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How the Body in Action Shapes the Self

Abstract: *In the present paper we address the issue of the role of the body in shaping our basic self-awareness. It is generally taken for granted that basic bodily self-awareness has primarily to do with proprioception. Here we challenge this assumption by arguing from both a phenomenological and a neurophysiological point of view that our body is primarily given to us as a manifold of action possibilities that cannot be reduced to any form of proprioceptive awareness. By discussing the notion of affordance and the spatiality of the body we show that both have to be construed in terms of the varying range of our power for action. Finally, we posit that the motor roots of our bodily self-awareness shed new light on both the common ground for and the distinguishing criterium between self and other. The properties of the mirror mechanism indicate that the same action possibilities constituting our bodily self also allow us to make sense of other bodily selves inasmuch as their action possibilities can be mapped onto our own ones. Our proposal may pave the way towards a general deconstruction of the different layers at the core of our full-fledged sense of self and others.*

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I. Introduction

Over the last two decades self-consciousness has been on the agenda of an increasing number of researchers from a variety of empirical and theoretical disciplines, including cognitive neuroscience, neuropsychology, developmental psychology, philosophy, and psychiatry. What is common to most of them is the insight that self-consciousness is a complex multi-layered phenomenon, so that dealing with it above all means dealing with the different layers which contribute to the shaping of our experience of ourselves, starting from the more primitive and basic ones. José Luis Bermúdez speaks for many when he writes:

> There are many distinct layers of self-consciousness. Obvious examples are the capacity to think of one's body as one's own; to recognize oneself as the bearer of mental states; to master the grammar of the first-person pronoun; to view oneself as one object among others; to have memories about one's past self; to construct autobiographical narratives; to formulate long-term plans and ambitions. Whichever one of these one is considering, however, it is tempting to think of it as somehow parasitic on a more primitive and already-existing form of self-awareness… If this is so, and if a regress is to be avoided, then it seems plausible to suppose that all these layers must eventually be grounded in a form of self-awareness primitive enough not to depend on a more basic self-awareness. (Bermúdez, 1995, p. 153)

Bodily self-awareness seems to be one of the most tempting and attractive candidates for the basic level of self-awareness that might be at the core of a comprehensive account of the manifold forms of self-consciousness. Indeed, a great deal of studies approaching the experience of the body from very different perspectives, by either exploring its neural underpinnings or investigating the components that make its phenomenology so distinctive, converge on the claim that bodily awareness has a primary role to play in self-awareness. However, despite such convergence and the undeniable progress in the knowledge of the sources and of the features of bodily awareness, it is still far from clear what bodily awareness primarily is and which among the various forms of self-awareness that are typically labelled as 'bodily' might actually incorporate the basic level of self-awareness. This is not (or not only) imputable to the alleged conflicts between the manifest or phenomenological image of ourselves as bodily selves and the scientific image of ourselves and our body as revealed by the cognitive neurosciences (Bayne and Levy, 2006). Rather, it is more likely to be due to the fact that some key aspects of our bodily experience have often been taken for granted and never radically questioned from a phenomenological, a psychological, or a neurophysiological point of view.

It seems, for instance, quite obvious for many contemporary neuroscientists, psychologists and philosophers of mind to think of bodily awareness in terms of proprioceptive awareness (see, for example, Bermúdez, Marcel and Elian, 1995; Gallagher and Shear, 1998; Gallagher and Zahavi, 2008). But what does proprioceptive awareness really mean? Does it consist in an interoceptive awareness closely related to a specific sensory modality? Or should it be interpreted in a broader sense as a kind of bodily awareness, which goes beyond the distinction between intero- and exteroceptive awareness, belonging to any sensory modality (vision, touch, hearing, etc.)? At any rate, are we really sure that, whatever the interpretation of proprioception, the phenomenological distinctiveness of bodily awareness should be *exclusively* or *primarily* construed in terms of proprioceptive awareness? Are we really sure that this is the only or the best way to understand the role of bodily awareness in shaping our basic forms of self-awareness? And are we really sure that this is really in line with all we know about the body from cognitive neuroscience? Is it not the case that the primacy assigned to proprioceptive awareness is due to a naïve model of the phenomenology of the body?

The aim of the present paper is to address these questions. A way of doing it is to provide a theoretical framework as unitary as possible to the psychological and neurophysiological findings that, over the past few years, have undermined the traditional way of interpreting bodily awareness and its role in shaping our self-awareness. This is what we have pursued in another work (Gallese and Sinigaglia, 2010). Here we will employ a different strategy. We will begin with some preliminary remarks on the ways in which we can be aware of ourselves and of our body. We will then scrutinize the various forms of bodily awareness in order to find out which of these, if any, could be considered the best candidate for the primary and basic form of self-awareness. Finally, we will investigate whether and to what extent our bodily awareness might play a critical role in shaping the primary and basic awareness not only of ourselves but also of others.

A methodological caveat is in order. Our concern will be neither the metaphysics nor the epistemology of self- and bodily awareness; rather (and more modestly), we will focus on the phenomenology of bodily self-awareness, taking it both as the departure and as arrival point of the investigation of the subpersonal mechanisms underlying our bodily experience. Indeed, we believe that such an investigation would be ‘blind’ were it not driven by an accurate phenomenology of bodily experience, as well as the latter would be ‘empty’ were it not anchored to the study of its corresponding neural underpinnings. Of course, this does neither amount to conflating the different levels of analysis, nor to postulating a simple isomorphism between them. More simply, it’s about acknowledging the necessity of an integrated approach, able to combine phenomenological analysis and empirical research, questioning what both approaches have often taken for granted.

II. The Bodily Self and Proprioception

Many authors have found compelling the notion that we have a specific sense of our own body providing us with an immediate knowledge of it, that is, proprioception. However, although the term ‘proprioception’ seems to suggest an intuitive connection of the body with the self, its meaning is far from clear and unambiguous. To this regard, it may be helpful to begin by distinguishing between *proprioceptive systems*, consisting of the different channels yielding information about the state and the performance of the body, *proprioceptive information*, including all the information available about the body, and *proprioceptive awareness*, taken as the conscious experience of the body from the inside (Eilan *et al.*, 1995, p. 14; see also Marcel, 2003).

Proprioceptive systems are, literally, systems in charge of mapping the perception of our own body. Such perception is classically considered distinct from our perception of internal visceral organs, defined as interoception (Sherrington, 1907). Proprioceptive systems provide information about the position and the sense of movement of our different bodily parts with respect to themselves and to the external world. However, some consider kinaesthesia, or movement sense, as an independent system. From a physiological point of view, proprioception is a functional property of part of the somatosensory system. Within the somatosensory system a variety of receptors (e.g. muscle spindles, Golgi tendon organs, skin stretch receptors, etc.) are distributed at the periphery of our body within muscles, tendons and joints. These receptors transduce mechanical energy applied to our body under the form of muscle or skin stretches, angular rotations, and the like, into action potentials travelling from the body periphery along large myelinated fibres contained in sensory nerves up to centres of the central nervous system occupying progressively higher hierarchical levels. In addition, when referring to proprioception, physiologists sometimes also include sensory signals originating from receptors contained within the vestibular apparatus of the inner ear. These receptors also transduce mechanical energy impinging upon them, because of the linear and angular displacements of our head in space, into action potentials, fed through the VIII cranial nerve to a variety of nuclei in the brain stem and to the cerebellum (for a more comprehensive account of these issues, see Kandel, Schwartz and Jessell, 2000).

