience the execution of movements they cannot execute because of their paralysis. Similarly, other patients affected by acquired or congenital limb deficiency can entertain the phenomenal awareness of moving the limb they no longer have or never had, a phenomenon known as 'phantom limb sensation'.

Let us start with the self-recognition of body parts in healthy subjects. Tsakiris, Haggard, Franck, Mainy, and Sirigu (2005) 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, and Gallagher (2007), this shows that "Self-recognition was significantly more accurate when subjects themselves were the authors of the action, even though visual and proprioceptive information always specified the same posture, and despite the fact that subjects judged the effects and not the action per se" (pp. 654, 655). The highest accuracy displayed by participants in body self-recognition was most likely due to the role played by the motor system in binding together in a coherent fashion visual and proprioceptive afferent signals.

The Rubber Hand Illusion (RHI, Botvinick & Cohen, 1998) 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.

Pavani, Spence, and Driver (2000) demonstrated that the correlation of visual and tactile percepts is a necessary but not sufficient condition to generate the illusion. In fact, they showed that the RHI can be evoked only if the rubber hand is occupying a position in space congruent with the real unseen hand, while the illusion disappears if the rubber hand is rotated by 90° with respect to participants' own hand (see also Tsakiris & Haggard, 2005). Tsakiris, Prabhu, and Haggard (2006) also showed that in the RHI proprioceptive awareness occurs in a piecemeal fashion, i.e., is fragmented so that if only one finger is synchronously stimulated in both the real and dummy hand, the illusion only applies to that finger and not to the non stimulated ones. However, if the RHI is tested during self-generated voluntary movements of one finger of the real hand, a global change in proprioceptive awareness occurs: participants perceive a drift of the whole hand – and not of the sole stroked finger – towards the location of the rubber hand. Such effect does not occur with passive movements of the same finger. On the basis of this evidence Tsakiris et al. (2006) correctly concluded that active movements integrate distinct body parts into a coherent unified self-awareness of the body.

It appears therefore that the RHI, in which vision dominates touch, is strictly dependent upon the action-compatibility of the perceived hand with the bodily self-awareness generated by the body schema in its functional character of potentiality for action. If the dummy hand occupies a position in space incompatible with the power for action intrinsic to the body schema, the illusion does not occur. In contrast, as shown by Longo, Schüür, Kammers, Tsakiris, and Haggard (2009), physical similarity between the real and the dummy hand does not affect the RHI, while previous experience of the RHI does affect the perceived similarity between the two hands.

This shows that the multisensory integration leading to the experience of our body as our own, far from being the outcome of a mere visual–propioceptive perceptual association, is conditioned by the possibility – or not – to perform actions with a given body part. Even when participants are completely still and not required to perform any overt movement, it is the bodily self to constrain and shape the modality of multisensory integration on the basis of the principles underpinning participants' potentiality for action. Coherent with our thesis is also the finding that feeling of ownership induced during the RHI is reflected by and linearly correlates with neural activity in the ventral premotor cortex (Ehrsson, Spence, & Passingham, 2004).

de Vignemont, Tsakiris, and Haggard (2006) recently argued against both empiricist and rationalist views of the self because both views can be hardly reconciled, on the one hand, with the fact that multisensory integration per se is not sufficient to generate the RHI and, on the other, with the fact that the RHI indeed occurs in spite of a pre-existing sense of self-attribution of bodily experiences. de Vignemont et al. (2006) suggest a third hypothesis, namely, that the sense of ownership arises from the integration of afferent and efferent sources of information modulated by a synthetic cognitive model of the body as a whole. We question that such cognitive modulation is a necessary requisite. We posit that the potentiality for action of our bodily self is a necessary condition to accomplish the sense of body ownership we normally entertain. In bodily self-consciousness we experience ourselves as bodily-anchored potential agents. This is probably also the reason why it never occurs to us to own or disown internal organs like the lungs or the heart, in spite of the fact that we entertain interoceptive awareness of the very same organs. This is simply due to the fact that such organs have no potentiality for somatic goal-related action.

