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## 5 Neuroscientific Approach to Intersubjectivity

### 5.1 Embodied simulation and its role in intersubjectivity

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Primates, and particularly human beings, are social animals whose cognitive development capitalizes upon the interaction with other conspecifics (adults, siblings, etc.). During social interactions we manifest our inner intentions, dispositions and thoughts by means of overt behavior. Similarly, we try to figure out what are the intentions, dispositions and thoughts of others, when witnessing their behavior. Detecting another agent's intentions, or other inner states, helps anticipating this agent's future actions, which may be cooperative, non-cooperative, or even threatening. Accurate understanding and anticipation enable the observer to adjust her/his responses appropriately. Fundamental among social abilities is the capacity to accurately detect and understand the intentional conduct of others, to anticipate their upcoming actions, and to appropriately adjust one's own behavior.

The phylogenetic origins of this capacity and its development in ontogenesis are matters of debate in both comparative and developmental psychology.

From an evolutionary perspective, the traditional view claims the existence of a sharp cognitive discontinuity between humans and nonhuman primates. Humans supposedly understand others by means of their capacity to mind read, that is, to attribute a causal role to internal mental states. All other animal species would be confined to the observable causal aspects of reality, that is, would be basically just behavior readers. From an ontogenetic perspective, theories differ about how and when the supposed mind reading ability emerges during infant cognitive development.

Recent findings in cognitive neuroscience shed light on the existence of a common neural mechanism that could account for action and intention understanding abilities both in humans and nonhuman primates. These findings revealed that the motor cortex, long confined to the mere role of action programming and execution, in fact plays a crucial role in complex cognitive abilities such as the understanding of the intentions and goals of actions. When observing other acting individuals, and facing their full range of *expressive* power (the way they act, the emotions and feelings they display), a meaningful embodied interpersonal link is automatically established.

The discovery of mirror neurons and of other mirroring mechanisms in the human brain shows that the very same neural substrates are activated when these expressive acts are both executed and perceived. Thus, we have a *neurally instantiated* we-centric space. I posit that a common underlying functional mechanism – embodied simulation – mediates our capacity to share the meaning of actions, intentions, feelings, and emotions with others, thus grounding our identification with and connectedness to others.

The chapter is structured as follows. I summarize recent neuroscientific evidence shedding light on the neural mechanisms likely underpinning important aspects of intersubjectivity and social cognition. This evidence has accumulated

since our discovery in the macaque monkey premotor cortex of a particular class of neurons known as “mirror neurons”. I discuss this evidence in relation to empathy and introduce my model of *embodied simulation*, a crucial functional mechanism of intersubjectivity by means of which the actions, emotions, and sensations of others are mapped by the same neural mechanisms that are normally activated when we act or experience similar emotions and sensations. Embodied simulation provides a model of potential interest not only for our understanding of how interpersonal relations work or but also for our understanding of important psychopathological aspects of intersubjectivity.

### **Mirror Neurons**

Mirror neurons are premotor neurons that fire both when an action is executed and when it is observed being performed by someone else. (Gallese et al. 1996; Rizzolatti et al. 1996). Neurons with similar properties were also discovered in a sector of the posterior parietal cortex (Gallese et al. 2002; Fogassi et al. 2005). The same motor neuron that fires when the monkey grasps a peanut is also activated when the monkey observes another individual performing the same action.

Action observation causes in the observer the automatic activation of the same neural mechanism triggered by action execution. The novelty of these findings is the fact that, for the first time, a neural mechanism allowing a direct mapping between the visual description of a motor act and its execution has been identified. This mapping system provides a parsimonious solution to the problem of translating the results of the visual analysis of an observed movement — in principle, devoid of meaning for the observer — into something that the observer is able to understand (Gallese et al. 1996; Rizzolatti et al. 1996).

The proposal that mirror neurons’ activity reflects an internal motor description of the perceived action’s meaning rather than a mere a visual description of its features has been demonstrated in two seminal experiments.