However, all of this is only part of the story. Indeed, a liberal understanding of *proprioceptive information* as self-specific information enables a broader and more useful conception of proprioception. The Gibsonian theory of ecological perception seems to be exemplar to this regard. As it is well known, according to Gibson proprioception should be understood 'not as a special channel of sensations or as several of them', but as 'ego-reception', as 'sensitivity to the self'. In this vein, Gibson writes:

> all the perceptual systems are propriosensitive as well as exterosensitive, for they all provide information in their various ways about the observer's activities. The observer's movements usually produce sights and sounds and impressions on the skin along with stimulation of the muscles, the joints, and the inner ear. Accordingly, information that is specific to the self is picked up as such, no matter what sensory nerve is delivering impulses to the brain. The point I whish to make is that information about the self is multiple and that all kinds are picked up concurrently. (Gibson, 1979, p. 115)

Hence, investigating the basic forms of bodily self would mean investigating the structural invariants that provide us with the self-specifying information available in our perception of the surrounding world, regardless of whether such information is conveyed by one or another sensory system. Take, for instance, the case of visual perception. As Gibson repeatedly puts it, 'the optical information to specify the self… *accompanies* the optical information to specify the environment. The two sources of information coexist. The one could not exist without the other. When a man sees the world, he sees his nose at the same time; or rather, the world and his nose are both specified and his awareness can shift' (*ibid.*, p. 116). Whatever falls within our visual field may be hidden or occluded by a given part of our body. And there is no doubt that our nose occupies a dominant position in our visual field. The same is also partly true for our eye sockets, for our eyebrows, or even for our beard — not to mention, although to a lesser extent, our arms, legs, hands, and feet. While our nose is the nearest occluding edge, our body extremities protrude into our visual field from below. They are more peripheral occluding edges, but, differently from non-bodily physical objects, appear to be 'attached' to us and cannot be seen beyond a given distance from us.

According to Gibson, this is not the only way in which visual perception may provide us with self-specifying information. There are three more ways, at least. The first one has to do with the fact that our body bounds our visual field. This kind of boundedness is completely different from that which may be proper to any spatial object falling within our field of view. Indeed, although at first glance the boundaries of the visual field could look like the occluding edges of a window, they differ from them, as Gibson writes, 'inasmuch as, for the window, a foreground hides the background whereas, for the field of view, the head of the observer hides the background. Ask yourself what it is that you see hiding the surroundings as you look out upon the world — not darkness, surely, not air, not nothing, but the ego!' (*ibid.*, p. 116).

The second kind of self-specifying information supplied by visual perception is what Gibson called 'visual kinesthesis' (*ibid.*, p. 183). Every movement we perform produces a systematic flow pattern in our visual field. Imagine you are walking towards the opposite wall of your lecture hall, looking straight ahead: the constantly changing visual information available to you flows outward from a single central and stationary point that is exactly the point toward which you are moving. This enables you to *see* not only *that* you are moving but also *where* you are moving. In addition, this kind of systematic flow pattern provides you with optical information about your own body postures. By now the so-called 'moving room' experiments have become seminal, where the participants are standing on the solid floor of the lab surrounded by independently moveable walls. It has been shown that when the room is moving toward the observer, thus creating the optical flow pattern typically associated with moving forward, she sways backward to compensate; on the contrary, when the room is moving away from the observer, thus generating the optical flow pattern typically associated with moving backward, she leans forward to compensate (Butterworth, 1995).

Last but not least, there is a third kind of self-specifying structural invariants that can be directly perceived. To name such a kind of invariants Gibson was forced to coin a new term, i.e. *affordance*: 'The *affordances* of the environment are what it *offers* the animal, what it *provides* or *furnishes*, either for good or ill. The verb *to afford* is found in the dictionary, but the noun *affordance* is not. I have made it up. I mean by it something that refers to both the environment and the animal in a way that no existing term does. It implies the complementarity of the animal and the environment' (Gibson, 1979, p. 127). Affordances are not just physical properties of the environment;

rather, they incarnate the practical opportunities that the environment may offer to any organism which is able to perceive and use them. Thus, a surface may be stand-on-able or sit-on-able relative to a given organism. Similarly, an object can be graspable, throwable, pressable, portable, or kickable for an organism with hands and feet. Affordances should therefore be construed in terms of a mutual relationship between the environment and the organism (Turvey *et al.*, 1981; Turvey, 1992), providing information about both the environmental/objectual features and also about the organism's capabilities (Chemero, 2003). To quote again Gibson:

> An affordance… points two ways, to the environment and to the observer. So does the information to specifying an affordance. But this does not in the least imply separate realms of consciousness and matter, a psychophysical dualism. It says only that the information to specify the utilities of the environment is accompanied by information to specify the observer himself, his body, legs, hands, mouth. This is only to re-emphasize that exteroception is accompanied by proprioception — that to perceive the world is to coperceive oneself. (Gibson, 1979, p. 141)

III. Affording the Bodily Self

Up to now we've limited ourselves to the distinction between proprioceptive systems and proprioceptive information, thus leaving open the question as to how bodily self-awareness has to be construed in order to capture the phenomenological distinctiveness of its content.

Many philosophers and psychologists share the notion that not only the ways in which we are aware of our body are different from the ways in which we are aware of physical objects, but also that the basic forms of bodily awareness are non- (or pre-) reflective in nature (Butterworth, 1995; Bermúdez, 1998; 2002; Gallagher, 2000; 2003; Thompson, 2005; Legrand, 2006; 2007; Gallagher and Zahavi, 2005; 2008). However, if we take a closer look at how such awareness has been phenomenologically characterized, we can't help noticing that it has been differently defined, sometimes as 'peripheral' (Bermúdez, 1998), sometimes as experientially or attentively 'recessive' (O'Shaughnessy, 1995). This shows that the proximity of our body proceeds at the same rate as its 'elusiveness' (Eilan, 1995) or, better still, with its 'eccentricity' (Dokic, 2003) or 'excess' (Gallagher, 2003). These different characterizations of bodily awareness rely on different construals of its phenomenological status. According to some authors such awareness should be understood as a form of perception in which one becomes aware of one's own body

(O'Shaughnessy, 1995). According to others it should be conceived as a sort of a non-observational self-acquaintance (Shoemaker, 1984).

In the first case, it is paradigmatic what José Bermúdez (1998) wrote about somatic proprioception, by resuming under the phenomenological viewpoint a few arguments used by Gibson in the analysis of self-specifying information:

> The best description of the phenomenology of touch is that tactile experience is always both exteroceptive and proprioceptive. Attention can be directed either proprioceptively or exteroceptively, and it can be shifted from one to the other, but this should be viewed as an alternation of the balance between focal and peripheral awareness. When attention is directed exteroceptively toward the spatial properties of an object, the perceiver remains peripherally aware of the spatial properties of the relevant limb, and vice versa. (Bermúdez, 1998, p. 139)

Of contrary advice is Shaun Gallagher, who, perhaps more strongly than others, has argued that bodily self-awareness is not perceptual in nature. Such conviction clearly emerges from Gallagher's phenomenological description of the similarities and differences between vision and proprioception:

> Are the fingers, as they function in haptic exploration, analogous to objects in peripheral vision, or to the way that eyes function in vision? Would it be right to say… that the eyes and their movements are part of the peripheral perceptual field? My eyes are obviously not part of my visual field — when I see an object, I do not see my eyes, even in peripheral vision. Rather, I see *with* my eyes… Just I see *with* my eyes, I touch *with* my fingers. I touch *with* my fingers, I have tactile experience, and I perceive the shape of the object in my hand, precisely when I am *not perceiving* my fingers. The tactile perception of an object is not accomplished through my perceptual awareness of the changing spatial properties of my fingers; awareness of my fingers is not equivalent to my tactile awareness of the object. The body's mode of being in perceiving is more than to be perceived. (Gallagher, 2003, p. 61)

However, besides these divergences about the status of bodily awareness, all or almost all authors take it for granted that such awareness is, in its most typical form, a proprioceptive awareness. It doesn't matter whether bodily awareness might be enteroceptively or exteroceptively produced, what really counts is that this awareness is generally understood as awareness of one's own body postures, of one's own body-parts and limbs, with their position, with their boundaries, and with their being at rest or in movement. One should wonder, though, whether we are really primarily aware of our body in this way. This, obviously, doesn't mean denying that proprioception, in whatever sense such term may be understood, contributes to our bodily awareness. Quite the contrary, but the question still remains unanswered as to whether it really is *exclusively* and *primarily* by means of proprioception that we are aware of ourselves as bodily selves. Is this, as a matter of fact, the only and primary way to understand the self-reference constitutive of bodily awareness? Doesn't the mere extension of the concept of proprioception contribute to question the idea that our bodily awareness should primarily be understood in terms of 'awareness of one's own movement and posture' (Neisser, 1988, p. 37)?

