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Mirror Neurons, Embodied Simulation, and the Neural Basis of Social Identification

Vittorio Gallese, M.D.
University of Parma

The shared intersubjective space in which we live since birth enables and bootstraps the constitution of the sense of identity we normally entertain with others. Social identification incorporates the domains of action, sensations, affect, and emotions and is underpinned by the activation of shared neural circuits. 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. Social identification, empathy, and "we-ness" are the basic ground of our development and being. Embodied simulation provides a model of potential interest not only for our understanding of how interpersonal relations work or might be pathologically disturbed but also for psychoanalysis. The hypothesis is that embodied simulation is at work within the psychoanalytic setting between patient and analyst. The notions of projective identification and the interpersonal dynamic related to transference and countertransference can be viewed as instantiations of the implicit and prelinguistic mechanisms of the embodied simulation-driven mirroring mechanisms here reviewed.

INTRODUCTION

> A path leads from identification by way of imitation to empathy, that is to the comprehension of the mechanism by which we are enabled to take up any attitude at all towards another mental life.
>
> — Freud (1921, p. 110)

From the very beginning of our life, the social dimension plays a very powerful role, shaping our relation to the world. Social behavior is not peculiar of primates. Nevertheless, central to all social species and—within more evolved species of primates—central to all social cultures of whatever complexity, is the notion of social identification of the individuals within those species and cultures. All levels of social interaction employed to characterize cognition in single individuals, must intersect or overlap to enable the development of mutual recognition and intelligibility.

How is social identification built? What are the neural mechanisms enabling its emergence? This paper tries to provide preliminary answers to both questions.

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Vittorio Gallese, M.D., Professor of Human Physiology, Department of Neuroscience–Section of Physiology, University of Parma, via Volturno 39 Parma, Italy 43100. E-mail: vittorio.gallese@unipr.it

Social identification can be articulated on many different levels of complexity. However, whatever this complexity might be, social identification is crucial to allow the sense of belonging to a larger community of other organisms. The hypothesis being proposed here is that social identification incorporates the domains of action, sensations, affect, and emotions and is underpinned by the activation of shared neural circuits. The shared intersubjective space in which we live since birth enables and bootstraps the constitution of the sense of identity we normally entertain with others. 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. Social identification, empathy, and "we-ness" are the basic ground of our development and being.

The paper 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. I then present a concise overview of developmental psychology research showing the early onset of social identification. I finally sketch some implications of this perspective for psychoanalysis. My main point is that embodied simulation provides a model of potential interest not only for our understanding of how interpersonal relations work or might be pathologically disturbed, but also for our understanding of interpersonal relations within the psychoanalytic setting.

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, Fadiga, Fogassi, & Rizzolatti, 1996; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996). Neurons with similar properties were also discovered in a sector of the posterior parietal cortex (Fogassi et al., 2005; Gallese, Fogassi, Fadiga, & Rizzolatti, 2002). 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 coexistence 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, 2005a,b, 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 nonlinguistic species, could scaffold more sophisticated social cognitive abilities, as those characterizing our species (Gallese & 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 multimodal 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 Neuron System (MNS; for review, see Gallese, 2003a, 2003b, 2006; Gallese, Keysers, & Rizzolatti, 2004; Rizzolatti & Craighero, 2004; Rizzolatti, Fogassi, & Gallese, 2001). 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 football activates the same neurons of our brain that would fire if we were doing the same.

The MNS 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 MNS is involved in processing action-related words and sentences (Buccino et al., 2005; Hauk, Johnsrude, & Pulvermüller, 2004; Tettamanti et al., 2005; see also Pulvermüller, 2002), suggesting—as it will become clearer in the final part of this paper—that mirror neurons together with other parts of the sensory-motor system could play a relevant role in language semantics (Gallese, 2007, 2008; Gallese & Lakoff, 2005).