Another example showing the crucial importance of the potentiality for action in determining bodily self-awareness is represented by asomatognosia. Asomatognosia (see Arzy, Overney, Landis, & Blanke, 2006; Arzy, Molnar-Szakacs, & Blanke, 2008; Giummarra, Gibson, Georgiou-Karistianis, & Bradshaw, 2008) consists in the patient's feeling that parts of his/her body are missing or have totally or partly disappeared from corporeal awareness. Several studies have reported that patients suffering focal brain lesions of the posterior parietal and/or premotor cortex show asomatognosia of the limbs contralateral to the side of the lesion. Arzy et al. (2006), for example, described a patient that after lesion of the right premotor cortex reported that part of her left arm had become transparent so that she could see through it. In sum, the evidence indicates that defective motor intentionality due to premotor lesion leads to defective body parts self-awareness.

Similarly, mostly right-sided cortical lesions affecting the posterior parietal and/or premotor cortex can produce somatoparaphrenia (for a review, see Vallar & Ronchi, 2009). In somatoparaphrenia patients normally experience delusions towards the contralateral affected parts of their body, whose ownership is denied or referred to others. Such feeling of disownership manifests itself as a feeling of strangeness of the affected body part, separation from the patient's body, and delusional belief that the affected body part belongs to others. As pointed out by Vallar and Ronchi (2009) evidence showing that somatoparaphrenia occurs also when the affected body part is placed in the non-neglected portion of space, demonstrates that such disownership disturbance does not depend upon a lesion of the body schema uniquely conceived as a spatial map of different body parts. We add that somatoparaphrenia shows how much the bodily awareness of the body as our own body depends upon the integrity of parieto-premotor circuits enabling the functionality of a body schema conceived as the source of our potentiality for actions.

This hypothesis is further corroborated by considering that the body schema does not reflect the physical postures or boundaries of the body, but reflects the power for action that may exceed the actual domain of actions available to the body. This functional property becomes fully apparent when actions cannot be performed, for example, because of paralysis caused by brain lesions, and nevertheless patients show anosognosia, i.e., they not only deny their paralysis, but can even experience the execution of movements they cannot perform. Berti et al. (2005) assessed the anatomical distribution of lesions in right brain-damaged hemiplegic patients, who obstinately denied their motor impairment, claiming that they could move their paralyzed limbs. The results showed that the patients' anosognosia was associated with lesions in areas related to the programming and monitoring of goal-related motor acts, particularly Brodmann's premotor areas 6 and 44, the primary motor cortex, and the somatosensory cortex. The premotor regions responsible for the control of action are thus also crucial for the agents' awareness of the same actions.

It appears therefore, as emphasized by Berti et al. (2005, p. 490), that bodily self-awareness is "neither the prerogative of some kind of central executive system, hierarchically superimposed on sensory–motor and cognitive functions, nor a function that is physiologically and anatomically separated from the primary process that has to be monitored".

The anatomical correlates of anosognosia for action show that action awareness is implemented in the same cortical network responsible for the process that has to be controlled. Fotopoulou et al. (2008) recently showed that anosognosia for hemiplegia (AHP) is modulated by patients' motor intention. The authors of this study presented to patients with and without AHP substituted visual feedback of movement or of its absence in their left paralyzed upper limb by means of a prosthetic hand. They assessed whether patients' ability to visually perceive the substituted movement varied according to whether they were instructed to move the paralyzed limb or not, or where told that the experimenter would do it for them.

All patients self-attributed the observed prosthetic hand located at the canonical position of their left hand. This again shows that preserved visual input even in absence of proprioception is sufficient to determine the sense of body ownership. All patients believed they moved their plegic arm in conditions of self-generated movement accompanied by a movement of the prosthetic hand. Remarkably, this occurred also to patients without AHP, i.e., fully conscious of their paralysis. Only patients with AHP, though, were unable to detect absence of movement correctly in the self-generated condition, while they were able to detect it in the externally generated condition or in the absence of movement condition. Patients with AHP disregarded the absence of visual feedback when seeing the static prosthetic hand and claimed to have seen the movement they intended to generate. Their motor awareness resisted the damage suffered by their motor programming/monitoring parieto-premotor circuits. The patients' experience of their own moving limb – a limb they could not physically move – was enabled by the possibility to entertain motor intentions, most likely issued in spared mesial premotor areas like SMA and pre-SMA and cingulate cortex.

Indeed patients with and without AHP can experience their body both as an acting body and as their own body even in absence of effective bodily movements (Berti et al., 2007; Fotopoulou et al., 2008) because the possibilities for action constituting their body as a bodily self still contain those movements whose execution is for them physically impossible. Such possibilities for action shape their action awareness in virtue of the coherent sensory–motor patterns they generate.

