The Paradigmatic Body

Embodied Simulation, Intersubjectivity, the Bodily Self, and Language

Vittorio Gallese & Valentina Cuccio

In this paper we propose a way in which cognitive neuroscience could provide new insights on three aspects of social cognition: intersubjectivity, the human self, and language. We emphasize the crucial role of the body, conceived as the constitutive source of pre-reflective consciousness of the self and of the other. We provide a critical view of contemporary social cognitive neuroscience, arguing that the brain level of description is a necessary but not sufficient condition for studying intersubjectivity, the human self, and language; which are only properly visible if coupled with a full appreciation of their intertwined relationship with the body. We introduce mirror mechanisms and embodied simulation and discuss their relevance to a new account of intersubjectivity and the human self. In this context, we focus on a specifically human modality of intersubjectivity: language. Aspects of social cognition related to language are discussed in terms of embodiment, while emphasizing the progress and limitations of this approach. We argue that a key aspect of human language consists in its decoupling from its usual denotative role, hence manifesting its power of abstraction. We discuss these features of human language as instantiations of the Greek notion of *paradeigma*, originally explored by Aristotle to refer to a typical form of rhetorical reasoning and relate it to embodied simulation. Paradigmatic knowledge connects the particular with the particular, moving from the contingent particular situation to an exemplary case. Similarly, embodied simulation is the suspension of the "concrete" application of a process: reuse of motor knowledge in the absence of the movement it realizes is an example of "paradigmatic knowledge." This new epistemological approach to intersubjectivity generates predictions about the intrinsic functional nature of our social cognitive operations, cutting across, and not subordinated to, a specific ontology of mind.

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1 Introduction

The last decades of the twentieth century were marked by great progress in cognitive neuroscience, made possible by recently-developed brain imaging technologies such as functional magnetic resonance imaging (fMRI)—which allowed for the first time non-invasive study of the human brain.

But what is cognitive neuroscience? We think it is fair to say that it is above all a methodological approach whose results are strongly influenced by which questions are being asked and how. Studying single neurons and/or the brain does not necessarily predetermine the questions to be asked that will help us understand how and how much our human nature depends upon our brains. Even less so the answers. Our purpose here is twofold. On the one hand, we aim to provide a brief overview of current cognitive neuroscience and its methods. We first present the limitations displayed by most

current mainstream cognitive neuroscience, followed by a proposal for an alternative approach, both in terms of the employed methodology and of its main goals. In short, in contrast with what many normally take for granted[1], we assume the brain level of description to be a necessary but not sufficient condition for studying intersubjectivity, language, and the human self, which are only properly visible if coupled with a full appreciation of their intertwined relationship with the body. This overview has been specifically designed to provide a useful tool for researchers working in the humanities. Section 2 is entirely devoted to this goal.

On the other hand, the authors of this essay are a cognitive neuroscientist and a philosopher of language, and as such our second purpose is to propose how cognitive neuroscience could provide new insights on specific aspects of human cognition. In section 3 we introduce mirror mechanisms and embodied simulation and, in the following sections, we discuss their relevance for a new account of intersubjectivity, the human self, and language—which privileges the body as the transcendental foundation of each.

We emphasize the crucial role of the body, conceived as the constitutive source of pre-reflective consciousness of the self and of the other and as the ground upon which linguistic meaning is also based. The body we talk about in this paper manifests itself in two different, complementary, and closely intertwined ways:[2] it is a *Leib*, a lived body entertaining experiences of self and others, and a *Körper*, the somatic object, of which the brain is a con-

stitutive part. We posit that this dual nature of our experienced body can be fully understood—and its genesis revealed—by investigating its motor neurophysiological underpinnings at the sub-personal level. The naturalization of intersubjectivity, the self, and language implies a first attempt to isolate the constituent components of the concepts we use to refer to these aspects of human social cognition by literally investigating what they are made of at the level of description of the brain–body system. This attempt in relation to the notions of intersubjectivity, the self, and language is intended here to form an identification of their constitutive mechanisms. We believe that this investigation becomes really effective only when it is framed within both comparative and developmental perspectives.[3]

The comparative perspective not only allows us to frame human social cognition within an evolutionary picture, thus providing access to its phylogenetic antecedents.[4] It also greatly reduces the risk of the empirical investigation of the human brain being subordinated to a specific human ontology of mind. A further reason for privileging the comparative perspective resides in the fact that it also brings us the most finely grained approach to date for studying the brain, and the possibility of correlating single neurons' activity with behaviour and cognition—as when studying single neurons' activity in non-human primates, like macaque monkeys.

The immanent transcendence[5] of the body's corporeality can be revealed, we contend, by bringing the analysis back to the level of the brain–body system; that is, to the level of the *Körper*. We show that this particular neurocog-

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1 "Still other accounts of grounded cognition focus on situated action, social interaction, and the environment (e.g., Barsalou 2003, Barsalou et al. 2007a, Glenberg 1997, W. Prinz 1997, Rizzolatti & Craighero 2004, Robbins & Aydede 2007, E. Smith & Semin 2004, Yeh & Barsalou 2006). From this perspective, the cognitive system evolved to support action in specific situations, including social interaction. These accounts stress interactions between perception, action, the body, the environment, and other agents, typically during goal achievement. It is important to note that the phrase 'embodied cognition' is often used when referring to this collection of literatures. Problematically, however, 'embodied cognition' produces the mistaken assumption that all researchers in this community believe that bodily states are necessary for cognition and that these researchers focus exclusively on bodily states in their investigations. Clearly, however, cognition often proceeds independently of the body, and many researchers address other forms of grounding." (Barsalou 2008, p. 619)

2 We find it useful to employ here the distinction originally proposed by Edmund Husserl in Husserl (1973, p. 119).

3 One of the major contributions to our understanding of human social cognition is provided by developmental psychology. In this paper, for sake of concision we don't focus on developmental aspects, in spite of the crucial importance we attribute to them to thoroughly address the issues we want to address here.

4 It is interesting to note that this comparative perspective seems to support the hypothesis of an evolutionary continuity between human and non-human primates in relation to the emergence of language from our sensori-motor abilities. For a discussion of this topic, see Glenberg & Gallese (2012).

5 The expression immanent transcendence is meant to signify here the fact that the body, by means of a biological mechanism (immanent), can transcend his usual function (for example, motion) to become expression (a model or paradeigma) of this bodily knowledge.

nitive approach is beginning to reveal the tight relationship between a core notion of the bodily self, its potentiality for action, and motor simulation at the level of the cortical motor system. Cognitive neuroscience can enable the analysis of several concepts and notions we normally refer to when describing ourselves and our social cognitive lives. In the present paper we apply this method to the notions of intersubjectivity, the self, and language.

To fully account for the specific quality of human social cognition one cannot undervalue the linguistic dimension. For this reason, we introduce aspects of social cognition related to language and discuss them in terms of embodiment, emphasizing the progress and limitations of this approach. Traditionally, the linguistic and corporeal sensorimotor dimensions of social cognition have been considered entirely unrelated. We posit that embodied simulation, conceived of as a model for important aspects of our relation to the world, might help in overcoming this apparently unsolvable dichotomy. We argue that a key aspect defining the unique specificity of human language consists in its decoupling from its usual denotative role. This means that language allows us to talk about general concepts such as beauty or mankind, without denoting any particular instance of these concepts. In so doing, human language manifests its power for abstraction. We discuss these features of human language as instantiations of the Greek notion of *paradeigma*, originally explored by Aristotle, and relate it to embodied simulation. When a word or syntagm, like the Latin word *Rosa*, is decoupled from its usual denotative role, it can function as a general rule of knowledge, e.g., as a paradigm for the female nominative case of Latin nouns belonging to the first declension. The notion of *paradeigma* does not establish a connection between a universal principle and its contingent aspects, as in deduction, it rather exemplifies a particular case of induction: specifically the transposition of inductive reasoning in in the field of studies of persuasive communication, known as rethorics, where contingent particular cases lead to general rules describing them. Paradigmatic knowledge, however, differently

from standard cases of induction, connects the particular with the particular, moving from the contingent particular situation to an exemplary case. We propose that embodied simulation could instantiate such a notion of paradigmatic knowledge, hence enabling its naturalization and helping us overcome the apparent gap between the linguistic and corporeal dimensions.

We conclude by emphasizing how the specific use of cognitive neuroscience here proposed can lead to a new take on social cognition. This new take brings about a demonstration on empirical grounds of the constitutive role played in foundational aspects of social cognition by the human body, when conceived of in terms of its motor potentialities; hence its transcendental quality.[6] Of course this only covers a partial aspect of social cognition. However, we think this approach has the merit of providing an epistemological model, which is also potentially useful for empirical investigation into the more cognitively sophisticated aspects of human social cognition.

2 The cognitive neuroscience of what?

It is a fact and an undisputable truth that there cannot be any mental life without the brain. More controversial is whether the level of description offered by the brain is also sufficient for providing a thorough and biologically-plausible account of social cognition. We think it isn't. We would like to ground this assertion on two arguments: the first deals with the often overlooked intrinsic limitations of the approach adopting the brain level of description, particularly when the brain is considered in isolation and its intimate relation with the body is neglected; the second deals with social cognitive neuroscience's current prevalent explanatory objectives and contents.

The contemporary emphasis divulgated by the popular media, namely the supposedly revolutionary heuristic value of cognitive neuroscience, mostly rests upon the results of brain imaging techniques, and in particular on fMRI.

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6 The "transcendental quality" attributed to the body is intended to mean that the body is considered as the a priori, non-further reducible condition of the possibility of experience.

fMRI is often presented as the ultimate method of investigation of the human mind. It should be pointed out, though, that fMRI studies do not constitute the whole story in cognitive neuroscience. Cognitive neuroscience can indeed carry out its investigation at a more drastic sub-personal level, such as at the level of single neurons (see below), both in macaque monkeys and, although much more rarely, even in humans. These alternative approaches notwithstanding, the main thrust of cognitive neuroscience in studying human brain function is, as we speak, mostly confined to fMRI.[7]

Unfortunately fMRI only indirectly "sees" the workings of the brain, by measuring neurons' oxygen consumption. Such a measure is also indirect, as it depends on the local difference between oxygenated and deoxygenated hemoglobin—the iron-rich molecule housed by red blood cells, which carriess oxygen to all bodily organs and tissues. Oxygenated and deoxygenated hemoglobin have different paramagnetic behaviours in relation to the strong magnetic field that is created by a big coil, inside which the head is placed. The measure of this functional parameter allows scientists to estimate local neural activity in terms of different MRI (magnetic resonance imaging) signals. The indirect quality of this kind of estimation of brain activity, which is based on local hemodynamic brain responses, inevitably introduces distortions and noise. Indeed, when studying any sensorimotor, perceptual, or cognitive function, in order to maximize the so-called "signal-to-noise ratio", several repetitions of the same task in many individuals are required.

This means that fMRI allows us to indirectly assess the average brain-activation level induced by any given task across a population of no less than twelve to fifteen different individuals. Within each studied individual brain the spatial resolution of fMRI is within the order of few millimetres. This implies that we are able to measure at best the potentially coherent activation pattern of several hundred thousand neighbouring neurons, possibly also differing

among one another in terms of their excitatory or inhibitory role.

Temporal resolution is even worse, since it is in the order of a few seconds. One should consider that action potentials, or "spikes" as neurophysiologists like to call them—the electric code employed by neurons to "communicate" with each other, and ultimately the true essence of neurons' activity—last less than one millisecond. fMRI cannot match such temporal resolution because it measures the delayed (of about two seconds) and prolonged (for about five seconds) local hemodynamic response providing neurons with all the oxygen their electric activity requires.

As we have previously argued, fMRI is not the only available experimental methodology for studying the brain. Many different techniques are available nowadays (e.g., PET (positron emission tomography), NIRS (near-infrared spectroscopy), Tdcs (transcranial direct-current stimulation) or TMS (transcranial magnetic stimulation)). Particularly, since the revolutionary introduction in 1927 by the Nobel Prize laureate Edgar Adrian (Adrian & Matthews 1927a, 1927b) of the extracellular microelectrode, which allows the recording of action potentials discharged by single neurons, neurophysiology has made enormous progress in revealing the brain's physiological mechanisms. Such neurophysiological investigation started with the study of the neural circuits that preside over elementary sensorimotor behaviours, like spinal reflexes, finally moving all the way up to the investigation of action and perception, reward and emotions, spatial mapping and navigation, working memory, decision-making, etc., in behaving animals like macaque monkeys. Unfortunately, such a finely grained level of description—both in terms of spatial and temporal resolution, is most of the time precluded in humans.

We posit that the scientific study of intersubjectivity and the human self requires a comparative approach, and that this is the only one capable of connecting the distinctive traits of human nature to their likely phylogenetic precursors. In so doing, and by making use of the single-neuron recording approach, neuro-

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7 For an intriguing discussion of the historical antecedents of brain imaging techniques and a passionate criticism of the limitations of current use of brain imaging by cognitive neuroscience, see Legrenzi & Umiltà (2011).

physiological mechanisms and the cortico-cortical networks expressing them can be related with several aspects of primates' social cognitive behaviour and thus be thoroughly investigated. Conceptual notions like intersubjectivity and the self should be analyzed in order to better understand their nature, structure, and properties. Such an analysis, which provides us a deflationary notion of the same concepts, intended as the identification of their minimal component and the detailed study of their origin, will be most successful if driven by a meticulous investigation of the underpinning neurophysiological mechanisms—which most of the time are available only from the study of non human primates' brains, hence the necessity of a comparative perspective.