To tackle these issues, let us go back to the notion of affordance which, according to Neisser, plays a critical role in the ecological approach to the self, because it captures a primary aspect of our experience of the surrounding world:

> At any given moment the environment affords a host of potentialities: I could grasp that object, sit on that chair, walk through that door. These are examples of *affordances*: relations of possibility between actors and environments. It is affordances that animals most need to see: here is prey that I might eat, a predator who might possibly eat me, a tree I might climb to escape him. (Neisser, 1991, p. 201)

It has been argued that these 'relations of possibility' should be construed as relations between the features of a situation as a whole and the motor abilities of an individual (Chemero, 2003; 2009; Costantini and Sinigaglia, in press). Sometimes it is tacitly assumed that the aspects that determine what the environment affords are just physical in nature as, for instance, the body scale. It is sometimes claimed, for example, that experiments on stair climbing, starting from the seminal Warren (1984) studies, would demonstrate that stair climbing affordances could be quantified in terms of the ratio between the leg length and the riser height. However, as Antony Chemero aptly remarks, 'the body scale is only occasionally a good place holder for ability' (Chemero, 2009, p. 143), and there is evidence that stair climbing affordances are a function of the stair climbing ability, not of leg length (see, among others, Cesari *et al.*, 2003).

Objectual or micro-affordances clearly show that the affordance relation is rooted in the individual's motor abilities (Ellis and Tucker, 2000). Indeed, a number of behavioural studies demonstrate that the sight of something graspable immediately retrieves the suitable set of hand-action possibilities, even in the absence of both any effective interaction and also any intention to act (Craighero *et al.*, 1999; see Gallese, 2000). In particular, it has been shown that task-irrelevant object information (e.g. the left-right orientation of the handle of a mug) may facilitate the execution of left-right hand motor acts when the orientation of the affording part of the object (e.g. handle) is spatially aligned with the responding hand (Tucker and Ellis, 1998; Ellis and Tucker, 2000; Tucker and Ellis, 2001; 2004).

Neurophysiological and neuroimaging studies have clarified the putative neural counterparts of these behavioural data. From a neurophysiological point of view, perceiving affordances implies that the same neuron must be able not only to encode the motor acts (e.g. hand-grasping) it controls, but also to respond to the situated visual features supporting or even demanding that motor act. Single cell recordings from the ventral premotor cortex (area F5) and inferior parietal lobule (area AIP) of the monkey brain have revealed the existence of a special class of visuomotor neurons responding to the visual presentation of objects of different size and shape, even when the monkey was just fixating them without being required to grasp them (Rizzolatti *et al.*, 1988; Jeannerod *et al.*, 1995; Murata *et al.*, 1997; Rizzolatti and Craighero, 2004; Raos *et al.*, 2006; Umiltà *et al.*, 2007).

Similar results have been found in humans. Indeed, several fMRI studies have demonstrated that the visual presentation of a graspable object automatically recruits the cortical motor system, even in the absence of any motor output (Grafton *et al.*, 1997; Chao and Martin, 2000; Grèzes *et al.*, 2003). More recently, a TMS experiment investigated the excitability of the primary motor cortex while observing manipulable familiar objects, i.e. a mug, with an intact or broken handle (Buccino *et al.*, 2009). The results showed that motor evoked potentials (MEPs) were larger only when the handle was complete, thus indicating that the cortical motor system is critically involved not only in the detailed programming and on-line control of elementary movements, but also in the processing of the pragmatic features of the surrounding objects. The motor system enables us to perceive them in terms of actual possibilities for action, that is, as effectively graspable or not.

All of this seems to be in line, at least at first glance, with the emphasis put on the crucial role of action in the ecological approach to perception by Gibson (1979) and the Gibsonians (Turvey, 1977; Neisser, 1988). For example, Neisser writes that 'the distinction between perception and action can be made only at the level of theoretical analysis; in ordinary behaviour, they are inseparably fused. Except in special cases, we do not perceive and only then proceed to move. We perceive *as* we act and *that* we act; often our actions constitute the very characteristics of the ecological self that we are simultaneously perceiving' (Neisser, 1988, p. 40). Now, it is true that according to most ecological theorists action enables us to pick up invariant information specifying both the environment and the self. However, the question arises here as to whether and to what extent action should be conceived as 'merely a means for gaining access to higher-order invariants present in afferent stimulation' (Hurley, 1998, p. 433), or rather as a constitutive principle for perception, even without the execution of any movement.

Indeed, the above-mentioned empirical findings clearly show that the sight of an object may evoke a motor activation in the observer's brain even in absence of any overt motor behaviour, thus indicating that the object is encoded in the same way in both the execution and observation condition. This suggests not only that object perception is strictly intertwined with action, but also that action constitutively shapes the way we perceive, characterizing the perceived object in terms of motor acts it may afford — and this even in the absence of any effective movement. The perception of an object, therefore, is at the basic level nothing but a call to arms, so to speak, which regardless of whether we actually pick the object up, primarily gives it to us as a virtual target for action, that is, as something that can be grasped with this or that bodily part (hand, mouth), with this or that grip (whole hand prehension, precision grip), and so on (Gallese, 2000).

The notion that our perception might be shaped by action, even when we are not executing any movement, and that such action-oriented perception is an original and primary way of being engaged with the surrounding world, has consequences for the phenomenological account of the way in which we experience ourselves as bodily selves. Indeed, in perceiving something as grasp*able*, throw*able* or kick*able* we are experiencing ourselves as bodies that *can* grasp, throw or kick. Such power is not to be conceived just as a general ability (Mele, 2002), but it refers to an action possibility, that is, to a possibilty that an individual is aware of as being actually ready to his/her hands. In perceiving something as graspable or as kickable our body is given to us as a grasping or kicking body, that is, in terms of a given action possibility. In other words, our experience of the surrounding things cannot but be accompanied by the experience of ourselves as a bodily 'power' for action, that is, as the variety of action possibilities belonging to our own motor repertoire, which contextually become ready to our hands (Gallese and Sinigaglia, 2010).

Again, this does not imply that we have to think of our body as performing a given action or to explicitly recognize that such and such motor possibilities belong to our own motor repertoire. Quite the contrary: our body can be given to us as power for action, regardless of whether we are attending to it. It is in this vein that Alva Noë writes: 'The body is present… as a range of potentialities of movement or action… For example, my arms can be present to me now, even though I am not now thinking of them: the feeling of their presence comes down to such things as my sense that the coffee cup on the table is within reach' (Noë, 2009, p. 77). Sensing the reachability and graspability of the coffee cup means to experience not only its call to action, but also and above all our own body as power for that action, that is, as a body that can reach and grasp. The two experiences can be distinguished only by abstraction, given that one could not exist without the other. To paraphrase Gibson, when a man sees the world, he sees his own action possibilities at the same time; or rather, the world and the possibilities are both specified and his awareness can shift.

IV. The Bodily Self as Manifold of Action Possibilities

If our characterization of affordances is correct, and, notably, if affordance perception implies, both at the subpersonal and personal level, a sense of body that is *primarily* motor in nature, one may wonder whether and to what extent such a bodily awareness can be considered to be 'primitive enough not to depend on a more basic [bodily] self-awareness' (Bermúdez, 1998, p. 153).

Indeed, even assuming that, as in the case of affordances, our body might be given to us as power for action, one could still argue that this form of bodily awareness generally presupposes proprioceptive awareness. The latter implies every kind of awareness of limb position and bodily configuration, regardless of whether it is exteroceptively or interoceptively generated.

Still, if one considers more closely the distinctiveness of the content of bodily awareness, it appears that proprioceptive awareness is neither prior to nor grounding bodily awareness as power for action. Of course, this is not say that proprioceptive awareness does not play any role in bodily awareness. It also does not imply that bodily awareness as power for action alone provides us with a full-fledged sense of body as bodily self. The point is that proprioception, even when conceived of in the broadest sense, falls short of giving us the specific sense of our own body we basically entertain when interacting with the world around us. This is true not only when we effectively act upon the world but also, and most importantly, when we merely perceive it.