In the first study, Umiltà et al. (2001) found a subset of premotor mirror neurons that discharged also during the observation of partially hidden actions, coding the action outcome even in the absence of the complete visual information about it. Macaque monkey’s mirror neurons therefore respond to observed acts not exclusively on the basis of their visual description, but on the basis of the anticipation of their final goal-state, simulated through the activation of its motor neural motor “representation” in the observer’s premotor cortex

Those data, of course, do not exclude the co-existence of a system that visually analyzes and describes the acts of others, most likely through the activation of extra-striate visual neurons sensitive to biological motion. However, such visual analysis per se is most likely insufficient to provide an understanding of the observed act. Without reference to the observer’s internal “motor knowledge”, this description is devoid of factual meaning for the observing individual (Gallese et al. 2009).

A second study (Kohler et al. 2002) demonstrated that mirror neurons also code the actions’ meaning on the basis of their related sound. A particular class of F5 mirror neurons (“audio-visual mirror neurons”) responds not only when the

monkey executes and observes a given hand action, but also when it just hears the sound typically produced by the same action. These neurons respond to the sound of actions and discriminate between the sounds of different actions, but do not respond to other similarly interesting sounds such as arousing noises, or monkeys' and other animals' vocalizations.

Mirror neurons' activity reveals the existence of a mechanism through which perceived events as different as sounds, or images, are nevertheless coded as similar to the extent that they represent the assorted sensory aspects of the motor act's goal. It has been proposed that mirror neurons by mapping observed, implied, or heard goal-directed motor acts on their motor neural substrate in the observer's motor system, allow a direct form of action understanding, through a mechanism of embodied simulation (Gallese 2005, 2006; Gallese et al. 2009).

### **Mirror neurons and the Understanding of Action Intentions**

So far we have seen that mirror neurons in macaque monkeys likely underpin a direct form of action understanding. However, human social cognition is far more sophisticated. We not only understand what others are doing but also why, that is, we can attribute *intentions* to others. Indeed, the mainstream view on action and intention understanding holds that humans when understanding others start from the observation of an intentionally opaque behavior, biological motion, which has to be interpreted and explained in mental terms. This explanatory process is referred to as "mind reading", that is, the attribution to others of internal mental states, mapped in the mind of the observer as internal representations in propositional format. These representations supposedly play a causal role in determining the observed behavior to be understood.

I challenge this purely mentalistic view of intersubjectivity. I posit that at the basis of our capacity to understand others' intentional behavior – both from a phylogenetic and ontogenetic point of view – there is a more basic functional mechanism, which exploits the intrinsic functional organization of parieto-premotor circuits like those containing mirror neurons. This proposal is based on the emergence of striking homologies between the neural mechanisms underpinning action understanding in monkeys and humans.

In fact, a recent study by Fogassi et al. (2005) showed that parietal mirror neurons in addition to recognizing the goal of the observed motor act, allow the observing monkey to predict the agent's next action, henceforth its overall intention. This neural mechanism, present in a non-linguistic species, could scaffold more sophisticated social cognitive abilities, as those characterizing our species (Gallese and Goldman 1998; see also Gallese 2006, 2007).

It must be emphasized that mirror neurons are not "magic cells". Their functional properties are the outcome of the integration they operate on the inputs received from other brain areas. What makes the *functional properties* of mirror neurons special, though, is the fact that such integration process occurs within the motor system. Far from being just another species of multi-modal associative neurons in the brain, mirror neurons anchor the multimodal

integration they operate to the neural mechanisms presiding over our pragmatic relation with the world of others. Because of this reason they enable social connectedness by reducing the gap between Self and others (Gallese et al. 2009).