Human brain imaging, because of the intrinsic limitations we briefly outlined above, can only provide correlations between particular brain patterns of activation and particular behaviours or mental states. This implies that the correlation between a particular brain state and a particular phenomenal mental state of a given individual human being[8] is most informative when the specificity and uniqueness of such a correlation can be firmly established. Unfortunately, this is not always the case with fMRI studies. Very telling is the supposed mindreading specificity of some cortical circuits comprising the ventral portion of the mesial frontal cortex and the TPJ (temporo-parietal junction; e.g., Leslie 2005; Saxe 2006). Such specificity is not only so far unproven, but is actually confuted by accumulated evidence (for a lengthier discussion of this point and for arguments and experimental evidence against such specificity see Ammaniti & Gallese 2014; Gallese 2014).

In spite of all these limitations, this neuroimaging approach turned out to be very productive, enabling us to study for the first time in parallel brains, behaviour and cognition, shedding new light not only on human brain structure, but also on its wiring pattern of con-

nectivity and many of its functions. If we put the newly-acquired knowledge on brain function provided by cognitive neuroscience under scrutiny, we can make very interesting discoveries. For example, we discovered that in many areas of investigation brain imaging replicates and validates *at a different scale* what had been previously discovered at the single neuron level in animals like macaques.[9]

The prominent discoveries, among others, of David Hubel, Torsten Wiesel, and Semir Zeki on the functional organization of primates' cortical visual system, like the orientation-, shape-, motion- and colour-selectivity of visual neurons, were made by correlating the discharge activity of single neurons in macaques' visual cortices with different parameters of the visual stimuli macaques were looking at (for a comprehensive review of this literature, see Zeki 1993). These results later promoted a similar investigation carried out on the human brain by means of fMRI. Remarkably enough, a similar functional architecture was detected in the human visual brain, in spite of the species difference and, most importantly, the different scale at which these investigations were carried out: a few hundreds recorded neurons at best, in the case of macaques' brains, versus hundreds of thousands if not millions of activated neurons detected by a local increase in blood flow in the case of the human brain.

Face-selective neurons, first described in the early nineteen-seventies by Charles Gross and colleagues in macaques' temporal cortex (Gross et al. 1972), and immediately ridiculed as "grand-mother cells", offer another very telling example.[10] Face-selective brain circuits appear to be strikingly similar in macaques and humans (see Ku et al. 2011). Furthermore, even in human brains single neurons were detected that selectively respond to a single face—such

8 For sake of concision and focus we do not discuss here the implicated topic of the apparently absent synchronicity between brain states and phenomenal consciousness (remember that fMRI does not provide a good temporal resolution to firmly match brain states and phenomenal consciousness). We simply want to stress the parallel existence of particular experiences and particular brain states.

9 The comparative approach is primarily intended here as a comparison between humans and other animals. As a consequence, it also implies a comparison between different experimental methods.

10 The notion of the grandmother cell was originally introduced by the neuroscientist Jerry Lettvin to refer to neurons with high integrative power, which are able to map concepts or objects. The term has since then mostly been employed with a negative connotation by supporters of a more distributed population-coding of objects, percepts, and memories. For an historical account of the notion of the grandmother cell, see Gross (2002).

as the so-called Jennifer Aniston's selective neurons (see Quiroga et al. 2005). These neurons respond to multiple representations of a particular individual, regardless of the specific visual features of the picture used. Indeed, these neurons respond similarly to different pictures of the same person and even to his or her written or spoken name. The authors of this study claimed that their evidence supported the notion that single neurons within the human medial temporal lobe cortex instantiate the abstract representation of the identity of a single individual.

Such examples seem to suggest that in spite of the big scale magnification implied when confronting single-neuron data from macaques and fMRI results from humans, some important functional features are nevertheless manifest across these different levels of description (i.e., single neurons vs. brain areas). One can study canonical or mirror neurons (see below) by recording the activity of a few hundred spiking neurons from a behaving macaque monkey during object and action observation, respectively. The same results can be replicated by detecting, by means of fMRI, and during object and action observation, the simultaneous activation of hundreds of thousands of human neurons within analogous cortical areas of the human brain.

This remarkable but often neglected fact cannot be the result of a pure coincidence. This evidence should thus invite us to resist and argue against those who downplay the heuristic power of single-neuron recording. Their thesis is that because of a supposedly incommensurable gap between single neurons and the incredible complexity of the human brain, where information would be exclusively mapped at the level of large populations of poorly selective neurons, it doesn't make any sense to study the brain by recording single neurons. The fact however is that in spite of the almost astronomic figures characterizing the human brain (about 100 billion neurons, each of which connects with thousands of other neurons), its complexity does not parallel such astronomic figures, or at least not in such a way as to deny any heuristic value to the single-neuron recording approach. Let's see why.

As argued by Chittka & Niven (2009), brain size may have less of a relationship with behavioural repertoire and cognitive capacity than generally assumed. According to the same authors, larger brains are, in part at least, a consequence of larger neurons that are necessary in large animals due to basic biophysical constraints. Larger brains also contain greater replication of neuronal circuits, adding precision to sensory processes, detail to perception, more parallel processing, enlarged storage capacity, and greater plasticity. These advantages, maintain Chittka & Niven (2009), are unlikely to produce the qualitative shifts in behaviour that are often assumed to accompany increased brain size, or at least not in a one-to-one manner.

The evidence so far briefly reviewed and that we will present in the next sections suggest that some functional properties of the brain exhibit a sort of "fractal quality", such that they can be appreciated at different scales and levels of investigation. For these reasons fMRI cannot be the sole neurocognitive approach to human social cognition,[11] but it must be complemented by other approaches compensating for some of its deficiencies: like TMS, EEG (electroencephalography), and the comparative functional study of non-human primates by means of brain imaging and single-neuron recordings.

After having clarified what we take to be the often-neglected limitations of cognitive neuroscience that may hinder its potential heuristic power (namely, that fMRI offers only an indirect estimation of brain activity, inferred by measuring neurons' oxygen consumption, and this inevitably leads to distortions and noise, and that it does not provide good temporal resolution because it measures the delayed and prolonged hemodynamic responses due to neurons oxygenation), let us now move to the second argument against the sufficiency satisfaction condition of the current approach of cognitive neuroscience to the study of human social cognition. This argument concerns the explanatory goals and contents of contemporary main-

11 Maybe no one explicitly claims this. However, it is very common that researchers neglect many (or all) of the complementary techniques that have been here suggested to be necessary and draw inferences about human social cognition and its neural implementation. As an example, see papers by Ian Apperly.

stream cognitive neuroscience. Vast quarters within cognitive neuroscience are still today strongly influenced by classical cognitivism, on one side, and by evolutionary psychology on the other. Classical cognitive science is the bearer of a solipsistic vision of the mind, according to which focusing on the mind of the single individual is all that is required in order to define what a mind is and how it works. The image of the mind that classical cognitive science gives us is that of a functional system whose processes are described in terms of manipulations of informational symbols in accordance with a series of formal syntactic rules.

According to evolutionary psychology, by contrast, the human mind is a set of cognitive modules, each of which has been selected during evolution for its adaptive value. Major figures of this current, such as John Tooby and Leda Cosmides, have gone as far as maintaining that the brain is a physical system that works like a computer (Cosmides & Tooby 1997). According to Steven Pinker (1994, 1997), our cognitive life can be referred to in terms of the function of a series of modules like the linguistic module, the module for the Theory of the Mind, etc.

Based on this theoretical framework, in the last twenty years cognitive neuroscience when investigating human social cognition has mainly tried to locate—as mentioned above— the cognitive modules in the human brain. Such an approach suffers from ontological reductionism, because it reifies human subjectivity and intersubjectivity within a mass of neurons variously distributed in the brain. This ontological reductionism chooses as a level of description the activation of segregated cerebral areas or, at best, the activation of circuits that connect different areas and regions of the brain. However, if brain imaging is not backed up by a detailed phenomenological analysis of the perceptual, motor, and cognitive processes that it aims to study and—even more importantly—if the results are not interpreted, as previously argued, on the basis of the study of the activity of single neurons in animal models, and the study of clinical patients, then cognitive neuroscience, when exclusively consisting in brain imaging, loses much of its heuristic power. Without the

demonstration of the specific correlation between brain states and mind states and the explanation of such correlation, much of the contemporary brain imaging approach to social cognition looks like a sort of high-tech version of phrenology.

For this reason a "phenomenologization" of cognitive neuroscience is desirable, as Gallese has proposed before (see Gallese 2007, 2009, 2011, 2014). In Gallese's view, to "phenomenologize" cognitive neuroscience means to start neuroscientific research from the analysis of subjective experience and of the role that the living body plays in the constitution of our experience of material objects and of other living individuals. In this way, the empirical study of the genetic aspects of subjectivity and intersubjectivity can be pursued on new bases—if compared to those thus far adopted by classical cognitivism. Francisco Varela a few years ago realized a similar possibility and set out on a pathway of analysis in this direction (Varela & Shear 1999).

Times change, however. We are insisting on nothing less than a change of paradigm. A new neuroscientific approach to the study of the human mind is gaining momentum. It capitalizes upon the study of the bodily dimension of knowledge: the so-called "embodied cognition" approach. In the next section we introduce mirror neurons and embodied simulation. Our purpose is to show that, starting from a sub-personal neuroscientific description of the pragmatic relationship with the world, a pathway can be traced to define the forms of subjectivity and intersubjectivity that distinguish human nature, rooted in the bodily interacting nature of human beings.

3 Mirroring mechanisms and embodied simulation

The discovery in the early 1990s of mirror neurons in the brain of macaques (Gallese et al. 1996; Rizzolatti et al. 1996), and the subsequent discovery of mirror mechanisms in the human brain (see Gallese et al. 2004; Rizzolatti & Sinigaglia 2010) suggest that there exists a direct modality of access to the meaning of other

people's behaviours—a modality that can be set aside from the explicit attribution of propositional attitudes. Mirror neurons are motor neurons, originally discovered in macaques' ventral premotor cortex area F5, later on also found in the reciprocally-connected posterior parietal areas AIP and PFG. Mirror neurons not only respond to the execution of movements and actions, but also respond to the perception of actions executed by others. Mirror neurons map the action of others on the observers' motor representation of the same action. Further research also demonstrated in the human brain the existence of a mechanism directly mapping action perception and execution, defined as the Mirror Mechanism (MM; for a recent review, see Ammaniti & Gallese 2014; Gallese 2014). In addition, in humans the motor brain is multimodal. Thus, it doesn't matter whether we see or hear the noise made by someone cracking peanuts, or locking a door. Different—visual and auditory—sensory accounts of the same motor behaviour activate the very motor neurons that normally enable it. The brain circuits showing evidence of the MM, connecting frontal and posterior parietal multimodal motor neurons, most likely analogous to macaques' mirror neurons, map a given motor content like "reach out" or "grasp" not only during their performance, but also when perceiving the same motor behaviour performed by someone else, when imitating it, or when imagining performing it while remaining perfectly still. The relational character of behaviour as mapped by the cortical motor system enables the appreciation of purpose without relying on explicit propositional inference.

Altogether, these findings led to the formulation of the "Motor Cognition" hypothesis as a crucial element in the emergence of social cognition (Gallese 2009). According to this hypothesis, cognitive abilities like the hierarchical representation of action with respect to a distal goal, the detection of motor goals in others' behaviour, and action anticipation are possible because of the peculiar functional architecture of the motor system, organized in terms of goal-directed motor acts. Traditionally, the relation between actions and their outcomes is assumed to be largely independent of the motor processes and representations underpinning action execution. Such processes and representations allegedly concern elementary motor features such as joint displacements or muscle contractions only. However, solid empirical evidence challenged this view. Motor processes may involve motor representations of action goals (e.g., to grasp, to place, etc.), and not only kinematic or dynamic components of actions. This suggests that beliefs, desires, and intentions are neither primitive nor the only bearers of intentionality in action. We do not necessarily need to metarepresent in propositional format the intentions of others to understand them. Motor outcomes and motor intentions are part of the "vocabulary" that is spoken by the motor system. On occasion we do not explicitly ascribe intentions to others; we simply detect them. Indeed, we posit that motor representation is enough to ground the directedness of an action to its outcome (Gallese 2000, 2003b; Butterfill & Sinigaglia 2014; compare also Gallagher's 2005 notion of direct perception).

One of the consequences of the discovery of mirror neurons was the possibility of deriving subjectivity from intersubjectivity at the subpersonal level of description. The sense of self is precociously developed, beginning from a self that is first of all physical and bodily, and which is constituted precisely by the possibility of interacting and acting with the other. Embodied simulation can provide the neurobiological basis for early forms of intersubjectivity, from which the sense of the self is built. The discovery of mirror neurons and the simulation mechanism would therefore seem to further stress that being a self also implies being with the other. The model of intersubjectivity suggested by mirror mechanisms and embodied simulation correlatively sheds new light on the subjective dimension of existence. Let us see first what type of intersubjectivity mirror neurons seem to suggest.

The discovery of mirror neurons gives us a new empirically-grounded notion of intersubjectivity connoted first and foremost as intercorporeality—the mutual resonance of intentionally meaningful sensorimotor behaviours. The ability

to understand others as intentional agents does not *exclusively* depend on propositional competence, but it is highly dependent on the relational nature of action. According to this hypothesis, it is possible to directly understand the meaning of other people's basic actions thanks to a motor equivalence between what others do and what the observer *can* do. Intercorporeality thus becomes the main source of knowledge that we have of others. The motor simulation instantiated by neurons endowed with "mirror properties" is probably the neural correlate of this human faculty, describable in functional terms such as "embodied simulation" (Gallese 2003a, 2005, 2011; Gallese & Sinigaglia 2011b).