Let's focus first on action execution. At the subpersonal level the possibility to perform a basic motor act, such as grasping a cup of coffee, is rooted in action-committed cortical circuits whose neurons are selectively wired to represent and control that motor act. As already mentioned when discussing the notion of affordance, there is compelling evidence of the existence in the cortical motor system of a set of motor neurons encoding motor goals and motor intentions (Rizzolatti *et al.*, 1988; Jeannerod *et al.*, 1995; Gallese, 2000; Murata *et al.*, 2000; Fogassi *et al.*, 2005; Umiltà *et al.*, 2008; Bonini *et al.*, 2010). Such encoding allows for a more general and at the same time more parsimonious characterization of the motor constraints relevant to action (Rizzolatti *et al.*, 2001). Indeed, by mapping actions in terms of their motor goals and intentions, the cortical motor system is able to represent them as such without needing to specify all the kinematic parameters. Interestingly, these goal-related motor neurons are somatotopically organized so that when they activate they instantiate a motor representation of their corresponding bodily part (e.g. hand, mouth, etc.) as accomplishing a given motor goal (e.g. grasping, biting, etc.). In other words, our body is mapped within the cortical motor system as a manifold of possibilities for action.

This cortical motor map makes action execution and control possible. All types of proprioceptive information do not specify anything about the content of our action possibilities as they are mapped for any bodily part by the motor system. Indeed, the proprioceptive representation of limb positions and bodily configuration might provide us with on-line information about the state and movement of our body. However, it does neither tell us what the body can actually do, nor what it is doing in terms of bodily-part specific, goal-directed motor acts. Proprioception, at best, conveys information about movements (e.g. muscle length, stiffness, etc.). Only the motor system conveys information about what movements are for. Take the case of the above-mentioned example of a hand grasping a cup of coffee. No proprioceptive description of the possible hand configurations implied by such a motor act could give us *per se* any information about the motor goal-relatedness of those configurations.

At the personal level it seems very hard to resist the temptation to consider proprioception as the mark of bodily self-awareness. However, we think that such temptation must be avoided. In fact, at the level of primary bodily self-awareness, what our body is primarily aware of is its motor possibilities for action, and not the grossly underdetermined and unspecific proprioceptive descriptions of its configurations that may accompany but never specify a given motor act. When we aim at a given object by moving our hand we are primarily aware of our own hand as a reaching-to-grasp hand. Proprioceptive awareness of our hand as a moving hand and of its finger configuration can help us during the on-line monitoring of action execution. Although such proprioceptive awareness might update bodily awareness, nevertheless, it is not by itself sufficient for generating the awareness of a bodily self. Differently from what is held by many authors, like Bermúdez (1995) or Gallagher (2003), the awareness of the configuration and displacements of our fingers cannot be assumed as a paradigmatic example of the attentively recessiveness (O'Shaughnessy, 1995) of bodily awareness, because it is not a constitutive part of its primary content. The actual 'eccentricity' (Dokic, 2003) or 'excess' (Gallagher, 2003) of bodily awareness concerns, first and above all, the fact that our body is primarily given to us as a manifold of possibilities for action as specified by our motor system.

The critical point is that this is true not only for action execution but also for object perception, as it is evident from our previous analysis of affordance. How can we possibly explain in terms of proprioceptive awareness the bodily awareness we experience any time we are engaged by the affording features of an object? While perceiving the handle of a cup as graspable we are at the same time aware of our body as a body that can grasp it. Of course, this type of bodily awareness is non-reflective in nature. And it is completely different from, and not reducible to, any form of proprioceptive awareness, kinaesthetic awareness included. Any postural adjustment or mere movement we might experience while perceiving a graspable object does not give us the primary awareness of our body as of the body that is constitutively part of the affording relation with the object.

A further argument in favour of our claim of the primacy of power for action in grounding bodily self-awareness comes from its spatial nature. Most philosophers and psychologists investigating bodily self-awareness have strongly emphasized that its characterizing aspect has to be found in the spatiality of its content (see, among others, Brewer, 1995; Martin, 1995; Bermúdez, 1998; 2002; 2004; 2006; Gallagher, 2003). Although this aspect has been construed in very different and sometimes conflicting ways, there seems to be general agreement upon the notion that the spatiality of bodily self-awareness has primarily to do with bodily space as proprioceptively experienced. However, neuroscientific research on brain space processing as well as a less naïve phenomenology of the experience of space both show that bodily space is basically and constitutively given to us as the horizon of our own action possibilities.

The distinction between personal, peri-personal and extra-personal space is critical to this regard. Personal space has been classically considered as the cutaneous space, while peri-personal and extra-personal space have been understood as the spaces within and outside immediate reach, respectively (Rizzolatti *et al.*, 1997). Now, there is a large amount of evidence that the actual space of our body exceeds its cutaneous boundaries, encompassing everything that is literally ready-to-our-own-hands. Indeed, several neurophysiological and neuropsychological studies showed that peri-personal space is not only multisensory (i.e. based on the integration of visual, tactile, auditory, and proprioceptive information), but also body-centred (i.e. encoded in somatic coordinates) and, first and above all, motor in nature (Gallese and Sinigaglia, in press).

A detailed analysis of these studies is beyond the scope of our paper. Nevertheless, it is worth mentioning here that single cell recordings from the premotor cortex (area F4 — Gentilucci *et al.*, 1988; Fogassi *et al.*, 1992; 1996; Graziano *et al.*, 1994) and the inferior parietal lobule (VIP area — Colby *et al.*, 1993; Duhamel *et al.*, 1998) of the macaque brain showed that peri-personal space is mostly encoded by bimodal visuotactile neurons, whose visual receptive fields (vRFs) are in register with the corresponding tactile receptive fields, being anchored to various body-parts (Graziano *et al.*, 1997).

Many F4 bimodal neurons discharge in association with arm reaching movements (Gentilucci *et al.*, 1988), thus suggesting that they are encoding the surrounding space in a motor format as a reaching space. As for the bimodal visuotactile parietal neurons, it has been shown that their vRFs can be modified by tool actions (Iriki *et al.*, 1996; Ishibashi *et al.*, 2000). After few minutes of tool-using the vRFs located on the paw extend to encompass the tool, as if the latter were incorporated into the former. When the monkey stops using the tool the vRFs return to their previous extension, even if the animal continues to hold it.

The action-dependency of peri-personal space has been also demonstrated in healthy (Maravita *et al.*, 2002; Serino *et al.*, 2007) and brain-damaged humans. Line-bisection studies on patients with selective neglect for the hemi-space close to (or far from) their body indicate 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 (Berti and Frassinetti, 2000; Pegna *et al.*, 2001; Ackroyd *et al.*, 2002; Neppi-Mòdona *et al.*, 2007). A dynamical space re-mapping has been also found in patients with visuotactile extinction selectively confined to the space close to one hand. The severity of the extinction can be modified by tool use, which extends the reach of hand actions (Farnè and Làdavas, 2000; Maravita *et al.*, 2001; Farnè *et al.*, 2005).

Taken together, these findings clearly indicate that peri-personal space is a bodily space characterized by an action-dependent dynamic plasticity (Gallese and Sinigaglia, in press). The construal of the space of the body exclusively or primarily as a proprioceptive space cannot account for this plasticity. Again: this is not to deny that proprioception might play a critical role in monitoring various bodily parts. However, the point is that the relationship between action and body space is much stronger and deeper than traditionally thought. It is not exclusively confined to the processing of proprioceptive information enabling the actual execution of a motor action, but it incorporates the motor goal-relatedness that characterizes a basic motor action as such, making it different from every other basic motor action (Rizzolatti and Sinigaglia, 2007).

Merleau-Ponty, probably better than anyone else, pinpointed the specific motor intentional nature of the space of the body, when he wrote that bodily awareness is 'neither the mere copy nor even the global awareness of the existing parts of the body', but the 'active integration of these latter only in proportion of their value to the organism's projects'. In other words, this '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).

Such *spatiality of situation* has been recently empirically studied by Costantini *et al.* (2010). They investigated whether and to what extent the effective processing of the affording features of an object might depend on their spatial location. Participants were instructed to execute a grasping movement as soon as a task irrelevant go-signal (i.e. a handled mug placed on a table) appeared. The handle of the mug afforded a motor act that could be congruent or incongruent with the action to be executed. Most importantly, the mug could be placed either within or outside the actually reachable space of the participants. The results showed that the spatial alignment of the oriented handled cup with the responding hand facilitated the execution of the reach-to-grasp motor act only when the mug was presented within the participants' reachable space, thus appearing as ready-to-their-own-hands. Since the affording relation is rooted in the mutual appropriateness of objectual features and individual's motor abilities, these data demonstrate that the space of the body as a reaching space, although not constitutive of the distinctiveness of that relation, makes it possible. This is due to the fact that the space of the body shares with the affording relation the same motor nature, that is, the reference to a same body experienced as power for action.