The case of phantom limb experiences provides another example of the role played by the sense of body as source of action in determining bodily self-awareness. Phantom limb experiences may occur after limb amputations, deafferentations, or spinal chord injuries (for review, see Giummarra et al., 2008). Interestingly, phantom limb movements can be evoked by the observation of others' movements (Brugger, 2006), and phantom limb pain sensations can be triggered by seeing another person in pain (Giummarra & Bradshaw, 2009).

The experience of owning a non-existing limb can lead some amputees to perform incipient motor acts with their phantom limb. Furthermore, the conscious intention to move the phantom limb produces awareness of action, which has been correlated with activation of the primary motor cortex (Mercier, Reilly, Vargas, Aballea, & Sirigu, 2006; Roux et al., 2003). There is evidence that congenitally limb deficient patients may develop phantom limb sensations (the so-called *aplasic phantoms*), despite the fact that they never moved these absent parts of their bodies (Melzack, Israel, Lacroix, and Schultz (1997); Ramachandran, 1993; Ramachandran & Hirstein, 1998; Ramachandran & Rogers-Ramachandran, 1996). Brugger, Kollias, Muri, Crelier, and Hepp-Reymond (2000) described one of these cases. fMRI imaging of their patient during phantom limb sensations of hand movements showed activation of premotor and posterior parietal cortex. Aplasic phantoms can therefore be explained as the phenomenal correlate of planning/monitoring action of an absent limb.

5. Mirroring bodies

The bodily self we have been dealing with up till now is still a "solipsistic" self. This clearly is an abstraction. Of course, this abstraction has been fruitful enabling us to highlight the core features of the sense of body as well as the way the bodily self as power for action contributes to a minimal sense of self. However, in spite of its usefulness and methodological relevance, the investigation of the bodily self as a bodily subject practically attuned with his/her own surrounding world exclusively populated by inanimate things still remains unilateral and partial. Indeed, there is ample evidence that primary and basic experiences of the body and of the self as a bodily self are from the very beginning modulated by the encounter with other self-modeling bodies.

Several studies have shown that the capacity of infants to establish relations with "others" is accompanied by the registration of behavioral invariance. As pointed out by Stern (1985), this invariance encompasses unity of locus, coherence of motion, and coherence of temporal structure. This experience-driven process of constant remodeling is one of the building blocks of cognitive development. It capitalizes upon coherence, regularity, and predictability as they are bodily experienced during the close and ever more rhythmically attuned motor exchanges between infants and their caregivers. These motor social interactions constitute the starting point for the development of a bodily self shaped by a shared motor intentional horizon (Gallese, 2001, 2003; Sinigaglia, 2008a, 2009).

Already at birth humans are engaged in interpersonal relations. Meltzoff and Moore (1977; see also Meltzoff, 2007a, 2007b) showed that newborns are capable of reproducing mouth and face movements displayed by the adult they are facing. That particular part of their body replies, though not in a reflex-way, to movements displayed by the equivalent body part of someone else. As Meltzoff recently wrote (2007a, p. 126), "the bedrock on which common-sense psychology is constructed is the apprehension that others are similar to the self. Infants are launched on their career of interpersonal relations with the basic perception: 'Here is something like me"'. The data on early imitation seem to suggest that human newborns are capable of tuning their behavior with that observed in others. The sensory–motor system is already set to be coordinated with the power for action of others in a shared, participatory sense.

Infants, very early on, show unequivocal signs of social interaction sequences. They actively solicit their caregivers' attention and engage themselves in body activity displaying "proto-conversational" turn-taking structure, i.e., characterized by a structure remarkably similar to adult conversations (Braten, 1988, 1992, 2007; Meltzoff & Brooks, 2001; Meltzoff & Moore, 1977, 1994; Stern, 1985; Trevarthen, 1979, 1993; Trevarten & Aitken, 2001; Tronick, 1989; for a recent updated survey, see Reddy, 2008).

Furthermore, few months-old pre-verbal infants when engaged in social interactions show even signs of so-called "self-conscious emotions" like embarrassment, pride, and coyness at a developmental age preceding the onset of self-reflective consciousness, definitely well before they are capable of self-recognition when looking at their reflection in a mirror (Reddy, 2008). As Reddy writes ". . .[Self-conscious-emotions] rather than derive from conceptual development in the second year of human infancy, exist in simple forms as ways of managing the exposure of self to other from early in the first year and are crucial for shaping the infant's emerging conception of self and other" (p. 41).