Action constitutes only one dimension of the rich baggage of experiences involved in interpersonal relations. Every interpersonal relation implies the sharing of a multiplicity of states like, for instance, the experience of emotions and sensations. Today we know that the very nervous structures involved in the subjective experience of emotions and sensations are also active when such emotions and sensations are recognized in others. A multiplicity of "mirroring" mechanisms is present in our brain. It was proposed that these mechanisms, thanks to the "intentional attunement" they generate (Gallese 2006), allow us to recognize others as our fellows, likely making intersubjective communication and mutual implicit understanding possible. The functional architecture of embodied simulation seems to constitute a basic characteristic of our brain, making possible our rich and diversified intersubjective experiences, and lying at the basis of our capacity to empathize with others.

4 Body and self

After having delineated a deflationary neurobiologically-grounded account of basic aspects of intersubjectivity, namely an account focused on the minimal core mechanisms of intersubjectivity, let us now address the relationship between body and self. A minimal manifestation of the sense of self can already be identified in our first bodily experiences, and this highlights the potential contribution of bodily experiences to

its constitution. Some aspects of the minimal self proposed by contemporary philosophical and empirical research are the notion of first-person perspective, the "mineness" of the phenomenal field (*Meinigkeit*), embodiment of point of view, and issues of agency and body ownership (Cermolacce et al. 2007).[12] On the philosophical side, phenomenology emphasizes the necessity of embodiment of the self for all the above-cited aspects of self experience. As argued by Cermolacce et al. (2007, p. 704, footnote 3), in phenomenology

> the field of experience is not yet considered to be subjective because this predicate already implies that there is a subject. For phenomenology, the very idea of the subject articulates itself in experience. In this sense, the manifestation and appearing of experience are the conditions for the experience of the subject in question.

This philosophical standpoint has important implications for the empirical investigation of the neural correlates of the self.[13] Rather than empirically addressing the self by starting with a search for the neural correlates of a pre-defined, explicit, and reflective self-consciousness, we believe it to be more productive to investigate what what set of constitutive conditions allows an implicit and pre-reflective sense of self to emerge, and how this is effected. The interesting questions to be first answered are: "What enables the basic experience of ourselves as bodily selves? What enables us to implicitly distinguish ourselves, as bodily selves, from other human bodily selves?" In the following we review and discuss recent empirical evidence providing preliminary answers to these questions.

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12 Again, for sake of concision, we do not deal here with the relationship between the notion of a core, minimal self as a bodily self and agency and body ownership. On this topic, see Gallese & Sinigaglia (2010, 2011a). Moreover, it is worth noting that the arguments proposed in this section in relation to the notion of a minimal bodily self could be applied to other non-human animals. The possibility that high-level self-awareness can emerge from a primitive and non-conceptual form of self-awareness, and that it is possible that we share this basic level of the sense of self with other non-human animals, has already been discussed. For a discussion of this and other related topics see Bermúdez (2003).

13 See Vogeley et al. (2003) and Vogeley et al. (2004) for an investigation of the neural correlates of the first-person perspective.

The relationship between the minimal sense of self and the cortical motor system was recently revealed. The motor experience of one's own body, even at a covert level, allows an implicit and pre-reflective bodily self-knowledge to emerge, leading to a self/other distinction. Indeed it was recently shown that in a task in which differently rotated static pictures of right and left human hands were presented, participants who had to determine whether each observed hand was the right or the left one produced faster responses when observing the pictures of their dominant hand with respect to others' hands (Ferri et al. 2011). However, when participants were asked to explicitly discriminate between their hands and the hands of others, the self-advantage disappeared. Implicit and explicit recognition of the bodily self dissociated: only implicit recognition of the bodily self, mapped in motor terms, facilitated implicit bodily self-processing.

A subsequent fMRI study by Ferri et al. (2012), using a similar hand mental rotation task, demonstrated that a bilateral cortical network formed by the supplementary and pre-supplementary motor areas, the anterior insula, and the occipital cortex was activated during processing of participants' own hands. Furthermore, the contralateral ventral premotor cortex was uniquely and specifically activated during mental rotation of the participants' own dominant hands. The ventral premotor cortex might represent one of the essential anatomo-functional bases for the motor aspect of bodily selfhood, also in light of its role in integrating self-related multisensory information. This hypothesis is corroborated by clinical and functional evidence showing its systematic involvement with body awareness (Ehrsson et al. 2004; Berti et al. 2005; Arzy et al. 2006). This evidence demonstrates a tight relationship between the bodily self-related multimodal integration carried out by the cortical motor areas, specifying the motor potentialities of one's body and guiding its motor behaviour, and the implicit awareness one entertains of one's body *as* one's own body and of one's behaviour *as* one's own behaviour. Because the ventral premotor cortex is anatomically connected to visual and somato-

sensory areas in the posterior parietal cortex and to frontal motor areas we hypothesize that premotor cortex activity, by underpinning the detection of congruent multisensory signals from one's own body, could be at the origin of the experience of owning one's own body parts.

This minimal notion of the self, namely the bodily self as power-for-action (see Gallese & Sinigaglia 2010, 2011a), tacitly presupposes ownership of an action-capable agentive entity; hence it primarily rests upon the functionality of the motor system. As we just saw, empirical evidence supports the neural realization of this implicit aspect of selfhood in the brain's motor cortex. Since the minimal bodily self rests neurally on the motor system, it logically follows that characteristics of the latter are defining for the former. This implies that one could attribute to the minimal bodily self known features of the motor system, including its capacities and limitations. The motor aspects of the bodily self provide the means to integrate self-related multimodal sensory information about the body and the world with which it interacts. This is also important from a theoretical point of view, because it opens the possibility of linking the openness of the self to the world to the motor potentialities its bodily nature entails.

One could then posit that the minimal bodily self when conceived in terms of its motor potentialities has a dual function. On the one hand, it constitutes important aspects of the basic sense of self. On the other, it shapes our perception and pre-reflective conception of others as other selves incarnated in a motorly-capable physical body with capacities and experiences similar to ours. Through mirror mechanisms and embodied simulation, others appear to us as second selves, or second persons. We believe that this perspective provides a more vivid experience of intersubjectivity, relative to the detached, propositional deliberation on the experiences of others available in standard mind reading of others.

5 Body and language: Reflexiveness

According to the perspective so far delineated, body, actions, and feelings play a direct role in

our knowledge of others. The question remains open as to whether our propositional representations are totally separate from this bodily dimension. Our hypothesis is that they are not. But it remains a fact that linguistic and bodily cognition afford us diversified modalities of epistemic access to the world, even though often such modalities contaminate one another and are inevitably interwoven.

The mind, from the perspective delineated here, is therefore an embodied mind, though it would be more correct to speak of a corporeal mind. The concept of embodiment can induce one to think that a mind pre-existing the body can subsequently live in it, and use it. The truth is that mind and body are two levels of description of the same reality, which manifests different properties according to the chosen level of description and the language employed to describe it. A thought is neither a muscle nor a neuron. But its contents, the contents of our mental representations, are inconceivable without our corporeity. Likewise it is difficult to imagine how the representational format of a propositional type can have developed without our corporeality. Language somehow allows us, as we will see, to transcend our corporeity; nevertheless, we posit that the bond with the body is always present.

A few years ago, Gallese (2000) proposed that we look at the evolution of human language as an exaptation[14] of functional sensorimotor processes, which put them into the service of human linguistic competence. The hypothesis of exaptation was then developed in subsequent papers and later elaborated in terms of "neural exploitation" (Gallese & Lakoff 2005; Gallese 2008), or "neural reuse" (Gallese 2014). "Neural exploitation" consists in the reuse of neural resources, originally evolved to guide our interactions with the world, to serve the more recently evolved linguistic competence. This notion of reuse implies a functional uncoupling of the sensorimotor system from muscular output, to guide the generative-syntactic aspects of language by functionally connecting it to the pre-

frontal and, more generally, non-sensorimotor circuits. According to this view, intentionality, the aboutness of our representations, is—in the first place—an exapted property of the action models instantiated by the cortical motor system (Gallese 2000, p. 34). The sensorimotor system, when uncoupled from muscular output, makes available to us a model, or paradigm, of our motor knowledge. As such, not only it houses causative properties but also content properties. And this relation to a content, or aboutness, is a primitive expression of intentionality, then exploited by other forms of representations. This perspective on reuse is acquiring more and more supporters (see Dehaene 2005; Anderson 2010).[15]

Compelling evidence shows that humans, when processing language, activate the motor system both at the phono-articulatory and at the semantic level. When listening to spoken words or looking at someone speaking to us, our motor system simulates the phono-articulatory gestures employed to produce those very same words. Furthermore, processing action-related linguistic expressions activates regions of the motor system congruent in somatotopic fashion with the processed semantic content. Reading or listening to a sentence describing a hand action activates the motor representation of the same action (for a review, see Gallese 2008; Glenberg & Gallese 2012). Interestingly, somatotopic motor activation has also been observed during the comprehension of abstract and figurative use of language such as metaphors and idioms (e.g., Guan et al. 2013; Boulenger 2012; see also Gallese & Lakoff 2005 on the bodily foundation of concepts). However, it is important to note that embodied simulation is not always involved in language comprehension, and that there is no contradiction in saying this. There are cases in which language, at least at the content level, is not tied to any form of bodily knowledge. In such cases (e.g., when we talk about the notions such as moral judgement or intelligence) no embodied simulation is likely to be at play.

Nevertheless, the problems that language raises for the embodied perspective on human

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14 Exaptation refers to the shift in the course of evolution of a given trait or mechanism, which is later on reused to serve new purposes and functions (see Gould & Lewontin 1979).

15 For a discussion of different views on the notion of reuse, see Gallese (2014).

social cognition are still enormous. As clearly underlined, among others, by the Italian philosopher Paolo Virno (2003, 2011), the common linguistic space shared by a community of speakers proves to be incommensurably different from the pre-linguistic one. The linguistic dimension is based on a distinction between linguistic utterances and facts about the world, be they referable to physical or psychological events. We can say that "today the sun is shining" and be understood, even if outside the window snow is falling. Or we can maintain that "all Italians want to pay taxes", again being understood and simultaneously contradicted by the factual truth of the enormous tax evasion in our country.

According to Virno, the gap between meaning and denotation (what he calls the neutrality of meaning, namely the fact that the meaning of a word such as, for example, "man", can be understood apart from any reference to an instance of man) is referable to linguistic reflexiveness, i.e., to the fact that language refers to itself and that with words we can talk about other words. It seems to us that the reflexiveness of language is a product of the symbolic nature of linguistic representations. The symbolic nature of such representations is what allows language to break away from the "here and now"; it is what allows the neutrality of meaning.

In order for a sign to be symbolic it necessarily has to be reflexive. What makes a sign a symbol is its being part of a system in which each term is correlatively defined in relation to the other terms within the system and in relation to the renegotiation of this relationship constantly taking place within the system itself. It is the use of a symbol within a given context that each time redefines relationships inside the language system.

Thus, symbolic relationships are by definition characterized by reflexiveness. Symbols are defined through other symbols. This level of reflexiveness is pre-theoretical; it emerges in the linguistic activity of each speaker and leads to a form of linguistic awareness of a practical character. This practical linguistic awareness has been called the *epilinguistic* quality and thus it

has been distinguished from the theoretical quality that is expressed in the metalanguage of linguistics (Culioli 1968; Lo Piparo 2003). The concept of epilinguistic quality refers to the natural tendency of speakers to reflect on their own language—a tendency made possible by the distinctive quality of language being able to speak of itself.

The uniqueness of human language is also maintained by classical cognitivism and by cognitive linguistics, but for very different reasons. The otherness of human language in comparison with other systems of communication known in the animal world derives from its linguistic recursive quality. In an often-quoted article written some years ago (Hauser et al. 2002) defined the faculty of language in a narrow sense (FLN) as being expressed by recursivity. Nevertheless, this perspective, in addition to suffering from the usual cognitivist solipsism, is exposed to comparative verification in the animal world. If the FLN marks human linguistic uniqueness in terms of syntactic recursivity, the latter must be entirely absent in the extra-human animal kingdom.

Actually, the facts tell us exactly the opposite. Recent studies (Gentner et al. 2006; Abe & Watanabe 2011; see also Margoliash & Nusbaum 2009; Bloomfield et al. 2011) have shown that singing species of birds like starlings or finches demonstrate, both in the production and in the reception of conspecifics' vocalizations, the ability to produce and to extract recursive syntactic characteristics. The study by Abe and Watanabe also shows that the development of this competence is dependent on social encounters with the vocalizations of other conspecific individuals. Finally, these authors have shown that lesion of the lateral magnocellular nucleus of the anterior nidopallium, a motor structure comparable to the basal ganglia of primates, involved both in the production and the perception of song, prevents finches from discriminating the syntactic-recursive characteristics of the song they hear.