### **Mirroring Mechanisms in Humans**

Several studies using different experimental methodologies and techniques have demonstrated also in the human brain the existence of a mechanism directly mapping action perception and execution, defined as the Mirror Mechanism (MM) (for review, see Rizzolatti et al. 2001; Gallese 2003a,b, 2006; Gallese et al. 2004; Rizzolatti and Craighero 2004). During action observation there is a strong activation of premotor and posterior parietal areas, the likely human homologue of the monkey areas in which mirror neurons were originally described. The mirroring mechanism for actions in humans is somatotopically organized; the same regions within premotor and posterior parietal cortices normally active when we execute mouth, hand, and foot related acts are also activated when we observe the same motor acts executed by others (Buccino et al. 2001). Watching someone grasping a cup of coffee, biting an apple, or kicking a foot-ball activates the same neurons of our brain that would fire if *we* were doing the same.

The MM in humans is directly involved in imitation of simple movements (Iacoboni et al 1999), imitation learning of complex skills (Buccino et al. 2004a), in the perception of communicative actions (Buccino et al. 2004b), and in the detection of action intentions (Iacoboni et al. 2005). Furthermore, the premotor cortex containing the MM is involved in processing action-related words and sentences (Hauk et al. 2004; Tettamanti et al. 2005; Buccino et al. 2005; see also Pulvermuller 2002), suggesting – as it will become clearer in the final part of this chapter – that mirror neurons together with other parts of the sensory-motor system could play a relevant role in language semantics (Gallese and Lakoff 2005; Gallese 2007, 2008).

The neurofunctional architecture of the premotor system structures action execution and action perception, imitation, and imagination, with neural connections to motor effectors and/or other sensory cortical areas. When the action is executed or imitated, the cortico-spinal pathway is activated, leading to the excitation of muscles and the ensuing movements. When the action is observed or imagined, its actual execution is inhibited. The cortical motor network is activated, though, not in all of its components and, likely, not with the same intensity<sup>1</sup>, but action is not produced, it is only simulated.

Other mirroring mechanisms seem to be involved with our capacity to share emotions and sensations with others (Gallese 2001, 2003a,b, 2006; de Vignemont and Singer 2006). When we perceive others expressing a given basic emotion such as disgust, the same brain areas are activated as when we subjectively experience the same emotion (Wicker et al. 2003). Similar direct matching mechanisms have been described for the perception of pain

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<sup>1</sup> On average, the response of mirror neurons in monkeys is stronger during action execution than during action observation.

(Hutchison et al. 1999; Singer et al. 2004; Jackson et al. 2005; Botvinick et al. 2005) and touch (Keysers et al. 2004; Blakemore et al. 2005; Ebisch et al., 2008).

These results altogether suggest that our capacity to empathize with others is mediated by embodied simulation mechanisms, that is, by the activation of the same neural circuits underpinning our own emotional and sensory experiences (see Gallese 2005a,b, 2006; Gallese et al. 2004). Following this perspective, empathy is to be conceived as the outcome of our natural tendency to experience our interpersonal relations first and foremost at the implicit level of intercorporeity, that is, the mutual resonance of intentionally meaningful sensory-motor behaviors (see below).

Recent studies suggest that these mechanisms could be deficient and/or altered in individuals affected by the Autistic Spectrum Disorder. In fact, autistic children experience severe problems in the facial expression of emotions and their understanding in others. They do not show automatic mimicry of the facial expression of basic emotions, as revealed by EMG recordings. When asked to imitate the facial expression of facial emotions they do not show activation of the MNS in the pars opercularis of the inferior frontal gyrus (for review, see Gallese 2003b, 2006). The lack of empathic engagement displayed by autistic children could, at least partly, depend on defective embodied simulation, likely underpinned by malfunctioning and/or altered regulation of the MM (Gallese 2003b, 2006; see also Oberman and Ramachandran 2007).