V. Mirroring and Bodily Selves

Envisaging the bodily self as a manifold of action possibilities becomes even more compelling when thinking about it as an interpersonal self (Neisser, 1988). There is ample evidence that our engagement with others is primarily rooted in our own action possibilities as instantiated by the motor system.

Single neuron recordings in the ventral premotor cortex (area F5) of macaque monkeys revealed the existence of a set of motor neurons (mirror neurons) discharging both during the execution and the observation of goal-directed movements (Gallese *et al.*, 1996; Rizzolatti *et al.*, 1996). Further experiments discovered neurons with similar properties in sectors (areas PF/PFG) of the inferior parietal lobule (Gallese *et al.*, 2002; Fogassi *et al.*, 2005; Nelissen *et al.*, 2005; Rozzi *et al.*, 2008; Bonini *et al.*, 2010) reciprocally connected with the area F5 (Rizzolatti and Luppino, 2001; Rozzi *et al.*, 2008).

Solid evidence shows that the sensory-to-motor direct mapping enabled by mirror neurons goes far beyond the mere kinematic features of movement, since it occurs at the level of the motor goal-relatedness shared by the actively executed and the only partially seen (Umiltà *et al.*, 2001) or heard (Kohler *et al.*, 2002) motor acts of someone else. fMRI evidence shows that posterior parietal and ventral premotor areas are activated also in humans by the observation of goal-related motor acts or by listening to action-related sounds (see Rizzolatti and Sinigaglia, 2010). A similar functional property was revealed in congenitally blind patients (Ricciardi *et al.*, 2009).

Neurophysiological experiments in monkeys (Fogassi *et al.*, 2005; Bonini *et al.*, 2010) and studies in humans (Iacoboni *et al.*, 2005; Cattaneo *et al.*, 2007) demonstrated that the mirror mechanism can also map basic motor intentions. This higher level of motor representation subserves not only the execution, but also the recognition (in the perceptual domain) of an orderly sequence of motor acts chained to accomplish a given motor intention. The problem of translating the sensory information of others' bodily movements into something that the observer is able to grasp as part of a given motor act accomplished with a given motor intention can be parsimoniously solved by a neural mechanism — the mirror mechanism — that directly maps observed motor behaviours onto observers' potential motor actions. In virtue of this mapping the observer is immediately tuned with the witnessed motor behaviour of others, understanding their motor goals and motor intentions in terms of her/his own motor goals and motor intentions (Gallese and Sinigaglia, 2010).

The mirror mechanism highlights the extent to which our action possibilities shape our engagement with others, at least at a basic level (Sinigaglia, 2009). Indeed, recent evidence shows that the onset of mirror neurons activation during action observation correlates with the monkey's motor expertise (Rochat *et al.*, 2010). Similarly, brain imaging studies in humans demonstrate that the richer our motor repertoire is, the sharper our tuning to others is (Calvo-Merino *et al.*, 2005; 2006; Cross *et al.*, 2006; Haslinger *et al.*, 2006; Aglioti *et al.*, 2008). In other words, the range and fineness of grain of our action possibilities affect the nature and range of our making sense of others.

In the previous section we highlighted the action dependency of peri-personal space, by showing that its extension is produced by and reflects our possibilities for action. The very same possibilities for action modulate the discharge of F5 mirror neurons during action observation (Caggiano *et al.*, 2009). It has been shown that about half of the recorded neurons responded to action observation only when the observed agent acted either inside or outside a monkey's peri-personal space. Most interestingly, this modulation doesn't simply measure the physical distance between agent and observer. A consistent percentage of mirror neurons not responding to the experimenter's grasping actions carried out near to the monkey resumed firing when a transparent barrier was interposed between the object target of the action and the observing monkey. Blocking the monkey's possibility to act upon the target of the action of someone else re-maps the spatial location of the observed agent according to a system of coordinates dictated by and expressing the monkey's relational possibilities for interaction.

When discussing the functional relevance of the mirror mechanism much emphasis has been put on its role in mapping others' motor behaviour on the observers' motor representations, enabling action understanding. One could argue that the mirror mechanism is completely opaque to the issue of self and other reference (see, for instance Pacherie and Dokic, 2006). There are different levels at which self-reference may occur. It has been recently shown that the intensity of the discharge of F5 mirror neurons is significantly stronger during action execution than during action observation (Rochat *et al.*, 2010). Furthermore, one should never forget that the mirror neurons' discharge during action observation normally occurs in parallel with a correct attribution of the same observed action to someone else. We hypothesize that the mirror mechanism, because of its mapping, is also likely to contribute to our implicit sense of our bodily self. In other words, it likely contributes to a primitive bodily self-awareness that is before and below any reflective self-awareness as well as any explicit sense of agency and sense of ownership (Gallese and Sinigaglia, 2010). This primitive self-awareness makes us immediately aware of our body as a manifold of action possibilities that are actually our own, distinguishing our body from the bodies of others and from their action possibilities. While resonating with others' acting bodies we are aware of our action possibilities as *our* own and of others' action possibilities as *their* own.

The motor system hence provides at the same time the common ground for and the distinguishing criterium between self and other bodily awareness. Self-other interactions are shaped and conditioned by the same body and by the environmental constraints in which it operates. As a matter of fact we do not experience ourselves as bodily selves without sharing a common motor intentional horizon. Before any explicitly reflective recognition of oneself as the author of one's own actions and/or as the owner of one's own body, there is a sense of self as bodily self that, by virtue of its intrinsically being a manifold of action possibilities, is actively engaged with other bodily selves, shaping both one's own and others' self experiences.

It must be added that the same logic applies to the domain of emotions and sensations. Brain imaging evidence shows that whenever we witness the emotions or sensations experienced by others, some of our brain regions display mirror activation. The same sector of the anterior insula activated by our own first-person experience of disgust is also activated when we see the facial expression of disgust displayed by another individual (Wicker *et al.*, 2003). Similarly, the same somatosensory-related cortical regions activated when one of our bodily parts is touched are also activated when observing tactile stimuli applied to the body parts of someone else (Keysers *et al.*, 2004; Blakemore *et al.*, 2005; Ebisch *et al.*, 2008). Such sharing, however, is only partial. Other cortical regions are exclusively activated for one's own emotion and not for others' emotion (Jabbi *et al.*, 2008), or are activated for one's own tactile sensation, but are actually deactivated when observing the same sensation experienced by someone else (Ebisch *et al.*, 2010). Neuroscientific evidence shows that our bodily awareness not only shapes the primary and basic awareness of ourselves but also our awareness of others as of other bodily selves. Mirror neurons and other mirroring mechanisms of our brain ground the emergence of a basic sense of self and of a basic sense of others because they reflect the intrinsic link between the owness and the otherness characterizing our experience of acting and sensing bodily selves.

In our species bodily *otherness* appears to affect the way our motor system guides our interactions with the world very early on, actually well before birth. A recent study (Castiello *et al.*, 2010) showed that foetal twins already at the fourteenth week of gestation display upper limb movements with different kinematic profiles according to whether they target their own body or the body of the other twin. Furthermore, between the fourteenth and the eighteenth week of gestation the proportion of self-directed movements decreases, while that of the movements targeting the sibling increases. These data clearly show that the human motor system, well before birth, is already instantiating functional properties enabling social interactions, and that such social interactions are expressed obeying to different motor possibilities. This suggests that the dawning of what Neisser (1988) defined the *interpersonal self* occurs before birth. When the context enables it, as in the case of twin pregnancies, bodily otherness is mapped onto one's own motor possibilities, similarly to the basic social interactions taking place after birth.

VI. Concluding Remarks

In the present paper we addressed the issue of bodily self-awareness as being 'a form of self awareness primitive enough not to depend on a more basic self-awareness' (Bermúdez, 1995, p. 153). We challenged what is generally taken for granted, that is, that basic bodily self-awareness has primarily or even exclusively to do with proprioception, in whatever sense this term might be understood. Indeed, neither the narrowest nor the broadest notion of proprioception allows one to account for both the phenomenological content of our bodily self-awareness and its neural underpinnings.