Even a richer notion of the self, accounting for complex emotional experiences stemming from self-evaluative capabilities that would not be possible without the capacity to entertain the notion of other selves, is rooted in the reciprocity intrinsic to social interactions. "In the absence of reciprocity there is no alter Ego", writes Merleau-Ponty (1962, p. 357). It is not possible to conceive of oneself as a self without rooting this process of appraisal in the sharing of the same motor intentional horizon. Self–other interactions are shaped and conditioned by the same body and by the environmental constraints in which it operates.

This common relational character might be in part underpinned, at the neural (subpersonal) level, by the mirror mechanism. The discovery of mirror neurons, i.e., of a specific class of motor neurons discharging during both the execution and the observation of goal-related movements, and the subsequent research this discovery generated have shed light on the neural mechanism at the basis of the capacity of entertaining an intersubjective mapping, which does not require an explicit inference by analogy because it operates at the level of pre-reflective motor intentionality (Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996; for a comprehensive and updated account, see Rizzolatti & Sinigaglia, 2008).

The relevance of the mirror mechanism stems from the fact that for the first time it has been found a neural mechanism allowing direct matching between observed and potential executable motor actions, thus providing a parsimonious and effective solution to the problem of translating the sensory information of others' bodily movements into something that the observer is able to immediately recognize, to the extent that it refers to his/her own motor ability to act. In virtue of its peculiar mapping of others' actions the mirror mechanism enables the observer to be immediately tuned with the witnessed behavior of others and to understand their motor goals and intentions. This tuning with others is practical in nature and represents a constitutive part of the *praktognosia* that, according to Merleau-Ponty, provides one's own body with a primary access to the world and the objects (1962, p. 140).

By emphasizing the role played by the mirror mechanism in basic forms of intersubjectivity we do not want to say that such mechanism is per se able to reflect the self-reference at the basis of the explicit recognition of one's actions as one's own actions or of others' actions as their own actions. Also we will not deal here with the problem whether in order to get a full-blown understanding of action the mirror mechanism should be integrated by a neural mechanism specifically devoted to code the agent of action (de Vignemont & Fourneret, 2004). Rather, we want to highlight that such a mechanism is at the basis of our primary ways of interacting with others. These ways of interacting with others, in turn, do contribute to the emergence of a minimal sense of self as bodily self.

To this regard, the distinction between mirror-based motor resonance and mirror-based action understanding (Rizzolatti, Fadiga, Fogassi, & Gallese, 1999) becomes crucial. Mirror-based motor resonance allow infants and their caregivers to make contact, thus achieving a primary form of the parity condition that is at the basis of any type of social engagement and communication. Being rooted in the infant's motor repertoire, this kind of motor resonance cannot but capitalize on the deepest entrenched motor responses and facilitate their execution. In early imitation as well as in proto-conversations infants experience the emergence of a motor intentional self-structuring body that is modulated by and at the same time modulates the experience of other acting bodies (Stern, 1985). Throughout their motor (and emotional) attunement with others infants develop a sense of their own body as power for action that, even if not fully unitarily integrated, enables the emergence of a primary sense of self as bodily self.

Of course, this is just a primitive form of bodily self-awareness, devoid of the stability and coherence typical of the full-fledged senses of self. Nonetheless, this primitive bodily self-awareness is at the basis of the development of more structured forms of intersubjective dealings and body experiences taking place during the first year of life, thus contributing to refine the infant's sense of body as power for action. Such primitive form of bodily self-awareness also shows that it is not necessary to postulate an a priori self to distinguish self-related from other-related sensory and motor experiences. What the mirror mechanism does – at the level of motor resonance – is to promote the first forms of motor (and emotional) attunement with other bodies enabling infants to carve out their own first motor potentialities, without explicitly recognizing them as stemming from a body conceived as the vehicle of a full-fledged sense of self, characterized by the development of a mature and reflective sense of agency and sense of ownership.