These results show that the best strategy for studying some of the most relevant aspects of human social cognition, even demonstrating the bases of their uniqueness, consists in a pre-

liminary recognition of the mechanisms and faculties that we share with the rest of the animal world. As maintained in the past (Gallese 2003b, 2008), the difference between human and nonhuman nature could originally have been of a quantitative rather than a qualitative nature.[16]

6 Body and language: Facts and challenges

One of the key challenges for the embodied approach to human social cognition consists in trying to understand whether and how our bodily nature determines some of our linguistic activities, such as denying, asking, or doubting, that seem to be exclusively human. Are linguistic activities as those ones anchored to bodily mechanisms? The question is open and empirical research must address this challenge in the coming years. In the meantime, at least at a purely speculative level, let us try to delineate a possible point of contact between the anthropogenic power of language and embodied simulation.[17]

There is indeed a way to connect the common pre-linguistic sphere to the linguistic one (Gallese 2003b, 2007, 2008; Gallese & Lakoff 2005; Glenberg & Gallese 2012). This consists in showing that language, when it refers to the body in action, brings into play the neural resources normally used to move that very same body. Seeing someone performing an action, like grabbing an object, and listening to or reading the linguistic description of that action lead to a similar motor simulation that activates some of the same regions of our cortical motor system, including those with mirror properties, normally activated when we actually perform that action.

These data on the role of simulation in understanding language (see Pulvermüller 2013 for a review of this topic) broadly confirm a thesis already discussed in the history of philosophy (for instance, by Epicurus, Campanella, Vico,

see Usener 1887 and Firpo 1940 or Condillaco 2001). The thesis in question claims for the bodily, sensory, and motor dimensions a constitutive role in language production and understanding. However, it seems that the relationship between language and body does not move in a single direction. The fact is that language is without doubts constitutive of human nature and, as such, it seems to offer us wholly human modalities of experiencing our corporeity.

In this sense, neuroscientific data on the role of simulation during understanding of language also lend themselves to a mirror and complementary reading with respect to that previously proposed. On the one hand it is plausible that embodied simulation might play a crucial role in understanding language. Indeed, if one reversibly interferes with this process, for instance by means of TMS stimulation, understanding of language is jeopardized. On the other hand, language allows us—and in this we are unique among all living species—to fix and relive specific aspects of our bodily experience. Through language we can crystallize and relive fragments of experiences that are not topical, that is to say are not *my* experiences *now*, but become a paradigm, a model, for understanding ourselves and others.

In the following section we discuss the role of embodied simulation seen as a *paradigm* or model in the light of the Aristotelian notion of *paradeigma*.[18] For the time being it suffices to stress that the possibility of hypostatizing and then segments of our experiences independently of our immediate physical context, or independently of specific physical stimuli, is a possibility that only the possession of language allows us to experience. The faculty of language is therefore, on one side, rooted in corporeality but, in turn, changes and moulds our way of living bodily experiences.

7 Body and language: Embodied simulation as a paradigm?

The relation between body and language was to a great extent underestimated in the last cen-

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[16] According to this perspective, linguistic syntax could originate and be modelled upon syntactic motor competence, the latter being exapted and put at the service of the new linguistic competence (see Gallese 2007, 2008).

[17] With the expression "anthropogenic power of language" we mean that the human nature, as we know it, depends on language.

[18] For an earlier formulation of this hypothesis, see Gallese (2013).

tury, thanks, above all, to Chomsky's major influence. In 1966 Chomsky published a book significantly entitled *Cartesian Linguistics.* Descartes is the originator of the idea that language has little to do with the body.[19] The Cartesian thesis on the relationship between language and body implies, on one side, that the body is not a substratum and material of language and, on the other, that language is exclusively a tool that expresses a thought formed independently of language itself. According to Descartes (1642) and the Cartesian tradition in which Chomsky stands, language is a tool through which we manifest an autonomous thought that precedes language—a thought structured by logic but certainly not by language, whose role is circumscribed and downsized to that of being a mere label of thoughts (cf. Hinzen & Sheehan 2013 for a critical discussion of the issue).

The theses informing the Cartesian idea of language are challengeable nowadays. Language makes meaning general, releasing it from the context, that is, from the dimensions of who, what, how, where, and when. Language, in other words, provides us with a unique modality of reference to the world, allowing us at the same time to transcend contingent determinations and to define them at a different level, thanks to the use of concepts like subject, object, time, space, universal, etc. It is perhaps not trivial to notice that such concepts correspond to precise grammatical structures and that, most likely, the use of a grammatically-structured language contributed, by co-evolutionary dynamics, to the structuring of rational thought characterized by such features (Hinzen & Sheehan 2013).

Hence, thanks to language we can speak of humankind without referring in particular to any of the single individuals sharing the property of belonging to the human species. We can speak of a subject aside from the individual embodiments of this attribute, etc. Language, as stressed by Virno, furnishes us with general meanings, that is, meanings valid for everybody but, at the same time, meanings that do not necessarily denote a particular instantiation.

Interestingly enough, according to Giorgio Agamben (2008) what holds "for everybody and nobody" is referable to the Greek notion of *paradeigma*, originally explored by Aristotle. The *paradeigma* is a typical form of rhetorical reasoning that moves between individual and individual according to a form of bipolar analogical knowledge. Agamben (2008, pp. 23-24), radicalizing Aristotle's theses, maintains that the paradigm can only be conceived of by abandoning the dichotomy between individual and universal: the rule does not exist before the single cases to which it is applied. The rule is nothing but its own exhibition in the single cases themselves, which thus it renders intelligible.

By applying the notion of paradigm to the grammatical "rules" of language, Agamben touches upon a central point: the so-called linguistic rule derives from the suspension of the concrete denotative application:

> [t]hat is to say, in order to be able to serve as an example, the syntagm must be suspended from its normal function, and, nevertheless, it is precisely through this non-operation and this suspension that it can show how the syntagm works, can allow the formulation of the rule. (Agamben 2008, p. 26)

To better explain the notions of rule and suspension of a denotative application, Agamben refers to Latin declensions. When we want to learn the first declension we inflect a noun, for example "*rosa*", "*rosae*", etc... In so doing, we are suspending the usual denotative application of this noun and, by means of this suspension, we are showing how the declension works. According to Agamben, "[...] in the paradigm, intelligibility does not precede the phenomenon, but is, so to speak, 'alongside' it (parà)" (2008, p. 29). In other words "[...] in the paradigm there is not an origin or an *arché:* every phenomenon is the origin, every image is archaic" (Agamben 2008, p. 33).

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19 It is worth noting that Descartes also defended the related thesis that animals don't have soul exactly because they do not have language. Cf. Descartes (1637).

On Agamben's reading, the Aristotelian *paradeigma* is a good model for describing the creation of linguistic rules. Starting from Agamben's intuition and seeking to move one step further, the hypothesis that we want to explore here is that the notion of *paradeigma* is a good model not only for the creation of linguistic rules but also for the definition of the embodied simulation mechanism. In this connection, simulation allows us, at a sensorimotor level, to hypostatize and reuse what holds "for everybody and nobody".

To understand to what extent the analogy between embodied simulation and *paradeigma* works it is necessary to go back to Aristotle. What is meant by *paradeigma* in Aristotelian thought and in what context does Aristotle make use of this notion?

The *paradeigma*, as already anticipated, is a typical is a typical argument form used to persuade and devoted to the discussion of "things that can be otherwise." Aristotle discusses this argument form, which does not have any demonstrative aim, both in *Prior Analytics* and in *Rhetoric.* Argumentation based on the *paradeigma*, for example, consists in the presentation by the orator of an exemplary case, based on a historical fact or a figment of the imagination, as in the case of fables. It is the juxtaposition of the present situation and an exemplary one that guides, or should guide, the actions of the person to whom the argumentation is addressed. Thus the *paradeigma*, among rhetorical argumentations, is that which goes from the particular to the particular, from an exemplary case to the present situation. Argumentation based on the *paradeigma* does not make a claim for universality. The orator is not bound to offer an exhaustive number of cases justifying a universally valid conclusion. One case is sufficient, provided that it is particularly suitable, and precisely exemplary, in relation to the context in which the argumentative discourse takes place.

For these reasons, though resembling inductive reasoning (*epagoghé*), which proceeds from the particular to the universal, and indeed considered by Aristotle himself as the transposition of inductive reasoning to the rhetorical

sphere, the *paradeigma* conquers its own autonomous space. To confirm this, one need only to think that in *Prior Analytics* Aristotle (Ross 1978) devotes two separate chapters to paradigm and induction: respectively XXIV and XXI of Book II.

On the one side the *paradeigma,* which proceeds "from the part to the part" (*Prior Analytics* 69a, 15), are peculiar aspects distinguishing it from the *epagoghé*; on the other, it is by all means a form of induction, as Aristotle expressly affirms at the start of Chapter XX of Book II of *Rhetoric.* According to Piazza (2008, p. 117) there are at least two reasons why the *paradeigma* can still be considered a form of *epagoghé*, despite the peculiarities that characterize it. Both these reasons seem interesting, not only for the definition of paradigm that, starting from Aristotle, Agamben discusses in relation to linguistic praxis, but also and above all in the framework of a reflection on the mirror mechanisms enacted in embodied simulation.

Following Piazza's (2008, p. 117) reading of Aristotle, the first of the characteristics of inductive reasoning also found in the paradeigma consists in always proceeding from what is "best known and first for us" (Aristotle, Analytica posteriora II.19), or from what is for us most immediate and most easily accessible, because being part of our baggage of experiences and knowledge. The second characteristic is, instead, identifying similarities between particular cases.

At another level of analysis, both these features also characterize embodied simulation. One condition for the simulation mechanism's being enacted is sharing a baggage of (motor) experiences and knowledge. Embodied simulation is enacted starting from what for us is "first," i.e., what for us is known and easily accessible in terms of motor potentialities and experiences. Sharing a repertoire of practices, experiences, and sensations is therefore an essential condition, since only by starting from what is well known to us it is possible to identify analogies between our actions and others'. We understand the other starting from our own bodily experience, which is what is "best known and first for us", again using Aristotle's words. On

the basis of this knowledge we identify similar elements in our experiences as well as in those of others.

Embodied simulation, when manifested in the phenomenon of action, emotion, or sensation *mirroring* always involves an original I-thou relationship in which the "thou" is the term with respect to which the self is constituted. On the other hand, the "self" is the basis on which immediate and implicit understanding of the "thou" is possible.

The analogy with the cognitive mechanism subtended by paradigmatic reasoning appears evident. Indeed, in the case of Aristotle's *paradeigma*, an example, a particular case, is understood because it is close to our feeling, our experiences, and our baggage of knowledge. And nevertheless the process does not stop here. This form of understanding of a particular that is not me will lead me to new conclusions and to a deeper understanding of myself, of *my* particular case, and of *my* situation. Our experiences are therefore the measure from which we understand others and their experiences (i.e., our previous actions, emotions, and so forth). And others' experiences (i.e., their actions, emotions and so forth) are for us a condition for deeper understanding of ourselves. Thus, the embodied simulation underpinning my present experience is also a *paradeigma* from which I can understand what I observe in others and draw inferences from it for others and for myself.

The embodied simulation mechanism, thus defined, is constitutive of the process of construction of meaning. In this connection, embodied simulation enacted while understanding language is not my present experience but the *paradeigma* in relation to which some of our linguistic expressions acquire a meaning that is rooted in the body. When we read or listen to the description of an action, the process of simulation that takes place in us is not the enactment of the same action; we would be echopractic if we were unable to avoid imitating and reproducing all the actions that we see or whose description we listen to or read. According to our hypothesis, embodied simulation rather makes available to us an exemplary case, a

model, in relation to which understanding of language is also realized. If therefore it is true that the symbolic dimension opens up some possibilities for us and creates worlds for us that only linguistic creatures can enter, it is also true that language strongly exploits mechanisms rooted in our corporeality. Enactment of the simulation process in understanding language seems to suggest that the symbolic dimension and the bodily dimension cohabit in linguistic praxis.

Nevertheless, the nature of this relationship is still not entirely clear, nor is the confine between the bodily dimension and the typically or exclusively symbolic dimension. Can it be hypothesized that corporeal knowledge also plays a role in understanding logical operators such as, for instance, negation or disjunction, or that it plays a role in understanding the interrogative form? The whole symbolic nature of these linguistic structures appears in some respects beyond question. Research on these issues is now open (Kaup et al. 2006, 2007; Tettamanti et al. 2005; Christensen 2009; Tomasino et al. 2010; Liuzza et al. 2011; Kumar et al. 2013) and today many wonder about the possibility of identifying mechanisms that can anchor such structures to our bodily experience. We take this to be the real challenge for the embodied cognition approach to the role played by language in human social cognition.

Let us once more return to the Aristotelian notion of *paradeigma* and appraise other possible hints for substantiating the analogy with the embodied simulation mechanism. The understanding that the rhetor calls for through reasoning based on the *paradeigma* should lead the citizen to choose what is best for him in various circumstances. The goal of such reasoning is to determine understanding of a present situation, by analogy with a historical example or a fable, and, on the basis of this more informed knowledge, to guide the human being's choices. In other words, the rhetorical example or *paradeigma* is knowledge whose main goal is practical and not theoretical.

A practical aim also characterizes embodied simulation. Embodied simulation is always aimed at "navigating" in the world and, there-

fore, eventually at acting. It was hypothesized that embodied simulation allows us a direct, experiential way of understanding other people's actions and experiences and, on the basis of this understanding, it allows us to regulate our actions and our experiences. These goals are always practical. In some respects, the process of embodied simulation that is enacted, for instance, when reading a novel (see Wojciehowski & Gallese 2011), also has a practical aim. Literature recreates a world of emotions and experiences: the emotions and the experiences of the literary characters inhabit the fictional world of the novel. The simulation mechanism helps us to "navigate" that world, even if it is a fictitious world; it allows us to understand and, in part, to relive the emotions of the protagonists and their vicissitudes. The aim in this case is practical insofar as the simulation mechanism allows us to approach the fictitious other with a second-person epistemic perspective (Gallese 2014).[20]

Embodied simulation makes implicit knowledge about others immediately available, with the aim of regulating our interactions with them. Our understanding of the literary other is almost always second-person, based on the possibility of perceiving analogies between our own experiences and others' and made possible through a hypostatization of our experiences that is achieved through the simulation mechanism (Wojciehowski & Gallese 2011).