We proposed to take seriously the investigation of bodily self-awareness as it is constituted in the affordance relation. This kind of relation has been shown to provide a primary way to be engaged with the world. When perceiving affordances we become aware of our body as the manifold of action possibilities that are evoked by the affording features of objects and/or situations. We argued that bodily self-awareness as awareness of a manifold of action possibilities cannot be reduced to any form of proprioceptive awareness. In addition, the motor nature of this kind of self-awareness fully accounts for the space of the body. Several authors have emphasized that what is really special about bodily self-awareness is its spatial content. Differently from most of them, however, we showed that such spatial content cannot be confined to the boundaries of our skin, but it has to be construed in terms of the varying range of our action possibilities.

Finally, one of the most intriguing aspects of our proposal is that bodily self-awareness as a manifold of action possibilities provides the common ground for and the distinguishing criterium between self and other, at least at a basic level. The discovery of the mirror mechanism for action indicates that the very same action possibilities that shape our bodily self also make us aware of other bodily selves inasmuch as their action possibilities can be mapped onto our own ones.

By highlighting the motor roots of the awareness of our bodily self and of the bodily self of others we believe that we have not only individuated the basic way in which we are given to ourselves as bodily selves, but also that we have paved the way towards a general deconstruction of the different layers typically considered to be at the core of our full-fledged sense of self and others. Such deconstruction will be the target of our future theoretical and empirical enquiries.

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References

Ackroyd, K., Riddoch, M.J., Humphreys, G.W., Nightingale, S. & Townsend, S. (2002) Widening the sphere of influence: Using a tool to extend extrapersonal visual space in a patient with severe neglect, *Neurocase*, **8**, pp. 1–12.

Aglioti, S.M., Cesari, P., Romani, M. & Urgesi, C. (2008) Action anticipation and motor resonance in elite basketball players, *Nature Neuroscience*, **11** (9), pp. 109–116.

Bayne, T. & Levy, N. (2006) The feeling of doing: Deconstructing the phenomenology of agency, in Sebanz, N. & Prinz, W. (eds.) *Disorders of Volition*, pp. 49–68, Cambridge, MA: MIT Press.

Bermúdez, J.-L. (1995) Ecological perception and the notion of a nonconceptual point of view, in Bermúdez, J.-L., Marcel, A. & Eilan, N. (eds.) *The Body and the Self*, pp. 153–173, Cambridge, MA: MIT Press.

Bermúdez, J.-L. (1998) *The Paradox of Self-Consciousness*, Cambridge, MA: MIT Press.

Bermúdez, J.-L. (2002) Sources of self-consciousness, *Proceedings of the Aristotelian Society*, **102**, pp. 87–107.

Bermúdez, J.-L. (2004) The phenomenology of bodily awareness, *Theoria et Historia Scientiarum: Internation Journal for Interdisciplinary Studies*, **7**, pp. 43–52.

Bermúdez, J.-L. (2006) The phenomenology of bodily awareness, in Thomasson, L. & Smith, D.W. (eds.) *Phenomenology and Philosophy of Mind*, pp. 259–317, Oxford: Oxford University Press.

Bermúdez, J.-L., Marcel, A. & Eilan, N. (1995) *The Body and the Self*, Cambridge, MA: MIT Press.

Berti, A. & Frassinetti, F. (2000) When far becomes near: Remapping of space by tool use, *Journal of Cognitive Neuroscience*, **12**, pp. 415–420.

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

Bonini, L., Rozzi, S., Serventi, F.U., Simone, L., Ferrari, P.F. & Fogassi, L. (2010) Ventral premotor and inferior parietal cortices make distinct contribution to action organization and intention understanding, *Cerebral Cortex*, **20**, pp. 1372–1385.

Brewer, B. (1995) Bodily awareness and the self, in Bermúdez, J.-L., Marcel, A. & Eilan, N. (eds.) *The Body and the Self*, pp. 291–309, Cambridge, MA: MIT Press.

Buccino, G., Sato, M., Cattaneo, L., Roda, F. & Riggio, L. (2009) Broken affordances, broken objects: A TMS study, *Neuropsychologia*, **47**, pp. 3074–3078.

Butterworth, G. (1995) An ecological perspective on the origin of self, in Bermúdez, J.-L., Marcel, A. & Eilan, N. (eds.) *The Body and the Self*, pp. 87–105, Cambridge, MA: MIT Press.

Caggiano, V., Fogassi, L., Rizzolatti, G., Thier, P. & Casile, A. (2009) Mirror neurons differentially encode the peripersonal and extrapersonal space of monkeys, *Science*, **324**, pp. 403–406.

Calvo-Merino, B., Glaser, D.E., Grèzes, J., Passingham, R.E. & Haggard, P. (2005) Action observation and acquired motor skills: An fMRI study with expert dancers, *Cerebral Cortex*, **15**, pp. 1243–1249.

Calvo-Merino, B., Grèzes, J., Glaser, D.E., Passingham, R.E. & Haggard, P. (2006) Seeing or doing? Influence of visual and motor familiarity in action observation, *Current Biology*, **16** (19), pp. 1905–1910.

Castiello, U., Becchio, C., Zoia, S., Nelini, C., Sartori, L., Blason, L., D'Ottavio, G., Bulgheroni, M. & Gallese, V. (2010) Wired to be social: The ontogeny of human interaction, *PLoS ONE*, **5** (10), e13199.

Cattaneo, L., Fabbi-Destro, M., Boria, S., Pieraccini, C., Monti, A., Cossu, G. & Rizzolatti, G. (2007) Impairment of actions chains in autism and its possible role in intention understanding, *Proceedings of The National Academy of Sciences*, **104**, pp. 17825–17830.

Cesari, P., Formenti, F. & Olivato, P. (2003) A common perceptual parameter for stair climbing for children, young and old adults, *Human Movement Science*, **22** (1), pp. 111–124.

Chao, L.L. & Martin, A. (2000) Representation of manipulable man-made objects in the dorsal stream, *Neuroimage*, **12**, pp. 478–484.

Chemero, A. (2001) What we perceive when we perceive affordances: Commentary on Michael's 'Information, Perception, and Action', *Ecological Psychology*, **13**, pp. 111–116.

Chemero, A. (2003) An outline of a theory of affordances, *Ecological Psychology*, **15**, pp. 181–195.

Chemero, A. (2009) *Radical Embodied Cognitive Science*, Cambridge, MA: MIT Press.

Colby, C.L., Duhamel, J.-R. & Goldberg, M.E. (1993) Ventral intraparietal area of the macaque: Anatomic location and visual response properties, *Journal of Neurophysiology*, **69**, pp. 902–914.

Costantini, M. & Sinigaglia, C. (in press) Grasping affordance: A window onto social cognition, in Seemann, A. (ed.) *Joint Attention: New Developments*, Cambridge, MA: MIT Press.

Costantini, M., Ambrosini, E., Tieri, G., Sinigaglia, C. & Committeri, G. (2010) Where does an object trigger an action? An investigation about affordances in space, *Experimental Brain Research*, DOI 10.1007/s00221-010-2435-8.

Craighero, L., Fadiga, L., Rizzolatti, G. & Umiltà, C. (1999) Action for perception: A motor-visual attentional effect, *Journal of Experimental Psychology and Human Perceptual Performance*, **25**, pp.1673–1692.

Cross, E.S., Hamilton, A.F. & Grafton, S.T. (2006) Building a motor simulation de novo: Observation of dance by dancers, *Neuroimage*, **31** (3), pp. 1257–1267.

Dokic, J. (2003) The sense of ownership: An analogy between sensation and action, in Roessler, J. & Eilan, N. (eds.) *Agency and Self-Awareness*, pp. 321–344, Oxford: Oxford University Press.

Duhamel, J.R., Colby, C.L. & Goldberg, M.E. (1998) Ventral intraparietal area of the macaque: Congruent visual and somatic response properties, *Journal of Neurophysiology*, **79** (1), pp. 126–136.

Ebisch, S.J.H., Perrucci, M.G., Ferretti, A., Del Gratta, C., Romani, G.L. & Gallese, V. (2008) The sense of touch: Embodied simulation in a visuo-tactile mirroring mechanism for the sight of any touch, *Journal of Cognitive Neuroscience*, **20**, pp. 1611–1623.

Ebisch, S.J.H., Ferri, F., Salone, A., d'Amico, L., Perrucci, M.G., Ferro, F.M., Romani, G.L. & Gallese, V. (2010) Differential involvement of somatosensory and interoceptive cortices during the observation of affective touch, *Journal of Cognitive Neuroscience*, July 28 2010 [Epub ahead of print].