### **Embodied Simulation and Intercorporeity**

All of these intriguing findings link to our understanding of broader contours of intersubjectivity, clarifying how intersubjectivity has a multilayered embodied basis mapped on shared neural circuits. The discovery of mirror neurons provide a new empirically based notion of intersubjectivity, viewed first and foremost as *intercorporeity* – the mutual resonance of intentionally meaningful sensory-motor behaviors – as the main source of knowledge we directly gather about others (Gallese 2007, 2009). Intercorporeity describes a crucial aspect of intersubjectivity not because the latter is to be viewed as phylogenetically and ontogenetically grounded on a merely perceived similarity between our body and the body of others. Intercorporeity describes a crucial aspect of intersubjectivity because humans share the same intentional objects and their situated sensory-motor systems are similarly wired to accomplish similar basic goals and experience similar emotions and sensations.

Anytime we meet someone, we are implicitly aware of his/her similarity to us, because we literally embody it. The very same neural substrate activated when actions are executed or emotions and sensations are subjectively experienced, is also activated when the same actions, emotions and sensations are executed or experienced by others. A common underlying functional mechanism – *embodied simulation* – mediates our capacity to share the meaning of actions, intentions, feelings, and emotions with others, thus grounding our identification with and connectedness to others.

The notion of simulation is employed in many different domains, often with different, not necessarily overlapping, meanings. Simulation is a functional process that possesses certain content, typically focusing on possible states of its target object. In philosophy of mind, the notion of simulation has been used by proponents of the Simulation Theory of mind reading (see Goldman 2006) to characterize the pretend state adopted by the attributer in order to understand another person's behavior. Basically, according to this view, we use our mind to put ourselves into the mental shoes of others.

At difference with standard accounts of Simulation Theory, I qualify simulation as embodied in order to characterize it as a mandatory, pre-rational, non-introspectionist process. The model of mind reading proposed by standard accounts of Simulation Theory (Goldman 2006) does not apply to the pre-linguistic and non-metarepresentational character of embodied simulation (Gallese 2003, 2005a,b, 2006). My embodied simulation model is in fact challenging the notion that the sole account of interpersonal understanding consists in explicitly attributing to others propositional attitudes like beliefs and desires, mapped as symbolic representations. Before and below mind reading is intercorporeity as the main source of knowledge we directly gather about others (Gallese 2007).

A direct form of understanding of others from within, as it were, – intentional attunement – is achieved by the activation of neural systems underpinning what we and others do and feel. Parallel to the detached third-person sensory description of the observed social stimuli, internal non-linguistic “representations” of the body-states associated with actions, emotions, and sensations are evoked in the observer, as if he or she were performing a similar action or experiencing a similar emotion or sensation.

It must be stressed that the term “representation” is used here very differently from its standard meaning in classic cognitive science and analytic philosophy. It refers to a particular type of content, generated by the relations that our situated and inter-acting brain-body system instantiates with the world of others. Such content is pre-linguistic and pre-theoretical, but nevertheless has attributes normally and uniquely attributed to conceptual content.

By means of an isomorphic format we can map others' actions onto our own motor representations, as well as others' emotions and sensations onto our own visceromotor and somatosensory representations. This is what I mean by embodied simulation. I posit that embodied simulation is a crucial functional mechanism for empathy.

### **Embodied Simulation and Empathy**

The embodied simulation model, which stems from recent neuroscientific evidence, has illustrious philosophical antecedents. The affective dimension of interpersonal relations has very early on attracted the interest of philosophers, because recognized as a distinctive feature of human beings. In the eighteenth century, Scottish moral philosophers identified our capacity to interpret the feeling of others in terms of “sympathy” (see Smith 1759). During the second half of the nineteenth century these issues acquired a multidisciplinary character, being tackled in parallel by philosophers and scholars of a new

discipline, psychology.