In the end, what is embodied simulation if not a suspension of the application of a process? Let us think of when mirror neurons are activated in observing actions performed by others; or of when canonical neurons are activated while we are looking at the keyboard of a computer thinking about what we want to write; or when cortical motor neurons are activated when we imagine ourselves writing on that keyboard. These responses on the part of motor neurons manifest the activation of implicit knowledge, that is, bodily motor knowledge expressing the motor potentialities of the bodily self mapped by the motor system in terms of their motor outcomes.

Reuse of motor knowledge, in the absence of the movement that realizes it, as exemplified by embodied simulation, is an example of "paradigmatic knowledge." Thus, embodied simulation is a case of implicit paradigmatic knowledge. According to our hypothesis, embodied simulation allows us to naturalize the notion of paradigm, anchoring it at a level of sub-personal description, whose neural correlates we can study.

Our openness to the world is constituted and made possible by a motor system predisposing and allowing us to adapt our daily and contingent pragmatic relationships with the world against the background of a prefigured but highly flexible plan of motor intentionality. Such a plan, intended as the sum of our motor potentialities, provides its coordination to any single contingent modality of relation with the world, that is, to any single action we perform, in which it continues to actualize itself. This aspect seems important to us because it shows how specific aspects of human social cognition are made possible and scaffolded upon processes not necessarily specific to humans, like embodied simulation.

8 Body and soul

It is improper, or at least it seems so to us, to say that the soul, the spirit, or intelligence are embodied. If it were so, we would thus return to a dualistic conception of human nature. Such dualism is always present in the tradition of Western thought, though it is often disguised in forms that, rightly or wrongly, are deemed politically more correct. Today nearly all cognitive scientists declare themselves to be monists and physicalists. Nevertheless, the conception still dominant today about the cognitive structure of humans and their functions draws a clear-cut and apparently unsolvable division between linguistic-cognitive processes and sensory-motor processes. It matters little that everybody admits that both are in some way referable to the biological physicality of the brain. The brain, according to classical cognitivism, is divorced from the body and conceived of as a box of algorithmic wonders.

Classical cognitivism sees the body as an appendix of little or no interest for decoding the supposed algorithms reportedly presiding over

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20 A second-person perspective is adopted in social contexts when, implicitly or explicitly, we re-use our own experiences to understand others. On the notion of second-person perspective see Pauen (2012).

our cognitive life. Such is a cognitive life with very little vitality, totally divorced not only from effectual reality, as we try to show here, but also from our daily phenomenal experience. It is not by chance that the language usually used to describe cognitive processes is borrowed from artificial intelligence: algorithms, information processing, etc.

Humans, however, cannot be assimilated to information-processing entities. Even less acceptable is the thesis that the concept of meaning is wholly assimilable to the concept of information. Classical cognitivism has maintained for decades that intelligence depends on the algorithms that substantiate it and not on the material substrata on which the algorithms themselves are believed to be implemented. This is the so-called principle of the multiple realizability of cognitive processes. Embodied Simulation and its relation to language and cognition casts severe doubts on this principle and adds arguments in support of the thesis that human cognition is tightly and necessarily dependent on the kind of body we have. As such, the mechanism of Embodied Simulation and the role it plays in human cognition provide further arguments in support of the idea that the principle of multiple realizability is false. We are who we are because we evolved by adapting to a physical world that obeys a series of physical laws, such as that of gravity.

As the art historian Heinrich Wölfflin wrote in his 1886 *Prolegomena zu einer Psychologie der Architektur*, if we were exclusively optical creatures, aesthetic judgment of the physical world would be precluded to us. Are the amazement and sense of elevation transmitted to us by the contemplation of a Gothic cathedral conceivable in purely algorithmic terms? Is it conceivable to divorce aesthetic experience from our daily muscular, tactile, and viscero-motor experience of reality? Wölfflin (and together with him many others, among them Merleau-Ponty) maintained it was not, and we think that he was right.

We believe that our "natural" propensity to dualism is, on the one side, the product of our being asymmetrically positioned between mind and body, as Helmuth Plessner (2006) maintained. We are corporeal beings, but at the same time we maintain that we *have* a body. On the other side, the account of the historical result of the progressive de-centralization of the anthropological dimension leads us to be dualist. We are no longer the living image of God, we are no longer at the centre of the universe, and perhaps in postmodern times we are no longer even subjects or selves. What are we left with but with the claim of the total otherness and discontinuity of our cognitive social life and its underlying processes? Their immaterial nature, or more exactly their total otherness in relation to a corporeity whose animal origin or essence is—evolutionarily speaking—pretty much clear, is perhaps the only way of reaffirming our uniqueness. The dualism between mind and body become, thus, a mechanism of defence. The so-called mental Rubicon that separates us from other non-human living beings is a very powerful anti-depressive argument for a disorientated humanity.

At this point, however, a clarification is required in order to avoid unpleasant misunderstandings. It is beyond doubt that the least intelligent among humans is incommensurably different and *other* in relation to the most intelligent among chimpanzees, despite their almost complete sharing of a genetic endowment. The point is that this quantum leap can be explained, perhaps, by remaining within an evolutionary framework that does not look for discontinuities founded on theories of "cognitive catastrophes," genetic big bangs (as in the case of the so-called "grammar gene" invoked by Pinker), and so forth. The mysterious uniqueness—and loneliness—of humankind in the universe proves more comprehensible, or at least more easily approachable, if empirically investigated after having set aside the anti-continuist and self-consoling recipes of classic cognitive science. In our continuist approach, humankind is not special, because his evolution follows the same laws that regulate evolution of all other animals and is in continuity with evolutionary paths of other animals. However, our peculiar evolutionary path leaded us to acquire species-specific characteristics that only human beings share.

Sigmund Freud realized long before others how much the self is a bodily self (1923). Freud also helped us to understand how little we know

about who we are, particularly when aspiring to ground this knowledge solely on self-questioning rationality. What are the drives of which Freud spoke but a further manifestation of the double status of our flesh? We are *Körper* (objectual and represented body) and *Leib* (lived body), as Edmund Husserl maintained. Today cognitive neuroscience can shed new light on the *Leib* by investigating the *Körper*. The point is not to reduce the *Leib* to the *Körper*, but to understand that the empirical investigation of the *Körper* can tell us new things about the *Leib*.

9 Provisional conclusions

In this paper we addressed and discussed the notions of intersubjectivity and of the self as indissolubly intertwined outcomes of the bodily and symbolic dimensions. We proposed that embodied simulation seems to be able to naturalize the notion of paradigm, thus naturalizing one of the processes that makes language reflexiveness possible, and thus contributing to "creating" the human being. Being a subject perhaps means being a body that learns to express itself and to express its world thanks to the paradigm —embodied simulation—that allows one to go beyond the body while remaining anchored to it. A new understanding of intersubjectivity can benefit from a bottom-up study and characterization of the non-declarative and non-metarepresentational aspects of social cognition (see Gallese 2003a, 2007).

One key issue of the new approach to intersubjectivity we proposed here is the investigation of the neural bases of our capacity to be attuned to the intentional relations of others. At a basic level, our interpersonal interactions do not make explicit use of propositional attitudes. This basic level consists of embodied simulation processes that enable the constitution of a shared meaningful interpersonal space. The shared intersubjective space in which we live from birth constitutes a substantial part of our semantic space. Self and other relate to each other because are opposite extensions of the same correlative and reversible we-centric space (Gallese 2003a). Observer and observed are part of a dynamic system governed by reversible

rules. By means of intentional attunement, "the other" is much more than a different representational system; it becomes a bodily self, like us.

This new epistemological approach to intersubjectivity has the merit of generating predictions about the intrinsic functional nature of our social cognitive operations, cutting across, and not being subordinated to a specific ontology of mind, like that purported by the classic cognitivist approach. Open questions that need to be further investigated in the future concern the biological mechanisms underlying our species-specific forms of self-knowledge and intersubjectivity. Language will have a special role in this investigation. To what extent and how are symbolic operations constrained by biological mechanisms? Is this connection between symbolic representations and bodily mechanisms that has been responsible for our specificity? These and other questions will be object of investigation in the next years

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Multisensory Spatial Mechanisms of the Bodily Self and Social Cognition

A Commentary on Vittorio Gallese & Valentina Cuccio

Christian Pfeiffer

This commentary aims to find the right description of the pre-reflective brain mechanisms underlying our phenomenal experience of being a subject bound to a physical body (bodily self) and basic cognitive, perceptual, and subjective aspects related to interaction with other individuals (social cognition). I will focus on the proposal by Gallese and Cuccio that embodied simulation, in terms of motor resonance, is the primary brain mechanism underlying the pre-reflective aspects of social cognition and the bodily self. I will argue that this proposal is too narrow to serve a unified theory of the neurobiological mechanisms of both target phenomena. I support this criticism with theoretical considerations and empirical evidence suggesting that multisensory spatial processing, which is distinct from but a pre-requisite of motor resonance, substantially contributes to the bodily self and social cognition.

My commentary is structured in three sections. The first section addresses social cognition and compares embodied simulation to an alternative account, namely the attention schema theory. According to this theory we pre-reflectively empathize with others by predicting their current state of attention which involves predicting the spatial focus of attention. Thereby we derive a representational model of their state of mind. On this account, spatial coding of attention, rather than motor resonance, is the primary mechanism underlying social cognition. I take this as a theoretical alternative complementing motor resonance mechanisms.

The second section focuses on the bodily self. Comparison of the brain networks of the bodily self and social cognition reveals strong overlap, suggesting that both phenomena depend on shared multisensory and sensorimotor mechanisms. I will review recent empirical data about altered states of the bodily self in terms of self-location and the first-person perspective. These spatial aspects of the bodily self are encoded in brain regions distinct from the brain network of embodied simulation. I argue that while motor resonance might contribute to body ownership and agency, it does not account for spatial aspects of the bodily self. Thus, embodied simulation appears to be a necessary but insufficiently "primary" brain mechanism of the bodily self and social cognition.

The third section discusses the contributions of the vestibular system, i.e., the sensory system encoding head motion and gravity, to the bodily self and social cognition. Vestibular cortical processing seems relevant to both processes, because it directly encodes the world-centered direction of gravity and allows us to distinguish between motions of the own body and motions of other individuals and the external world. Furthermore, the vestibular cortical network largely overlaps with those neural networks relevant to the bodily self and social cognition. Thus, the vestibular system may play a crucial role in multisensory spatial coding relating the bodily self to other individuals in the external world.

Keywords

Attention schema | Bodily self | Embodied simulation | First-person perspective | Mirror neurons | Self-location | Social cognition | Vestibular system

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1 Introduction

The paper by Gallese and Cuccio provides an integrated theoretical framework explaining how the brain and body relate to social cognition, the human self, and language. The authors review empirical evidence from electrophysiological and neuroimaging studies supporting embodied simulation (ES) theory (Gallese & Cuccio this collection, p. 8). According to ES, the brain covertly simulates the bodily actions, perceptions, and emotions observed in other individuals by using parts of our neural architecture involved in acting, sensing, and feeling emotions. Thereby, we infer the goals, intentions, and states of mind of others in a pre-reflective and non-conceptual fashion. But the authors take this a step further and propose that ES is the key mechanism underlying, and hence unifying, both social cognition, the human self, and language. Throughout the paper, the authors emphasize the tight functional coupling between the body and the brain, which when taken into account bears the potential to significantly advance the scientific study of the hard problem of consciousness (Chalmers 1996).

This commentary on Gallese and Cuccio aims to find the right description of the brain mechanisms underlying pre-reflective aspects of both the bodily self and social cognition. Specifically, I will focus on Gallese and Cuccio's central claim that ES, based on motor resonance and neural processing in the motor system, is the primary brain mechanism underlying pre-reflective representations of the bodily self and social cognition (Gallese & Cuccio this collection, pp. 8–14). I ask the following questions: Could there be an alternative theory or empirical evidence countering the claim of a primacy of motor resonance underlying social cognition and the bodily self? Which brain mechanisms in addition to motor resonance might contribute to pre-reflective aspects of social cognition and the bodily self? I will defend the following three theses:

(1) Social cognition and the bodily self depend on multisensory spatial coding, which is distinct from motor resonance.

Thus, motor resonance may be a necessary but insufficiently "primary" brain mechanism of social cognition and the bodily self (cf. section 1, 2).

(2) The brain networks underlying social cognition and the bodily self largely overlap. Specific functional associations exist (a) between motor resonance and body ownership/agency and (b) between multisensory spatial coding and self-location/the first-person perspective (cf. section 2).

(3) The vestibular system, i.e., the sensory system encoding head motion and gravity, might provide unique information used for multisensory spatial coding that relates the bodily self to other individuals and the external world. This is further suggested by the large overlap existing between the human vestibular cortex and the brain networks underlying the bodily self and social cognition (cf. section 3).