Eilan, N. (1995) Consciousness and the self, in Bermúdez, J.-L., Marcel, A. & Eilan, N. (eds.) *The Body and the Self*, pp. 291–310, Cambridge, MA: MIT Press.

Eilan, N., Marcel, A. & Bermúdez, J.-L. (1995) Self-consciousness and the body, in Bermúdez, J.-L., Marcel, A. & Eilan, N. (eds.) *The Body and the Self*, pp. 1–28, Cambridge, MA: MIT Press.

Ellis, R. & Tucker, M. (2000) Micro-affordance: The potentiation of components of action by seen objects, *British Journal of Psychology*, **91** (4), pp. 451–471.

Farnè, A. & Làdavas, E. (2000) Dynamic size-change of hand peripersonal space following tool use, *Neuroreport*, **11**, pp. 1645–1649.

Farnè, A., Iriki, A. & Làdavas, E. (2005) Shaping multisensory action-space with tools: Evidence from patients with cross-modal extinction, *Neuropsychologia*, **43**, pp. 238–248.

Fogassi, L., Gallese, V., di Pellegrino, G., Fadiga, L., Gentilucci, M., Luppino, G., Matelli, M., Pedotti, A. & Rizzolatti, G. (1992) Space coding by premotor cortex, *Experimental Brain Research*, **89**, pp. 686–690.

Fogassi, L., Gallese, V., Fadiga, L., Luppino, G., Matelli, M. & Rizzolatti, G. (1996) Coding of peripersonal space in inferior premotor cortex (area F4), *Journal of Neurophysiology*, **76**, pp. 141–157.

Fogassi, L., Ferrari, P.F., Gesierich, B., Rozzi, S., Chersi, F. & Rizzolatti, G. (2005) Parietal lobe: From action organization to intention understanding, *Science*, **302**, pp. 662–667.

Gallagher, S. (2000) Philosophical conceptions of the self: Implications for cognitive science, *Trends in Cognitive Sciences*, **4**, pp. 14–21.

Gallagher, S. (2003) Bodily self-awareness and object perception, *Theoria et Historia Scientiarum: International Journal for Interdisciplinary Studies*, **7**, pp. 53–68.

Gallagher, S. & Shear, J. (eds.) (1998) *Models of the Self*, Exeter: Imprint Academic.

Gallagher, S. & Zahavi, D. (2005) Phenomenological approaches to self-consciousness, *Stanford Encyclopedia of Philosophy*.

Gallagher, S. & Zahavi, D. (2008) *The Phenomenological Mind: An Introduction to Philosophy of Mind and Cognitive Science*, London: Routledge.

Gallese, V. (2000) The inner sense of action: Agency and motor representations, *Journal of Consciousness Studies*, **7** (10), pp. 23–40.

Gallese, V., Fadiga, L., Fogassi, L. & Rizzolatti, G. (1996) Action recognition in the premotor cortex, *Brain*, **119**, pp. 593–609.

Gallese, V., Fadiga, L., Fogassi, L. & Rizzolatti, G. (2002) Action representation and the inferior parietal lobule, in Prinz, W. & Hommel, B. (eds.) *Common Mechanisms in Perception and Action: Attention and Performance, Vol. XIX*, pp. 247–266, Oxford: Oxford University Press.

Gallese, V. & Sinigaglia, C. (2010) The bodily self as power for action, *Neuropsychologia*, **48**, pp. 746–755.

Gallese, V. & Sinigaglia, C. (in press) Cognition in action: A new look at the cortical motor system, in Metcalfe, J. & Terrace, H. (eds.) *Joint Attention and Agency*, Oxford: Oxford University Press.

Gentilucci, M., Fogassi, L., Luppino, G., Matelli, M., Camarda, R. & Rizzolatti, G. (1988) Functional organization of inferior area 6 in the macaque monkey: I. Somatotopy and the control of proximal movements, *Experimental Brain Research*, **71**, pp. 475–490.

Gibson, J.J. (1979) *The Ecological Approach to Visual Perception*, Boston, MA: Houghton Mifflin.

Grafton, S.T., Fadiga, L., Arbib, M.A. & Rizzolatti, G. (1997) Premotor cortex activation during observation and naming of familiar tools, *NeuroImage*, **6** (4), pp. 231–236.

Graziano, M.S.A., Yap, G.S. & Gross, C.G. (1994) Coding of visual space by premotor neurons, *Science*, **266**, pp. 1054–1057.

Graziano, M.S.A., Hu, X. & Gross, C.G. (1997) Visuo-spatial properties of ventral premotor cortex, *Jouranl of Neurophysiology*, **77**, pp. 2268–2292.

Grèzes, J., Tucker, M., Armony, J., Ellis, R. & Passingham, R.E. (2003) Objects automatically potentiate action: An fMRI study of implicit processing, *European Journal of Neuroscience*, **17**, pp. 2735–2740.

Haslinger, B., Erhard, P., Altenmuller, E., Schroeder, U., Boecker, H. & Ceballos-Baumann, A.O. (2006) Transmodal sensorimotor networks during action observation in professional pianists, *Journal of Cognitive Neuroscience*, **17**, pp. 282–293.

Hurley, S. (1998) *Cosciousness in Action*, Cambridge, MA: Harvard University Press.

Iacoboni, M., Molnar-Szakacs, I., Gallese, V., Buccino, G., Mazziotta, J. & Rizzolatti, G. (2005) Grasping the intentions of others with one's owns mirror neuron system, *PLOS Biology*, **3**, pp. 529–535.

Iriki, A., Tanaka, M. & Iwamura, Y. (1996) Coding of modified body schema during tool use by macaque postcentral neurones, *Neuroreport*, **7**, pp. 2325–2330.

Ishibashi, H., Hihara, S. & Iriki, A. (2000) Acquisition and development of monkey tool-use: Behavioral and kinematic analyses, *Canadian Journal of Physiology and Pharmacology*, **78**, pp. 958–966.

Jabbi, M., Bastiaansen, J. & Keysers, C. (2008) A common anterior insula representation of disgust observation, experience and imagination shows divergent functional connectivity pathways, *PLoS ONE*, **3** (8), e2939.

Jeannerod, M., Arbib, M.A., Rizzolatti, G. & Sakata, H. (1995) Grasping objects: The cortical mechanisms of visuomotor transformation, *Trends in Neuroscience*, **18**, pp. 314–320.

Kandel, E., Schwartz, J. & Jessell, T. (eds.) (2000) *Principles of Neuroscience, 4th Edition*, New York: McGraw-Hill Medical.

Keysers, C., Wicker, B., Gazzola, V., Anton, J-L., Fogassi, L. & Gallese, V. (2004) A touching sight: SII/PV activation during the observation and experience of touch, *Neuron*, **42**, pp. 1–20.

Kohler, E., Keysers, C., Umiltà, M.A., Fogassi, L., Gallese, V. & Rizzolatti, G. (2002) Hearing sounds, understanding actions: Action representation in mirror neurons, *Science*, **297**, pp. 846–848.

Legrand, D. (2006) The bodily self: The sensori-motor roots of pre-reflective self-consciousness, *Phenomenology and the Cognitive Sciences*, **5**, pp. 89–118.

Legrand, D. (2007) Pre-reflective self-as-subject from experiential and empirical perspectives, *Consciousness and Cognition*, **16**, pp. 583–599.

Maravita, A., Husain, M., Clarke, K. & Driver, J. (2001) Reaching with a tool extends visual-tactile interactions into far space: Evidence from cross-modal extinction, *Neuropsychologia*, **39**, pp. 580–585.

Maravita, A., Spence, C., Kennet, S. & Driver, J. (2002) Tool use changes multimodal spatial interactions between vision and touch in normal humans, *Cognition*, **83**, pp. 25–34.

Marcel, A. (2003) The sense of agency: Awareness and ownership of action, in Roessler, J. & Eilan, N. (eds.) *Agency and Self-Awareness*, pp. 48–93, Oxford: Oxford University Press.

Martin, M.G.F. (1995) Bodily awareness: A sense of ownership, in Bermúdez, J.-L., Marcel, A. & Eilan, N. (eds.) *The Body and the Self*, pp. 267–289, Cambridge, MA: MIT Press.

Mele, A. (2002) Agents' abilities, *Nous*, **37**, pp. 447–470.