Similarly, mirror-based action understanding (Rizzolatti et al., 1999) provides a coherent neural functional framework to account for infants' development of intentional understanding. A number of studies indicate that infants are able to recognize the goal-relatedness of bodily movements performed by someone else inasmuch they have developed the motor expertise necessary to achieve such motor goals and intentions. Indeed, a series of looking-time experiments have shown that infants of 5/6 months of age – the age by which they master the ability to perform smooth and efficient reaching and grasping movements (Bertenthal & Clifton, 1998) – are able to discriminate between motor intentional and mere kinematics cues. This did not occur when the observed scene involved objects (e.g. a claw) or, even more interestingly, bodily movements that were incoherent with respect to a given motor goal (e.g. the back of the hand was approached to the object in order to grasp it) (Woodward, 1998, 1999). Infants are shown to be sensitive to the goal-relatedness of observed movements even at 3 months of age, but only when facilitated by previous motor experience (Sommerville, Woodward, & Needham, 2005).

Motor expertise shapes infants' understanding also of tool-use action (Sommerville, Hildebrand, & Crane, 2008) as well as of complex motor actions, displaying specific motor goal hierarchies (Woodward & Sommerville, 2000). A study of 10-month-old infant looking times has demonstrated that only those infants who were themselves able to execute determined sequences of hierarchically organized motor acts were able to recognize the same sequences performed by others (Sommerville & Woodward, 2005). Finally, 12-month-old infants have been shown to produce proactive goal-directed eye movements when observing a goal-directed placing action only to the extent they can perform it (Falck-Ytter, Gredeback, & von Hofsten, 2006).

These data suggest both that an action observation and execution matching mechanism such as the mirror mechanism undergoes critical developments within infancy, accounting for infant's growing sensibility to other's motor goals and intentions (Lepage & Théoret, 2007; Sinigaglia, 2008b; Gallese, Rochat, Cossu, & Sinigaglia, 2009), and also that this mechanism contributes to further articulate the primary bodily self-awareness enabling infants to be intentionally attuned with others and not only to motorically resonate with them. Such intentional attunement takes the form of motor intentional dealing between different bodily selves. Occurring at the level of a basic and minimal self, this dealing turns out to be a mutual interaction between different powers for action characterized by more or less complex patterns of sensory–motor coherence.

What is critical in the mirror mechanism is the fact that it capitalizes upon the same motor potentialities for action that constitute the minimal sense of self as bodily self. The more this motor potentialities for action diversify and refine, the more the pre-reflective bodily awareness of self-diversify and refine together with the interaction modalities with other self-modeling bodies. This means that even before any explicit recognition of oneself as the author of one's action and/or as the subject of one's body, there is a sense of self as bodily self that for its own nature (i.e., for its intrinsically being power for action) is practically attuned with other bodily selves, shaping both one's own and others' self-experience. We do not mean to say that the mirror mechanism encodes per se the self- and other-relatedness of actions. Rather, more simply, we want to emphasize that the mirror mechanism capitalizes upon the very same power for action at the basis of our first-person capability for acting. In so doing the mirror mechanism contributes to the emergence of a bodily self, as it develops during the different stages of one's practical attunement with other bodily selves.

6. Concluding remarks

In the present paper we argued that there is a minimal sense of self as bodily self that is necessary for and antecedent to both the sense of agency and the sense of ownership, contributing to make them possible. This minimal sense of self is at the basis of our practical attunement with the surrounding world of objects and others. For this reason the bodily self cannot be reduced to a mere product of associative sensory–motor couplings or to a more or less sophisticated action monitoring mechanism. Rather, the bodily self has to be primarily and originally construed in terms of motor potentiality for actions, inasmuch the nature and the range of such potentiality define the nature and the range of pre-reflective bodily self-awareness.

Our notion of bodily self enables to go beyond the dichotomy between sense of agency and sense of ownership, highlighting the constitutive role of the bodily space of action in generating a minimal sense of self. It also sheds new light on the binding mechanism presiding over the coherent sensory–motor integration characterizing our experience of action. The evidence here reviewed shows how crucial parieto-premotor cortical networks are both in producing a coherent sense of bodily self and in explaining some of the most bizarre and striking cases of action awareness. All of these cases show that irrespective of whether action execution be requested or physically possible, there is one dimension of action that is at the same time motor intentional (goal-related) and potential in nature that prefigures and enables the emergence of a coherent bodily self-awareness.

Finally, it is just the emphasis on the motor intentional and potential dimension of action that allows us to avoid any solipsistic temptation when investigating the minimal sense of self. From the very beginning our bodily self-awareness is built upon the motor potentialities that enable to interact with other bodies and to tune our motor goals and intentions with respect to the motor goals and intentions of others and vice versa.

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