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,[1] 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 (de Vignemont & Singer, 2006; Gallese, 2001, 2003a, 2003b, 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 (Botvinick et al., 2005; Hutchison, Davis, Lozano, Tasker, & Dostrovsky, 1999; Jackson, Meltzoff, & Decety, 2005; Singer et al., 2004; Ebisch et al., 2008) and touch (Blakemore, Bristow, Bird, Frith, & Ward, 2005; Keysers et al., 2004). 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, 2005b, 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 next).

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 seems to depend on defective embodied simulation, likely underpinned by malfunctioning and/or altered regulation of the MNS (Gallese, 2003b, 2006; see also Oberman & Ramachandran, 2007).

SOCIAL IDENTIFICATION AND EMBODIED SIMULATION

> It is only by empathy that we know the existence of psychic life other than our own.
>
> — Freud (1926, p. 104)

All of these intriguing findings link to our understanding of broader contours of intersubjectivity, clarifying how social identification 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

[1]On average, the response of mirror neurons in monkeys is stronger during action execution than during action observation.

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 or 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 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, prerational, nonintrospectionist process. The model of mind reading proposed by standard accounts of Simulation Theory (Goldman, 2006) does not apply to the prelinguistic and nonmetarepresentational character of embodied simulation (Gallese, 2003, 2005a, 2005b, 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 nonlinguistic "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 interacting brain–body system instantiates with the world of others. Such content is prelinguistic and pretheoretical, 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 viscero-motor 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 18th century, Scottish moral philosophers identified our capacity to interpret the feeling of others in terms of "sympathy" (see Smith, 1759/1976). During the second half of the 19th 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 & Gallese, 2007). Vischer was strongly influenced by the ideas of Lotze (1856–64/1923), 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 Nachamung) of the perceived movements of others. When watching an acrobat walking on a suspended wire, Lipps noted, *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's words, and the capacity of understanding others by ascribing feelings, emotions and thoughts to them. The fact that Lipps's notion of Einfühlung closely matches Freud's (1921) take on empathy is no surprise, since Freud considered Lipps as "the clearest mind among present-day philosophical writers," as he wrote to Fliess in 1898 (Freud, 1985, p. 324).

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 emphasized 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 onward 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,* Edith Stein (1912/1964, English translation), 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 pointed 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 able not only to recognize a walking person but also to discriminate whether it is ourselves or someone else we are watching (see Cutting & 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 (1945/1962) in the *Phenomenology of Perception* wrote,

> 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.[2] 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. (p. 185)

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.

The concise overview of aspects of the phenomenological tradition in philosophy offered in this section and the neuroscientific evidence presented throughout the paper 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 psychoanalytic thought.

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[2]My emphasis *without confusing it with cognitive operation*.

Embodied Simulation and Intentional Attunement

Our capacity to conceive of the acting bodies of others as selves like us depends on the constitution of a shared meaningful interpersonal space. This "shared manifold" (see Gallese, 2001, 2003a, 2003b, 2005a, 2005b) 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 paper constitute the subpersonal 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 or 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 or 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 involves 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 preverbal tasks like preferential looking (Onishi & 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. This is one of the many reasons why developmental psychology is so important in shedding light on social cognition.

SOCIAL IDENTIFICATION AND INFANT RESEARCH

The developmental psychology research during the last decades has provided one of the major contributions to a new understanding of human social cognition. Several studies have shown that the capacity of infants to establish relations with "others" is accompanied by the registration of behavioral invariance. As pointed out by Stern (1985), this invariance encompasses unity of locus, coherence of motion, and coherence of temporal structure. This experience-driven process of constant remodeling is one of the building blocks of cognitive development, and it capitalizes upon coherence, regularity, and predictability. Social identification guarantees all these features, henceforth its high social adaptive value. The experience of identity between infant and caregiver is the starting point for the development of social cognition.