My commentary is structured in three sections. In the first section I shall compare ES to an alternative theory of social cognition that assigns priority to spatial coding of attention, rather than to motor resonance. I shall show that both theories bear the potential that their proposed brain mechanisms cooperatively work together in order to support social cognition. The second section addresses the bodily self. I shall review data from neurological patients and full-body illusion experiments, which highlight the importance of two spatial aspects of the bodily self not mentioned by Gallese and Cuccio, i.e., self-location and the first-person perspective. These spatial aspects of the bodily self depend primarily on multisensory integration and on cortical processing outside regions involved in ES. Furthermore, comparisons between the brain networks encoding the bodily self and social cognition show large overlaps, suggesting shared functional mechanisms. In the third section I propose that because multisensory spatial processing appears to be critical for

the bodily self and social cognition, important contributions may come from the vestibular system (Lenggenhager & Lopez this collection). I shall show that the vestibular cortical network largely overlaps with the brain networks underlying the bodily self and social cognition. I shall discuss potential contributions of vestibular cortical processing to these target phenomena and suggest directions for future research.

2   Is social cognition based on motor resonance or attention tracking?

Social cognition refers to cognitive processes, perceptions, and subjective experiences related to interaction with conspecifics. This section asks: Which are the brain mechanisms underlying pre-reflective aspects of social cognition? Could there be alternative theories and empirical evidence countering the primary role of motor resonance?

Gallese and Cuccio propose that social cognition mainly depends on ES based on motor resonance and processing of mirror neurons (see citations in Gallese & Cuccio this collection). Mirror neurons were initially discovered in fronto-parietal networks of the macaque monkey brain. They are a specific type of canonical neuron involved in planning and executing hand actions and were found to be activated both when the monkey executed a specific grasping or reaching action and when the monkey passively observed somebody performing similar actions (Gallese et al. 1996; Rizzolatti et al. 1996). Neuroimaging studies in humans also showed mirror neuron-like activation patterns at the level of populations of neurons in distinct brain regions—mainly the ventral premotor cortex (vPM), the intraparietal sulcus (IPS), but also the insula cortex and the secondary somatosensory cortex (Rizzolatti & Sinigaglia 2010; see also figure 1a gray dots). ES proposes that based on mirror neurons the brain maps observed actions into an action space, into motor potentialities, within our hierarchically-organized motor system, and thereby infers and predicts the action goals of the individual. In this way it penetrates the state of mind of the other, and thus links self and other in a pre-reflective empathical fashion (Gallese & Cuccio this collection, p. 7).

I would like to point out that motor resonance, i.e., the mapping of observed actions into motor potentialities, necessarily depends on multisensory spatial coding. I argue that this is the case because of five points: First, the brain has access to the physical world only through the different sensory receptors of the body that bombard it with exteroceptive (e.g., vision, audition), proprioceptive (somatosensory, vestibular), and interoceptive (somatosensory, visceral) signals. Second, these multisensory signals must be integrated according to their spatial and temporal parameters (Stein & Stanford 2008) to inform neural representations of the states of the body and of the world around us—including the agents whose actions are subject to motor resonance. Third, the observed movements of these agents are coded in coordinates distinct from the egocentric spatial frame of reference upon which our motor system operates. Fourth, the brain must necessarily perform spatial transformations of the observed movements by the other agent into the egocentric frame of reference, upon which motor resonance can operate. In sum, multisensory spatial coding is a pre-requisite of motor resonance.

According to Gallese and Cuccio, the outcomes of such multisensory spatial coding are readily available to the brain network of ES through anatomical connections to the vPM that are "anatomically connected to visual and somatosensory areas in the posterior parietal cortex and to frontal motor areas" (Gallese & Cuccio this collection, p. 10). However, it seems that the multisensory spatial coding required for a precise description of complex motor acts might be computationally costly. Might there be a computationally more effective alternative by which multisensory spatial coding is used to decode the intentions of observed agents?

The attention schema (AS) theory of awareness (Graziano 2013; Graziano & Kastner 2011) proposes that brain mechanisms related to attention and spatial coding, which are distinct from neural processing relevant to ES, primarily underlie pre-reflective aspects of social cognition. Graziano and Kastner define *atten-*

tion as an information-handling mechanism of the brain that serves to give priority to some information (e.g., representational features) out of several equally probable alternatives that are in constant competition for awareness. Furthermore, *awareness* is defined as the process of consciously experiencing something, it is the process of relating the subject (i.e., a phenomenal self, see also Metzinger 2003) to the object/content of experience. Graziano and Kastner summarize AS as follows:

> [Awareness is information and] depends on some system in the brain that must have computed [it] [...]; otherwise, the information would be unavailable for report. [...] People routinely compute the state of awareness of other people [and] the awareness we attribute to another person is our reconstruction of that person's attention. [...] The same machinery that computes socially relevant information [...] also computes [...] information about our own awareness. [...] Awareness is [...] a perceptual model [...] a rich informational model that includes, among other computed properties, a spatial structure. [...] Through the use of the social perceptual machinery, we assign the property of awareness to a location within ourselves. (Graziano & Kastner 2011, pp. 98–99)

Related to social cognition, AS proposes that by using a schematic representation of the state of attention of other individuals—including a prediction of the spatial location of their focus of attention—we predict the current state of awareness of the individual, which is informative about their intentions and potential future actions. In short: Awareness of others is an attention schema. As compared to ES, AS is a relatively recent theory that requires extensive empirical studies. Yet the evidence so far shows that indeed the brain has a neural circuitry for monitoring the spatial configuration of one's own attention independent of the sensory modality (Downar et al. 2000), including the direction of gaze (Beck & Kastner 2009; Desimone &

Duncan 1995). These structures are the proposed neural expert system upon which AS is based and consist of the right-hemispheric temporo-parietal junction (TPJ) and superior temporal sulcus (STS) (see figure 1a in black). Notably, this expert system relevant to AS shows little anatomical overlap with the neural structures relevant to ES (figure 1a compare black with gray).

Because the AS relies on coding of the spatial relationship between the location of the observed individual and the likely spatial location of this individual's attention (i.e., independent of a particular sensory modality), the required spatial computations seem simple and straightforward. They require two points, i.e., the individual as a reference point and the potential spatial location of the attention of that individual. According to AS, using such spatial labeling the brain is able to simultaneously track the aware and attending minds of several individuals simultaneously. Thus, spatial coding in the context of AS appears to be less complex and less computationally demanding than spatial transformations underlying ES (see above).

Which of these seemingly distinct brain mechanisms proposed by AS and ES more plausibly underlies social cognition: the neural expert system decoding the state of attention according to AS or the mirror mechanism system decoding observed motor plans according to ES? It has been proposed that AS and ES may in principle work together. Graziano and Kastner propose that the expert system of AS may take a leading role by formulating a hypothesis about the state of awareness of an individual that is likely to drive further behavior and therefore provide a set of predictions based upon which motor resonance could more efficiently perform simulations (Graziano & Kastner 2011). Motor resonance would thus add richer detail to the state-of-attention hypothesis made by the expert system.

This combined mechanism is compatible with the predictive processing principle (Clark this collection; Hohwy 2013, this collection), which has been proposed relevant to the bodily self (Apps & Tsakiris 2013; Limanowski &
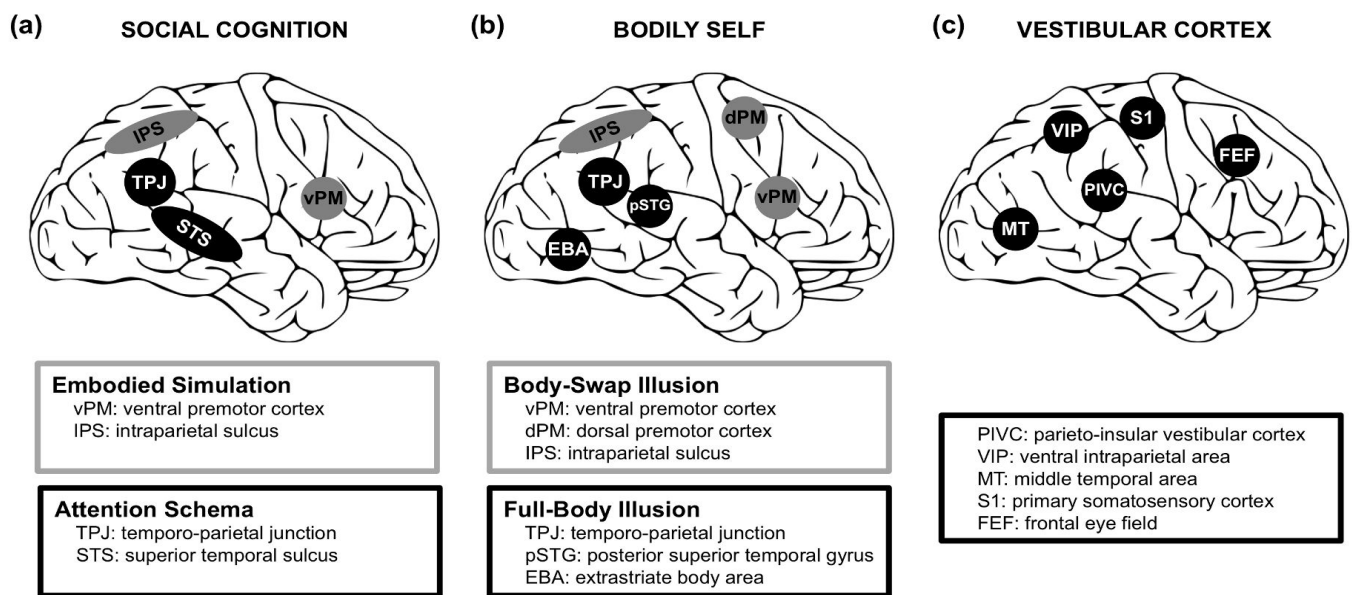
Figure 1: Summary of cortical brain regions involved in social cognition, the bodily self, and vestibular processing. (a) Whereas for social cognition there is little overlap between the brain regions proposed relevant for the attention schema (*in black*) and embodied simulation (*in gray*), both sets of brain regions overlap with (b) the brain network of the bodily self as identified by full-body illusion experiments manipulating self-location and first-person perspective (*in black*) and the body-swap illusion manipulating mainly body ownership (*in gray*). (c) The human vestibular cortical regions (*in black*) are widely distributed and overlap with several regions relevant to both the bodily self and social cognition. (The images are derived from images by NASA, licensed under creative commons.)

Blankenburg 2013; Seth this collection). According to *predictive processing* the brain constantly predicts the potential causes of sensory input by minimizing prediction errors via update of the predicted causes or by action that changes sensory input (Friston 2005). Applying the predictive processing principle to Graziano and Kastner's proposal that AS is a hypothesis-generating tool to which ES adds further detail, one could conceive of both mechanisms as different predictive processing modules aimed at anticipating the state of awareness and of intentional actions observed in others. Although no empirical study so far has addressed this specific hypothesis, a recent functional magnetic resonance imaging study found that predictive processing principles accounted for the blood oxygen-level dependent activity related to the perception of faces, which is an important perceptual function for social cognition in the human species (Apps & Tsakiris 2013).

These common and distinct predictions based on ES, AS, and predictive processing call for empirical research aimed at providing evidence to further refine, integrate, or reject them.

3 Multisensory and motor mechanisms of the multifaceted bodily self

The *bodily self* refers to the phenomenal experience of being an experiencing subject (i.e., a phenomenal self) bound to a physical body, which gives rise to the dual nature of the body (Husserl 1950; Gallese & Cuccio this collection, p. 2). The unified experience of being a bodily self can be decomposed into different aspects, including the experience that we identify with a particular body (self-identification or *body ownership*), the experience that the self is situated in a specific spatial location (*self-location*), that we take a specific experiential perspective at the world (*first-person perspective*), and that we are the authors of our actions, including having control of attentional focus (*agency*; (Blanke 2012; Ehrsson 2012; Jeannerod 2003; Metzinger 2003).

In their paper, Gallese & Cuccio highlight the relevance of mirror mechanisms, in particular related to processing in the cortical motor system, to the sense of body ownership and the sense of agency, in particular in the context of action and action observation:

> This minimal notion of the self, namely the bodily self as power-for-action […], tacitly presupposes ownership of an action-capable agentive entity; hence, it primarily rests upon the functionality of the motor system. (this collection, p. 10)

However, recent philosophy of mind and cognitive neuroscience research reveals the crucial role of *spatial aspects of the bodily self*, consisting of a first-person perspective and self-location. In this section I shall compare the brain network contributing to spatial aspects of the bodily self with the brain network underlying body ownership and ask: Do these neuroimaging results support the proposal that motor resonance is a primary mechanism underlying all aspects of the bodily self? What is the relationship between the neural networks of the bodily self and social cognition? Which functional associations can be derived from this?

3.1 Brain mechanisms of spatial aspects of the bodily self

The phenomenal experience of being a subject is associated with a spatial location, which typically is the space of the physical body (see also Alsmith & Longo 2014; Limanowski & Hecht 2011). However, there are exceptions to these prototypical states of the bodily self in neurological disorders and experimental illusions pointing to a specific set of brain regions involved in spatially linking the phenomenal self to the physical body.