Empathy is a later English translation (see Titchener 1909) of the German word *Einfühlung*. As pointed out by Pigman (1995), Robert Vischer introduced the term in 1873 to account for our capacity to symbolize the inanimate objects of nature and art (on the relationship between empathy and aesthetic experience, see Freedberg and Gallese 2007). Vischer was strongly influenced by the ideas of Lotze (1854-64/1923), who already proposed a mechanism by means of which humans are capable of understanding inanimate objects and other species of animals by “placing ourselves into them” (*sich mitlebend... versetzen*).

Lipps (1903), who wrote extensively on empathy, extended the concept of *Einfühlung* to the domain of intersubjectivity that he characterized in terms of *inner imitation* (*Innere Nachahmung*) of the perceived movements of others. When watching an acrobat walking on a suspended wire, Lipps (1903) notes, I feel myself so inside of him (*Ich fühle mich so in ihm*). We can see here a first suggested relation between imitation, though “inner” imitation, in Lipps’ words, and the capacity of understanding others by ascribing feelings, emotions and thoughts to them.

Phenomenology has further developed the notion of *Einfühlung*. A crucial point of Husserl’s thought is the relevance he attributes to intersubjectivity in the constitution of our cognitive world. Husserl’s rejection of solipsism is clearly epitomized in his fifth Cartesian Meditation (1977, English translation), and even more in the posthumously published *Ideen II* (1989, English translation), where he emphasizes the role of others in making our world “objective”. It is through a “shared experience” of the world, granted by the presence of other individuals, that objectivity can be constituted.

Interestingly enough, according to Husserl the bodies of self and others are the primary instruments of our capacity to share experiences with others. What makes the behavior of other agents intelligible is the fact that their body is experienced not as material object (*Körper*), but as something alive (*Leib*), something analogous to our own experienced acting body. Neuroscience today shows that the scientific investigation of the “*Körper*” (the brain-body system) can shed light on the “*Leib*” (the lived body of experience), as the latter is the lived expression of the former.

From birth onwards the “*Lebenswelt*”, our experiential world inhabited by living things, constitutes the playground of our interactions. Empathy is deeply grounded in the experience of our lived-body, and it is this experience that enables us to directly recognize others not as bodies endowed with a mind but as *persons* like us. According to Husserl there can be no perception without *awareness of the acting body*.

The relationship between action and intersubjective empathic relations becomes even more evident in the works of Edith Stein and Merleau-Ponty. In her book “On the Problem of Empathy” (1912/1964, English translation), Edith Stein, a former pupil of Husserl, clarifies that the concept of empathy is not confined to a simple grasp of the other’s feelings or emotions. There is a more basic connotation of empathy: the other is experienced as another being as oneself through an appreciation of *similarity*. An important component of this

similarity resides in the common experience of action. As Edith Stein points out, if the size of my hand were given at a fixed scale, as something predetermined, it would become very hard to empathize with any other types of hand not matching these predetermined physical specifications.

However, we can perfectly recognize children's hands and monkeys' hands as such despite their different visual size and texture. Furthermore, we can recognize hands as such even when all the visual details are not available, even despite shifts of our point of view, and when no visual shape specifications is provided. Even if all we can see are just moving light-dot displays of people's behavior, we are not only able to recognize a walking person, but also to discriminate whether it is ourselves or someone else we are watching (see Cutting and Kozlowski 1977). Since in normal conditions we never look at ourselves when walking, this recognition process can be much better accounted for by a mechanism in which the observed moving stimuli activate the observer's motor schema for walking, than solely by means of a purely visual process. Again we see how our understanding of others cannot be reduced to a purely vision-driven enterprise.

This seems to suggest that our "grasping" of the meaning of the world doesn't *exclusively* rely on the cognitive hermeneutic of its "visual representation", but is strongly influenced by action-related sensory-motor processes, that is, we rely on our own "embodied personal knowledge". The monolithic character of perception must be refuted. There are different ways of perceiving others, only some of which enable the sense of connectedness that I define *intentional attunement*.