Merleau-Ponty, M. (1962) *The Phenomenology of Perception*, Smith, C. (trans.), London: Routledge and Kegan Paul.

Murata, A., Fadiga, L., Fogassi, L., Gallese, V., Raos, V. & Rizzolatti, G. (1997) Object representation in the ventral premotor cortex (Area F5) of the monkey, *Journal of Neurophysiology*, **78**, pp. 2226–2230.

Murata, A., Gallese, V., Luppino, G., Kaseda, M. & Sakata, H. (2000) Selectivity for the shape, size and orientation of objects in the hand-manipulation-related neurons in the anterior intraparietal (AIP) area of the macaque, *Journal of Neurophysiology*, **83**, pp. 2580–2601.

Neisser, U. (1988) Five kinds of self-knowledge, *Philosophical Psychology*, **1**, pp. 35–59.

Neisser, U. (1991) Two perceptually given aspects of the self and their development, *Developmental Review*, **11**, pp. 197–209.

Nelissen, K., Luppino, G., Vanduffel, W., Rizzolatti, G. & Orban, G.A. (2005) Observing others: Multiple action representation in the frontal lobe, *Science*, **310**, pp. 332–336.

Neppi-Mòdona, M., Rabuffetti, M., Folegatti, A., Ricci, R., Spinazzola, L., Schiavone, F., Ferrarin, M. & Berti, A. (2007) Bisecting lines with different tools in right brain damaged patients: The role of action programming and sensory feedback in modulating spatial remapping, *Cortex*, **43**, pp. 397–410.

Noë, A. (2009) *Out of Our Heads: Why You Are not Your Brain, and Other Lessons from Biology of Consciousness*, New York: Hill and Wang.

O'Shaughnessy, B. (1995) Proprioception and the body image, in Bermúdez, J.-L., Marcel, A. & Eilan, N. (eds.) *The Body and the Self*, pp. 175–203, Cambridge, MA: MIT Press.

Pacherie, E. & Dokic, J. (2006) From mirror neuron to joint actions, *Cognitive Systems Research*, **7**, pp. 101–112.

Pegna, A.J., Petit, L., Caldara-Schnetzer, A.S., Khateb, A., Annoni, J.M., Sztajzel, R. & Landis, T. (2001) So near yet so far: Neglect in far or near space depends on tool use, *Annals of Neurology*, **50**, pp. 820–822.

Raos, V., Umilta, M.A., Fogassi, L. & Gallese, V. (2006) Functional properties of grasping-related neurons in the ventral premotor area F5 of the macaque monkey, *Journal of Neurophysiology*, **95**, pp. 709–729.

Ricciardi, E., Bonino, D., Sani, L., Vecchi, T., Guazzelli, M., Haxby, J.V., Fadiga. L. & Pietrini, P. (2009) Do we really need vision? How blind people 'see' the actions of others, *Journal Neuroscience*, **29**, pp. 9719–9724.

Rizzolatti, G., Camarda, R., Fogassi, M., Gentilucci, M., Luppino, G. & Matelli, M. (1988) Functional organization of inferior area 6 in the macaque monkey: II. Area F5 and the control of distal movements, *Experimental Brain Research*, **71**, pp. 491–507.

Rizzolatti, G., Fadiga, L., Gallese, V. & Fogassi, L. (1996) Premotor cortex and the recognition of motor actions, *Cognitive Brain Research*, **3**, pp. 131–141.

Rizzolatti, G., Fadiga, L., Fogassi, L. & Gallese, V. (1997) The space around us, *Science*, **277**, pp. 190–191.

Rizzolatti, G., Fogassi, L. & Gallese, V. (2001) Neurophysiological mechanisms underlying the understanding and imitation of action, *Nature Reviews Neuroscience*, **2**, pp. 661–670.

Rizzolatti, G. & Luppino, G. (2001) The cortical motor system, *Neuron*, **31**, pp. 889–901.

Rizzolatti, G. & Craighero, L. (2004) The mirror-neuron system, *Annual Review of Neuroscience*, **27**, pp. 169–192.

Rizzolatti, G. & Sinigaglia, C. (2007) *Mirrors in the Brain: How our Minds Share Actions and Emotions*, Oxford: Oxford University Press.

Rizzolatti, G. & Sinigaglia, C. (2010) The functional role of the parieto-frontal mirror circuit: Interpretations and misinterpretations, *Nature Reviews Neuroscience*, **11**, pp. 264–274.

Rochat, M.J., Caruana, F., Jezzini, A., Escola, L., Intskirveli, I., Grammont, F., Gallese, V., Rizzolatti G. & Umiltà, M.A. (2010) Responses of mirror neurons in area F5 to hand and tool grasping observation, *Experimental Brain Research*, June 26 2010 [Epub ahead of print].

Rozzi, S., Ferrari, P.F., Bonini, L., Rizzolatti, G. & Fogassi, L. (2008) Functional organization of inferior parietal lobule convexity in the macaque monkey: Electrophysiological characterization of motor, sensory and mirror responses and their correlation with cytoarchitectonic areas, *European Journal of Neuroscience*, **28**, pp. 1569–1588.

Serino, A., Bassolino, M., Farné, A. & Ladavas, E. (2007) Extended multisensory space in blind cane users, *Psychological Science*, **18**, pp. 642–648.

Sherrington, C.S. (1907) On the proprioceptive system, especially in its reflex aspect, *Brain*, **29**, pp. 467–485.

Shoemaker, S. (1984) Self-reference and self-awareness, in Shoemaker, S., *Identity, Cause and Mind*, Cambridge: Cambridge University Press.

Sinigaglia, C. (2009) Mirror in action, *Journal of Consciousness Studies*, **16** (6–8), pp. 309–334.

Thompson, E. (2005) Sensorimotor subjectivity and the enactive approach to experience, *Phenomenology and the Cognitive Sciences*, **4**, pp. 407–427.

Tucker, M. & Ellis, R. (1998) On the relations between seen objects and components of potential actions, *Journal of Experimental Psychology: Human Perception and Performance*, **24** (3), pp. 830–846.

Tucker, M. & Ellis, R. (2001) The potentiation of grasp types during visual object categorization, *Visual Cognition*, **8**, pp. 769–800.

Tucker, M. & Ellis, R. (2004) Action priming by briefly presented objects, *Acta Psychologica*, **116**, pp. 185–203.

Turvey, M.T. (1977) Preliminaries to a theory of action with reference to vision, in Shaw, R. & Bransfor, J. (eds.) *Perceiving, Acting and Knowing: Towards an Ecological Psychology*, pp. 211–265, Hillsdale, NJ: Lawrence Erlbaum Associates.

Turvey, M.T. (1992) Affordances and prospective control: An outline of the ontology, *Echological Psychology*, **4**, pp. 173–187.

Turvey, M.T., Shaw, R.E., Reed, E.S. & Mace, W.M. (1981) Ecological laws of perceiving and acting: In reply to Fodor and Pylyshyn (1981), *Cognition*, **9**, pp. 237–304.

Umiltà, M.A., Kohler, E., Gallese, V., Fogassi, L., Fadiga, L., Keysers, C. & Rizzolatti, G. (2001) 'I know what you are doing': A neurophysiological study, *Neuron*, **32**, pp. 91–101.

Umiltà, M.A, Brochier, T., Spinks, R.L. & Lemon, R.N. (2007) Simultaneous recording of macaque premotor and primary motor cortex neuronal populations reveals different functional contributions to visuomotor grasp, *Journal of Neurophysiology*, **98**, pp. 488–501.

Umiltà, M.A., Escola, L., Intskirveli, I., Grammont, F., Rochat, M., Caruana, F., Jezzini, A., Gallese, V. & Rizzolatti, G. (2008) When pliers become fingers in the monkey motor system, *Proceedings of the National Academy of Sciences*, **105**, pp. 2209–2213.

Warren, W.H., Jr. (1984) Perceiving affordances: Visual guidance of stair climbing, *Journal of Experimental Psychology and Human Perception Performance*, **10**, pp. 683–703.

Wicker, B., Keysers, C., Plailly, J., Royet, J.-P., Gallese, V. & Rizzolatti, G. (2003) Both of us disgusted in my insula: The common neural basis of seeing and feeling disgust, *Neuron*, **40**, pp. 655–664.