Which brain mechanisms link the phenomenal self to the physical body to give rise to the dual nature of the body as lived body and as physical object? Research in neurological patients who have had out-of-body experiences (OBE) shows that damage or interference with the right TPJ can lead to dissociations between the bodily self and physical body (Blanke et al. 2004; Blanke et al. 2002; De Ridder et al. 2007; Ionta et al. 2011). During an OBE, patients typically experience a disembodied self-location in elevation above their physical body, and an altered first-person perspective that originates from an elevated location in the room and is directed downwards at the physical body (Blanke et al. 2004; Metzinger 2009). These patients do not identify with their physical body but with an illusory double outside of the borders of the physical body. At the phenomenological level, self-location and the first-person perspective are often experienced as having their spatial origin in the same position. However, during OBE there are instances where self-location can be dissociated from the first-person perspective in different sensory modalities (De Ridder et al. 2007). Further evidence from asomatic OBEs and bodiless dreams suggests that a phenomenal first-person perspective may be reducible to a single point in space (Windt 2010). In fact, vestibular hallucinations systematically preceded OBEs in patients with sleep paralysis, i.e., a motor paralysis characterised by the transient inability to execute bodily actions when waking up from sleep (Cheyne & Girard 2009), showing further dissociations of the spatial location of the bodily self and the physical body and links to sensory processing. These studies seem to suggest that the first-person perspective and self-location may depend on different neural mechanisms (Blanke 2012).

OBE in epileptic patients can be induced by subcortical electrical stimulation of a specific intensity at the TPJ. However, stimulating the same brain region with either lower or higher stimulation intensity induces bodily sensations (including vestibular, visual, somatosensory, kinesthetic sensations) without inducing an OBE (Blanke et al. 2002). These observations gave rise to the idea that the spatial aspects of the bodily self are based on the accurate integration of multisensory signals (i.e., which was perturbed by electrical stimulation in the patient in Blanke et al. 2002, which are sensory signals from personal space to sensory signals from the external environment Blanke et al. 2004).

These clinical observations in patients were corroborated by different full-body illusion experiments in healthy subjects, such as the so-called "body-swap illusion" (Petkova & Ehrsson 2008; Petkova et al. 2011; van der Hoort et al. 2011), the "full-body illusion" (Ionta et al. 2011; Lenggenhager et al. 2009; Lenggenhager 2007; Pfeiffer et al. 2013; Pfeiffer, Schmutz & Blanke 2014), and the "out-of-body illusion" (Ehrsson 2007; Guterstam & Ehrsson 2012). In these experiments, healthy subjects receive conflicting signals about the spatial location of their body and of the temporal synchrony of exteroceptive and interoceptive signals, including somatosensory, cardiac, and vestibular signals that at the same time are applied to a virtual or fake body seen by the subject (Aspell et al. 2013; Ionta et al. 2011; Pfeiffer et al. 2013; Pfeiffer et al. 2014). For example, in the *full-body illusion*, synchronous stroking of a virtual or fake body seen from a distance can induce the feeling in participants that they are more closely located to the position of the virtual or fake body, and that they experience and increase of ownership for the seen body. The brain regions involved in these spatial experimental manipulations of the experienced bodily self most consistently involve the right TPJ region, but also draw on somatosensory and visual regions that process the sensory inputs (Blanke 2012; Ionta et al. 2011; figure 1b in black). Recently, several studies have manipulated visual and vestibular signals about the direction of gravity, affecting self-location and perspective and thus showing that those visual spatial cues affect our subjective experience of the first-person perspective (Ionta et al. 2011; Pfeiffer et al. 2013). These authors presented images on virtual-reality goggles showing visual gravitational cues, similar to the visual perspective during an OBE showing a scene from an elevated spatial location and a visual viewpoint directed downwards into the room. At the same time the somatosensory and the vestibular signals received by the participant, who was lying on the back, suggested that the physical body was oriented upwards with respect to veridical gravity. Thus the visual gravity cues (i.e., downwards) and the vestibular gravity cues (i.e., upwards) were in directional conflict. When the full-body illusion was induced under these conflicting conditions, participants reported subjective changes in their experienced direction of the first-person perspective (upward or downward) in line with experimentally-induced multisensory conflict (Ionta et al. 2011; Pfeiffer et al. 2013).

3.2 Brain mechanisms of body ownership

A different brain network encodes experimental manipulations of another aspect of the bodily self: body ownership. This was shown by the *body-swap illusion* (Petkova & Ehrsson 2008; Petkova et al. 2011), during which the participant views from a first-person visual viewpoint the body of a mannequin or another person. Thus no conflict between the visual spatial coordinates of the participant's physical body and the visually-perceived location of the mannequin is presented. However, conflicting sensory information about the shape, gender, size, or overall spatial context surrounding the virtual body were presented that typically prevented feeling ownership of the virtual body. If under these conditions visuo-tactile stroking on the abdomen of the participant and the virtual body was synchronously administered, an illusion of ownership for the body emerged, reflected in increased responses to threatening the mannequin. In different variants of the body-swap illusion subjects reported experiencing and adopting different sizes of both the virtual body and the contextual environment (Petkova & Ehrsson 2008; Petkova et al. 2011; van der Hoort et al. 2011). Neuroimaging experiments of the body-swap illusion show activation of the vPM and IPS regions, notably without involving actions made by subjects or performed by the virtual body (Petkova et al. 2011). These brain regions are key nodes of the mirror mechanism network of ES (see Serino et al. 2013). For a recent review see figure 1b.

3.3 A shared brain network of bodily self and social cognition

Although the neuroimaging evidence so far suggests that distinct brain regions encode the spa-

tial aspects of the bodily self and body owner-ship (Blanke 2012; Serino et al. 2013), the ensemble of those bodily self-encoding regions closely matches the brain regions relevant for social cognition (compare in figure 1a with figure 1b). These empirical data indeed suggest that the bodily self and social cognition are encoded by at least overlapping neural circuits supporting the proposal of ES that neural capacities to control and monitor the own body are used in understanding others.

These neuroimaging data suggest particular functional associations between different aspects of social cognition and the bodily self. In particular, the brain network of ES anatomically overlaps with regions encoding experimentally-induced changes in body ownership during the body-swap illusion (figure 1a–b in gray), which involves spatial congruence of the observational viewpoint and position of the fake body and the participant's body. A second association can be observed between the brain network of AS and the brain regions encoding spatial aspects of the bodily self, as manipulated during the full-body illusion (figure 1a–b in black). During the latter, the position and observational viewpoints of the virtual body and the participant's body are in spatial conflict, and thus closely resemble social interaction settings.

Based on these functional and neuroanatomical observations, I propose that ES seems to contribute to the bodily self and social cognition in a way primarily related to the sense of body ownership and agency. However, ES does not account for multisensory spatial representations that relate the physical body to the bodily self in space. These spatial aspects of the bodily self are encoded by brain regions outside of the brain network of ES, and rather resemble those brain regions relevant for coding the spatial configuration of attention (or awareness, according to AS).

Because two crucial aspects of the bodily self, i.e., self-location and the first-person perspective, are encoded in the TPJ region, and full-body illusions show that they can be manipulated without action or motor manipulations, it seems implausible that ES as based on

motor resonance is the primary brain mechanism underlying the bodily self. Instead, the brain networks coding self-location and the first-person perspective, which overlap with brain regions proposed to encode spatial aspects of an attention schema (see figure 1), seem to contribute to at least an equal degree to both the bodily self and social cognition. Thus, ES seems to be a necessary but insufficiently "primary" brain mechanism underlying the bodily self and social cognition.

I do not mean to imply that these are independent processes, because it is possible that they cooperatively work together (Graziano & Kastner 2011). However, I think that Gallese and Cuccio's claim of a primacy of motor resonance underlying the multifaceted aspects of the bodily self and social cognition is questionable on empirical and theoretical grounds.

4 Vestibular contributions to the bodily self and social cognition

In the previous sections I have provided theoretical considerations and empirical evidence assigning a critical role to multisensory spatial processing in the neural computations underlying representations of the bodily self and social cognition. This section will further examine the multisensory mechanisms relating the space of the bodily self to other individuals and the external world. I propose that important contributions to the brain's multisensory spatial coding might come from a particular sensory system, i.e., the vestibular system, which has often been neglected in studies of higher brain functions related to subjectivity and intersubjectivity. I will ask: What might be the functional contribution of the vestibular system to pre-reflective representations of the bodily self and social cognition? How does the human vestibular cortex relate to the neural networks of the bodily self and social cognition?

The *vestibular system* consists of sensory organs in the inner ear that sense accelerations of the head in space, including rotational and linear movement of the head and whole body and the constant acceleration of gravity on earth (Day & Fitzpatrick 2005). Vestibular sig-

nals are processed by subcortical and cortical structures (Angelaki & Cullen 2008; Cullen 2012; Lopez & Blanke 2011). Research initially focused on subcortical processing as related to gaze control, postural stabilization, and neural computations of head motion directions (Fernandez & Goldberg 1971; Goldberg & Fernandez 1971). More recently, studies have revealed the contribution of vestibular cortical processing to spatial cognition, body perception, and the bodily self (see Lenggenhager & Lopez this collection; Lopez & Blanke 2011; Pfeiffer et al. 2014 for reviews). These studies show that vestibular cortical processing is based on a neural network of distinct, distributed, and multisensory cortical regions. In distinction from any other sensory modality, there is no primary vestibular cortex that processes purely vestibular signals. Instead, a core vestibular cortical input region, the human parieto-insular vestibular cortex (PIVC; Lopez et al. 2012; zu Eulenburg et al. 2012), processes vestibular, somatosensory, and visual signals and is connected to a number of multisensory brain regions in the parietal, temporal, cingulate, and frontal regions (figure 1c).

The vestibular system contributes to spatial aspects of the bodily self. For instance, OBEs were associated with vestibular sensation, such as floating in elevation (Blanke et al. 2004; Blanke & Mohr 2005; Blanke et al. 2002), and vestibular sensations preceded OBEs in persons with sleep paralysis (Cheyne & Girard 2009). Other studies presented conflicting visual and vestibular signals about earth gravity during the full-body illusion and induced changes in the subjectively-experienced spatial direction of the first-person perspective and self-location (Ionta et al. 2011; Pfeiffer et al. 2013). Thus, it has been argued that vestibular cortical processing does not merely signal the motions of the own body and the external world, but is also constitutive of spatial aspects of the bodily self (Lopez et al. 2008; Pfeiffer et al. 2014).

Previously, Lopez et al. (2013), Deroualle & Lopez (2014), and Lenggenhager & Lopez (this collection) have argued that the vestibular system probably contributes to social cognition. I will briefly summarize their main arguments and complement them with own points:

First, because the human species evolved under the steady influence of the earth's gravitational field, adaptation to gravity also framed and affected action, perception, and social interaction. More recently, research has shown that the brain hosts internal models of gravity, representing the effects of gravity on the motion of objects under the influence of gravity, of self-motion, of bodily actions, and of the direction of the gravitational acceleration. Those internal models of gravity strongly overlap with the vestibular cortex (Indovina et al. 2005; Indovina et al. 2013; McIntyre et al. 2001; Sciutti et al. 2012). More evidence for a vestibular contribution to social perception comes from studies showing the effects of gravitational signals on the perception of emotional faces (Thompson 1980) and the perception of the spatial orientation of bodies (Lopez et al. 2009).

Second, the vestibular system might contribute to social cognition because it detects head motions in space and hence directly enables us, when compared to other sensory signals, to discern movements made by our own body from motions of other individuals and motions of the external environment (Deroualle & Lopez 2014).

Third, mental spatial transformation of the own visual viewpoint to that of another person presents an important underlying cognitive aspect of social cognition (Furlanetto 2013; Hamilton 2009; Newen & Vogeley 2003; also cited by Gallese & Cuccio this collection, pp. 9–11). More direct evidence supporting this hypothesis comes from a recent study that showed that physical whole-body rotations, which stimulate the vestibular sensory organs, affected the ability of participants to perform mental spatial transformations (van Elk & Blanke 2013).

Fourth, I have argued in previous sections of this commentary that multisensory spatial coding is a critical prerequisite that underlies pre-reflective brain mechanisms of the bodily self and social cognition. Because the vestibular cortical processing has been strongly associated with multisensory integration (for review see Lopez & Blanke 2011), it is likely that vestibu-

lar signals shape multisensory spatial coding relevant to the bodily self and social cognition (Deroualle & Lopez 2014; Pfeiffer et al. 2014).

Fifth, the distributed multisensory vestibular cortical network clearly overlaps with the neural structures involved in social cognition and the bodily self, which suggests that there is a functional contribution on the part of vestibular processing to these phenomena (compare figure 1c to 1a and 1b; compare also to Deroualle & Lopez 2014).

Together, these five points suggest that the vestibular system may be a promising candidate for future studies of the sensorimotor mechanisms of social cognition, which should motivate research on the intersection of vestibular cortical processing, mirror mechanisms, and intersubjectivity. These studies may, for instance, question how vestibular stimulation affects our ability to reconstruct the process of attention of another person, a function critical in the AS framework. Although the vestibular system is related to reflexive motor control, it is not clear whether it also affects motor resonance (see Deroualle & Lopez 2014 for a related proposal). One might ask whether vestibular processing facilitates or inhibits motor resonance and our understanding of intentional action observed in others. How about vestibular contributions to theory of mind and reasoning? On the other hand, does social interaction modulate vestibular functions, such as self-motion perception, postural stabilization, and gaze control? These questions address the role of vestibular processing in functional mechanisms relevant to the AS and ES frameworks. Furthermore, empirical research addressing the causal relationship between the AS and ES brain mechanisms and the bodily self and social cognition are needed, for instance by brain lesion analysis or direct brain stimulation.

5 Conclusion

At the beginning of this paper I asked which brain mechanisms underlie pre-reflective representations of the bodily self and social cognition. ES, based on motor resonance, substantially contributes to the representation of the bodily self and social cognition. However, a unified theory of the neural basis of these target phenomena cannot assign a primary role to motor resonance. I have argued that multisensory spatial coding is at least of equal importance and probably more basic than ES in contributing to several key aspects of the bodily self and social cognition.