Merleau-Ponty in the *Phenomenology of Perception* (1945; English transl. 1962, p. 185) writes:

" *The sense of the gestures is not given, but understood, that is, recaptured by an act on the spectator's part. The whole difficulty is to conceive this act clearly, without confusing it with a cognitive operation<sup>2</sup>. The communication or comprehension of gestures come about through the reciprocity of my intentions and the gestures of others, of my gestures and intentions discernible in the conduct of other people. It is as if the other person's intention inhabited my body and mine his*". These words fully maintain their illuminating power in the present century, even more so as they can now be grounded on solid empirical evidence.

By means of *Einfühlung* we come to know about the presence of others and of the specific nature of their experiences *directly*, rather than through a "cognitive operation". This way of entering intersubjectivity is the most basic; it includes the domain of action, and spans and integrates the various modalities for sensing and communicating with others. It is at the core of our experience of self and other, the root of intersubjectivity.

It must be added, though, that while it is certainly true that mirror neurons fire no matter whether the action is executed or perceived, it is also true that *the intensity of their response* is not the same in these two different situations. On average the motor discharge exhibited by mirror neurons in macaque monkeys

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2 My emphasis.

during action execution is significantly higher than that evoked by the observation of a similar action performed by others. More generally, it must be stressed that embodied simulation doesn't imply that we experience others the way we experience ourselves. The I-Thou identity relation constitutes only one side of the intersubjectivity coin. As posited by Edmund Husserl (1969, 1989), and recently re-emphasized by Dan Zahavi (2001), it is the alterity of the other to guarantee the objectivity we normally attribute to reality.

The alterity character of others as we experience them also maps at the sub-personal neural level, because the cortical circuits at work when *we* act neither completely overlap, nor show the same activation intensity as when *others* are the agents and we are the witnesses of their actions. The same logic also applies to sensations (see Blakemore et al. 2005) and emotions (see Jabbi et al. 2008). The study by Jabbi et al. is particularly informative in this respect, because it shows that experiences as different as being subjectively disgusted, imagining oneself being disgusted and seeing disgust portrayed in the facial expression of others not only encompass the activation of the same network of brain areas (the anterior insula and the anterior cingulate cortex), but also the activation of different brain areas according to the specific modality in which disgust is experienced (my real disgust, my imagined disgust, your disgust).

It must also be added that the functional mechanism of embodied simulation is not to be conceived as a rigid, reflex-like input output coupling. Several brain-imaging studies have shown that the intensity of the MNS activation during action observation depends on the similarity between the observed actions and the participants' action repertoire.

All of these considerations lead me to resist the notion that simulation must necessarily be characterized in terms of the *resemblance* between target and simulator. As argued by the late Susan Hurley (2007, 2008), simulation can be more plausibly characterized in terms of *reuse*. According to the reuse notion of simulation, what distinguishes simulation from theorizing is the reuse of a process for generating information about that process. Indeed the neuroscientific evidence here reviewed shows that humans do reuse motor processes in order to directly understand the actions of others and, similarly, reuse emotion-related processes to directly understand others' emotions.

What qualifies simulation as embodied is specifically this notion of reuse, describable as an isomorphic type of mapping between target and simulator. What makes the activation of mirror neurons during the observation of the actions of others an 'as-if' process is not its resemblance aspect, but the fact that in spite of an activation of the motor system in the observer's brain the action is not executed but only simulated. This is why I disagree with Gallagher when he claims that in order to invoke simulation, mirror neurons "must generate an extra copy of the actions as they would be if they were the perceiver's own actions" (2001, p. 102).

That said, I think that Gallagher's and mine perspectives share a lot more than what transpires from Gallagher's critique of embodied simulation. Both Gallagher and I think that the role traditionally assigned by classic cognitivism to Folk Psychology is exceedingly large and unjustified. Both Gallagher and I think that mind reading should not be identified with a mostly theoretical enterprise

usually defined as ‘Theory of Mind’. This is the main reason why I entitled my 2007 paper “Before and below Theory of Mind”, where I wrote: “...*social cognition is not only ‘social metacognition’, that is, explicitly thinking about the contents of someone else’s mind by means of symbols or other representations in propositional format*” (Gallese 2007, p. 659). Finally, both Gallagher and I think that the primary way of understanding others is *direct in nature*. However, I do believe, *pace* Gallagher, that such directedness is completely compatible with the reuse notion of simulation I am advocating. Claiming that the understanding of others is mediated by mirror-based embodied simulation is not tantamount to saying that a sort of pretence mediates the perception of others’ behavior. All of these considerations make it difficult to account for mirroring phenomena as forms of “direct perception”.

The concise overview of aspects of the phenomenological tradition in philosophy offered in this section and the neuroscientific evidence presented throughout the chapter suggest that the view heralded by classic cognitivism that considers social cognition as a solely theoretical enterprise is confining, arbitrary and reductive. The new empirically grounded perspective on *Einfühlung* I propose can be beneficial not only for a new approach to our understanding of human intersubjectivity, but perhaps also for new developments in psychopathological thought.

### **Embodied Simulation and Intentional Attunement**

Our capacity to conceive of the acting bodies of others as *se/ves* like us depends on the constitution of a shared meaningful interpersonal space. This “shared manifold” (see Gallese, 2001, 2003a,b, 2005a,b) can be characterized at the functional level as embodied simulation, a specific mechanism constituting a basic functional feature by means of which our brain/body system models its interactions with the world. The different mirroring mechanisms described in this constitute the sub-personal instantiation of embodied simulation.

According to my model, when we witness the intentional behavior of others, embodied simulation generates a specific phenomenal state of “intentional attunement”. This phenomenal state in turn generates a peculiar quality of identification with other individuals, produced by establishing a dynamic relation of reciprocity between the “I” and the “Thou”. By means of embodied simulation we do not just “see” an action, an emotion, or a sensation. Side by side with the sensory description of the observed social stimuli, internal representations of the body states associated with these actions, emotions, and sensations are evoked in the observer, “as if” he/she were doing a similar action or experiencing a similar emotion or sensation. That enables our social identification with others. To see others’ behavior as an ‘action’ or as an experienced emotion or sensation specifically requires such behaviors to be mapped according to an isomorphic format. Such mapping *is* embodied simulation.

Any intentional relation can be mapped as a relation between an acting subject and an object. The mirroring mechanisms described here map the different intentional relations in a fashion that is – to a certain degree – neutral about the identity of the agent/subject. No matter who the agent is, by means of a shared functional state realized in two different bodies obeying to the same functional rules, the “objectual other” becomes “another self”, a like-me, who nevertheless preserves his/her alterity character.

When we are exposed to the actions performed by others or to the way they express the emotions and sensations they experience, we do not necessarily start from an opaque sensory description of a given behavior to be interpreted and logically analyzed with our cognitive – and disembodied – apparatus. In many everyday situations others’ behavior is immediately meaningful because it enables a direct link to our own situated lived experience of the same behaviors, by means of processing what we perceive of others (their actions, emotions, sensations) onto the same neural assemblies presiding over our own instantiations of the same actions, emotions and sensations.

### **More Complex Mechanisms of Social Cognition**

Of course, embodied simulation is not the only functional mechanism underpinning social cognition. Social stimuli can also be understood on the basis of the explicit cognitive elaboration of their contextual perceptual features, by exploiting previously acquired knowledge about relevant aspects of the situation to be analyzed. Our capacity of attributing false beliefs to others, among our most sophisticated mentalizing abilities, likely involve the activation of large regions of our brain, certainly larger than a putative and domain-specific Theory of Mind Module.