Specifically, I have argued that:

(1) Social cognition and the bodily self depend on multisensory spatial coding, which is distinct from motor resonance. Thus, motor resonance may be a necessary but insufficiently "primary" brain mechanism of social cognition and the bodily self (cf. section 1, 2).

(2) The brain networks underlying social cognition and the bodily self largely overlap. Specific functional associations exist (a) between motor resonance and body ownership/agency and (b) between multisensory spatial coding and self-location/the first-person perspective (cf. section 2).

(3) The vestibular system, i.e., the sensory system encoding head motion and gravity, might provide unique information used for multisensory spatial coding that relates the bodily self to other individuals and the external world. This is further suggested by the large overlap existing between the human vestibular cortex and the brain networks underlying the bodily self and social cognition (cf. section 3).

A unifying theory of pre-reflective brain mechanisms of the bodily self and social cognition must be able to account for the empirical evidence reviewed here; and it seems that such a theory cannot exclusively depend on motor resonance. Multisensory spatial coding, motor mechanisms, but also representations of the process of attention appear highly relevant to bodily self and social cognition.

I agree with Gallese & Cuccio (this collection, pp. 3–7) that cognitive neuroscience cannot fully explore these exciting topics by limit-

ing itself to a specific neuroimaging method, such as functional magnetic resonance imaging. Instead, we should exploit multi-method approaches in search for correlative and causal evidence relating brain function and anatomy to the phenomenology of the bodily self and social cognition. The body, but also the spatial representation of the world around us, are relevant to understanding brain function, and when taken into account can lead to novel approaches to phenomenal analysis of subjective experience. But we should be careful in assigning priority to a single brain mechanism when aiming to explain the human self and intersubjectivity. Scrutiny and dialogue at the intersection of philosophy of mind and cognitive neuroscience are necessary in order to advance our understanding of the nature of the human mind.

Acknowledgments

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Embodied Simulation: A Paradigm for the Constitution of Self and Others

A Reply to Christian Pfeiffer

Vittorio Gallese & Valentina Cuccio

The main criticism Pfeiffer advances in his commentary is that our proposal is too narrow. Embodied simulation (ES), in his view equated to motor resonance, is not a sufficiently primary mechanism on which we can base a unified neurobiological theory of the earliest sense of self and others. According to Pfeiffer, motor resonance needs to be complemented by other more basic and primary mechanisms. Hence, as an alternative to our proposal, he suggests that multisensory spatial processing can play this role, primarily contributing to the earliest foundation of the sense of self and others. In our reply we stress on the one hand that identifying ES only with motor resonance is a partial view that may give rise to fallacious arguments, since ES also deals with emotions and sensations. We also show, on the other hand, that ES and multisensory integration should not be seen as alternative solutions to the problem of the neural bases of the bodily self, because multimodal integration carried out by the cortical motor system *is* an instantiation of ES. We conclude by stressing the role ES might have played in the transition from bodily experience to symbolic expression.

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1 An overview of Pfeiffer's criticisms

We would like to thank Christian Pfeiffer for his very well-articulated commentary on our paper "The paradigmatic body: Embodied Simulation, Intersubjectivity, the Bodily Self, and Language" (Gallese & Cuccio this collection). His comments and criticisms offered us the opportunity to further reflect on some of the ideas proposed in our piece. The aim of our paper was to discuss the role of the body in the constitution of the earliest and primary sense of self and others and, also, to emphasize the constitutive role of the body in a specifically human modality of intersubjectivity: language. To be more precise, we identified a biological mech-

anism, embodied simulation (ES), as a primary source of intersubjectivity, the sense of self, and language. The mechanism of ES is widely described in the paper and its role in human cognition is explained by also resorting to the Aristotelian notion of *paradeigma.*

The commentary offered by Christian Pfeiffer is focused on a partial aspect of our much wider proposal. In fact, the author only discusses the constitutive role motor resonance has for the sense of self and for social cognition. However, motor resonance is just one dimension of the mechanism of ES. As argued in our paper and elsewhere (see Gallese & Sinigaglia 2011a; Gallese 2014) the mechanism of simulation is widespread in the brain and it also characterizes the nervous structures involved in the experience of emotions and sensations. All these dimensions of ES should be taken into account. To identify ES only with motor resonance is a partial view that may give rise to fallacious arguments.

The main criticism Pfeiffer advances in his commentary is that our proposal for the constitutive role of motor resonance is too narrow. ES, in his view equated to motor resonance, cannot be the primary neurobiological mechanism at the basis of both the sense of self and others. According to Pfeiffer, motor resonance needs to be complemented by other more basic and primary mechanisms. Hence, as an alternative to our proposal, he suggests that multisensory spatial processing can play this role, primarily contributing to the earliest foundation of the sense of self and others. To support this claim, he provides theoretical arguments and presents empirical data structured in three different sections. Each of these sections supposedly provides evidence of the role of multisensory spatial processing in the foundation of a bodily sense of self and others.

In the first section Pfeiffer addresses the issue of intersubjectivity and presents the Attention schema theory (AS). In his proposal, our ability to understand others is primarily based on a mechanism more primitive than ES-as-motor-resonance: spatial coding of attention. AS predicts that we understand the current state of awareness of our conspecifics by means

of schematic representations of their states of attention (Pfeiffer this collection, p. 4). In other words, according to AS, by using a representation of the spatial relationship between the individual we are observing and the spatial focus of her/his attention we can likely predict his intentions and, as a consequence, his actions. Pfeiffer (this collection, p. 4) also discusses recent empirical findings on the neural structures underlying the AS. It seems that the neural structures for the spatial coding of attention are based in the right temporo-parietal junctio (TPJ) and in the superior temporal sulcus (STS). These neural structures do not overlap with the neural circuits involved in ES.

In the second section Pfeiffer addresses the issue of the bodily foundation of the sense of self. The experience of being a bodily self can be decomposed into four different aspects (Pfeiffer this collection, p. 5): body ownership, self-location, first-person perspective, and agency. According to Pfeiffer, motor resonance can account only for body ownership and agency, directly contributing to these (non-spatial) aspects of the bodily self. However, for the two spatial components of the bodily self we need a different account. In fact, according to Pfeiffer, empirical evidence suggests that these spatial aspects of the bodily self, which imply multisensory spatial representations, are encoded in a brain region, the TPJ, not characterized by motor resonance. Hence, motor resonance, while being still necessary for the bodily foundation of some basic aspects of the self, is not a sufficiently primary mechanism, since different neural structures are also needed for the bodily foundation of the self. In support of this claim, Pfeiffer discusses data from neurological patients with out-of-body experiences and other kinds of altered states.

Finally, in the third section the constitutive role of the vestibular system to the bodily foundation of both the consciousness of self and others is discussed. It is proposed that this system, which encodes gravity and head motion and is associated with multisensory spatial processing, significantly and primarily contributes to our ability to distinguish between motions of our own body and motions of other

people's bodies, in this way contributing to both the foundation of the sense of self and social cognition. Empirical studies are reported to support these claims. In addition, empirical data showing that the vestibular cortical network overlaps with neural structures underlying the bodily foundation of both the sense of self and others, as discussed in the two previous sections, are presented.

In the light of the empirical evidence discussed in his commentary, Christian Pfeiffer concludes that ES-as-motor-resonance is not a sufficiently primary mechanism on which we can base a unified neurobiological theory of the earliest sense of self and others. In the next section we answer these criticisms.

2 Responses

First, we would like to point out that ES is not confined to motor resonance of others' actions, like that instantiated by macaques' mirror neurons, as in humans ES also encompasses the activation of somatosensory areas during the observation of others' tactile experiences, the activation of pain-related areas like the anterior insula and the anterior cingulate cortex during the observation of others' pain, and the activation of the anterior insula and limbic structures like the amygdala during the observation of others' emotions like disgust and fear (see our paper, p. 9 and Gallese & Sinigaglia 2011a). Thus, motor resonance only describes one partial aspect of ES.

Two distinct arguments can be used to explain why we do not think that AS constitutes a valid alternative to ES, as argued by Pfeiffer. We certainly agree with Pfeiffer that shared attention, that is, the capacity to direct the gaze to an object gazed by someone else, is a basic ingredient of social cognition. Indeed, as maintained by Colwyn Trevarthen (1977), shared attention marks in human infants around 9 months of age the transition from primary to secondary intersubjectivity. However, shared attention constitutes only one aspect of intersubjectivity and social cognition, thus AS at best only covers a partial aspect of social cognition and therefore appears to be more limited than

ES in this respect. Furthermore, and most importantly, shared attention can be linked to motor resonance. Shepherd, Klein, Deaner, and Platt 2009) discovered in macaques a class of mirror neurons in the lateral intraparietal (LIP) area involved in oculomotor control, signaling both when the monkey looked at a given direction in space and when it observed another monkey looking in the same direction. These authors suggested that LIP mirror neurons for gaze might contribute to the sharing of observed attention. This evidence shows that shared attention is not divorced from motor resonance, but actually requires it.

A further argument in our opinion demonstrates that ES and AS should not be seen as alternative solutions to the problem of social cognition. Multisensory integration is a pervasive feature of parieto-frontal centers involved in sensory-motor planning and control. Indeed an influential theory about attention, the "Premotor Theory of Attention" (see Rizzolatti et al. 1987; Rizzolatti et al. 1994) states that spatial attention results from the activation of the same "pragmatic" circuits that program oculomotor behavior and other motor activities, even if such activation does not produce any overt motor behavior, thus qualifying as motor simulation.

We would like to emphasize even more strongly than we did in the paper that a crucial role of the cortical motor system is precisely that of integrating multiple sources of body-related sensory signals, like tactile, visual and auditory stimuli (see our paper, pp. 10–11; see also Gallese & Sinigaglia 2010, 2011b; Gallese 2014). The ventral premotor cortex (vPMC) might represent one of the essential anatomo-functional bases for the motor aspect of bodily selfhood, specifically because of its role in integrating self-related multisensory information. This hypothesis is corroborated by clinical and functional evidence showing the systematic involvement of vPMC with body awareness (Ehrsson et al. 2004; Berti et al. 2005; Arzy et al. 2006). This evidence demonstrates a tight relationship between the bodily self-related multimodal integration carried out by the cortical motor areas specifying the motor potentialities of one's body and guiding its motor behavior

and the implicit awareness one entertains of one's body as one's own body and of one's behavior as one's own behavior.

The vPMC is anatomically connected to visual and somatosensory areas in the posterior parietal cortex and to frontal motor areas and for this reason it is plausible to assume that vPMC activity reflects the detection of congruent multisensory signals related to one's own body parts: this mechanism could be responsible for the feeling of body ownership. The motor aspects of the bodily self-enable the integration of self-related multimodal sensory information about the body and about the world with which the body interacts, as epitomized by the properties of macaques' premotor neurons in area F4 (see Fogassi et al. 1996; Rizzolatti et al. 1997) and the analogous functional properties displayed by the human homologue of area F4 (see Bremmer et al. 2001). The same neurons controlling the movement in space of the head or of the upper limb also respond to tactile, visual, and auditory stimuli, provided they are applied to the same body part, like tactile stimuli, or they occur in the body-part-centered peri-personal space, like visual and auditory stimuli. Thus, we think that ES and multisensory integration should not be seen as alternative solutions to the problem of the neural bases of the bodily self, because multimodal integration carried out by vPMC *is* an instantiation of ES. We agree with Pfeiffer, however, that other brain areas, like TPJ, might contribute to a coherent sense of one's own body. It must be added that TPJ is part of a network (including the posterior parietal cortex, and the premotor cortex) implicated in multisensory integration during self-related and other-related events and experiences. Indeed, as shown by Ebisch et al. (2011), the observation of others' affective tactile experiences leads to the activation of observers' vPMC and second somatosensory area and to the inactivation of observers' posterior insula. Functional connectivity revealed a significant interaction between the posterior insula, right TPJ, left pre-central gyrus, and right posterior parietal cortex during the observation of other's affective touch. These data suggest that TPJ might be involved in mapping the self–other differentiation, by means of lower-level computational mechanisms for generating, testing, and correcting internal predictions about external sensory events.

Last, we agree with Pfeiffer that the vestibular system might contribute to the bodily foundation of both the consciousness of self and others and we thank him for having pointed this out, thus integrating our perspective.

3 Conclusions

It seems that the data discussed in the previous section allow us to come to the conclusion that ES is the primary and earliest mechanism contributing to the foundation of the sense of self and others. That said, in conclusion, we would like to stress again the issue of the cognitive role ES has in relation to language. Though the aspect of the relation between ES and language was not addressed in Pfeiffer's commentary, this was a central point of our proposal. The relation between ES and language is two-sided. On the one hand, empirical evidence has shown the role ES plays in language comprehension. These data (for an overview see Gallese & Cuccio this collection, p. 13) suggest that the bodily, sensory, and motor dimensions play a constitutive role in language, both ontogenetically and phylogenetically. On the other hand, being linguistic creatures, we humans are the only living species able to fix and relive specific aspects of our bodily experiences by means of symbols. Words or other forms of symbolic representations such as art, for example, allow us to activate and relive our bodily experiences. In this way, by means of symbolic representations, we can share our bodily experiences, enacted by ES, even with people far away from us in time and space. As argued in our paper, ES is a model of our own experiences and its defining features are best explained by resorting to the Aristotelian notion of *paradeigma*. ES-as-*paradeigma* (and not just as motor resonance) provides a neurobiologically-based new perspective on human social cognition and ultimately on the very definition of human nature.

Acknowledgments

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