It must be added that the neural mechanisms underlying such complex mentalizing abilities are far from being understood. Furthermore, recent evidence demonstrates that infants as young as 15 months behave as if they were able to attribute false beliefs to others, when tested with pre-verbal tasks like preferential looking (Onishi and Baillargeon 2005). This shows that even apparently highly sophisticated mentalizing skills – like the attribution of false beliefs to others – might still be underpinned by low-level mechanisms still to be thoroughly investigated.

### **The Developmental Course of Mirroring Mechanisms**

One crucial issue still not clarified is how the MM develops in the course of development. We do not know yet to which extent the mirroring mechanisms described in this chapter are innate and how they are shaped and modeled during development. We do know, however, that motor skills mature much earlier on than previously thought. In a recent study (Zoia et al. 2007) the kinematic of fetal hand movements were measured. The results showed that the spatial and temporal characteristics of fetal movements were by no means

uncoordinated or unpatterned. By 22 weeks of gestation fetal hand movements show kinematic patterns that depend on the goal of the different motor acts fetuses perform. This results led the authors of this study to argue that 22 weeks old fetuses show a surprisingly advanced level of motor planning, already compatible with the execution of “intentional actions”. Given such sophisticated prenatal development of the motor system, it can be hypothesized that during prenatal development specific connections may develop between the motor centers controlling mouth and hand goal-directed behaviors and brain regions that will become recipient of visual inputs after birth. Such connectivity could provide functional templates (e.g. specific spatio-temporal patterns of neural firing) to areas of the brain that, once reached by visual information, would be ready to specifically respond to the observation of biological motion like hand or facial gestures, thus enabling, for example, neonatal imitation.

Neonates and infants, by means of specific connectivity developed during the late phase of gestation between motor and “to-become-visual” regions of the brain, would be ready to imitate the gestures performed by adult caregivers in front of them, and would be endowed with the neural resources enabling the reciprocal behaviors characterizing our post-natal life since its very beginning (see Gallese et al. 2009).

The earliest indirect evidence available to date of a MNS in infants comes from a study by Shimada and Iraki (2006) who demonstrated by means of near infrared spectroscopy (NIRS) the presence of an action execution/observation matching system in 6-months-old human infants. Interestingly, this study showed that the sensory-motor cortex of infants (but not that of adult participants) was also activated during the observation of a moving object when presented on a TV screen. These findings suggest that during the early developmental stages, even non-biological moving objects are “anthropomorphized” by means of their mapping onto motor representations pertinent to the observers’ acquired motor skills.

It can be hypothesized that an innate rudimentary MNS is already present at birth and can be flexibly modulated by motor experience and gradually enriched by visuomotor learning. Lepage and Theoret (2007) recently proposed that the development of the MNS can be conceptualized as a process whereby the child learns to refrain from acting out the automatic mapping mechanism linking action perception and execution. The development of pre-frontal inhibitory mechanisms likely turns motor contagion into motor simulation. Such development leads the gradual transition from mandatory re-enactment to mandatory embodied simulation.

### **Intersubjectivity Grounds the Human Condition**

The shared intersubjective we-centric space mapped by mirroring mechanisms is likely crucial in bonding neonates and infants to the social world, but it progressively also acquires a different role. It provides the self with the capacity to simultaneously entertain self-other identification and difference.

Once the crucial bonds with the world of others are established, this space carries over to the adult conceptual faculty of socially mapping sameness and difference (“I am a different self”). Social identification, the “selfness” we readily attribute to others, the inner feeling of “being-like-you” triggered by our encounter with others, are the result of the preserved shared we-centric space. Self-other physical and epistemic interactions are shaped and conditioned by the same body and environmental constraints. This common relational character is underpinned, at the level of the brain, by shared mirroring neural networks. These shared neural mechanisms enable the shareable character of actions, emotions and sensations, the earliest constituents of our social life. According to my model, we-ness and intersubjectivity ontologically ground the human condition, in which reciprocity foundationally defines human existence.

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