The discovery of an MNS and the subsequent research this discovery generated have shed light for the first time on the neural mechanism at the basis of the capacity of entertaining a "like-me" intersubjective mapping, which doesn't require an explicit inference by analogy. The shared we-centric space created by embodied simulation generates the social bootstrapping of cognitive and affective development because it provides a powerful tool to detect and incorporate coherence, regularity, and predictability in the course of the interactions of the individual with others. Our discovery provides the neuroscientific mechanisms that might explain within a unified and coherent framework a variety of discoveries made by developmental psychologists in the domain of the ontogenesis of intersubjectivity.

Already at birth humans appear to be engaged in interpersonal mimetic relations, by means of neonatal imitation. The seminal study of Meltzoff and Moore (1977) and the subsequent research field it opened (see Meltzoff, 2007a, 2007b) showed that newborns are capable of reproducing mouth and face movements displayed by the adult they are facing. That particular part of their body replies, though not in a reflex-way, to movements displayed by the equivalent body part of someone else. As Meltzoff (2007b) recently wrote, "the bedrock on which commonsense psychology is constructed is the apprehension that others are similar to the self. Infants are launched on their career of interpersonal relations with the basic perception: 'Here is something like me" (p. 27). These results suggest that neonates are innately prepared to link to their caregivers through imitation and affective attunement, clarifying yet another of the various capacities that locate human infants in the social world from the very beginning of life.

In addition, infants very early on show unequivocal signs of social interaction sequences, beside neonatal imitation. They actively solicit their caregivers' "protoconversational" turn-taking structure, that is, characterized by a structure remarkably similar to adult conversations (see Braten, 1988, 1992, 2007; Meltzoff & Brooks, 2001; Meltzoff & Moore, 1977, 1998; Stern, 1985; Trevarthen, 1979, 1993; Tronick, 1989). Furthermore, as shown by Reddy (2008), few-months-old preverbal infants when engaged in social interactions show even signs of so-called self-conscious emotions like embarrassment, pride, and coyness at a developmental age preceding the onset of self-reflective consciousness, definitely well before they are capable of self-recognition when looking at their reflection in a mirror. As Reddy wrote, "engaging with other minds is an emotional process form start to finish" (p. 41). Immediately after, she added [Self-conscious-emotions] "rather than derive from conceptual development in the second year of human infancy, exist in simple forms as ways of managing the exposure of self to other from early in the first year and are crucial for shaping the infant's emerging conception of self and other" (p. 41). As pointed out by Beebe, Knoblauch, Rustin, and Sorter (2005), the seminal research of developmental psychology has shown that the mind begins as a shared mind.

The shared we-centric space enabled by the activation of mirror neurons is paralleled by the development of perspectival spaces defined by the establishment of the capacity to distinguish self from other, as long as sensory-motor self-control develops. Infants progressively carve out an agentive, subjective perspective onto the world.

However, such process of personal identification anchored to an egocentric perspective contains and depends upon a contrastive element. "In the absence of reciprocity there is no alter Ego," wrote Merleau-Ponty (1945/1962, p. 357). It is not possible to conceive of oneself as a Self without rooting this process of appraisal in an earlier stage in which sharing prevails.

Within each of the newly acquired perspectival agentive and perceptual spaces, information can be better segregated in discrete channels (visual, somatosensory, etc.) making the perception of the world more finely grained; this includes the emergent self–other distinction. The concurrent development of language contributes to further segregate from the original multimodal perceptive world, single characters or modalities of experience. Yet the more mature capacity to segregate the modes of interaction, together with the capacity of carving out the subject and the object of the interaction, do not annihilate the shared we-centric space.

The mirroring mechanisms here briefly reviewed are involved in so many aspects of social cognition because the activation of the multiple and parallel cortico-cortical circuits instantiating mirror properties underpins a fundamental aspect of social cognition, that is, the multilevel connectedness among individuals within a social group. Such connectedness finds its phylogenetic and ontogenetic roots in the social sharing of situated experiences of action and affect. Mirroring mechanisms provide a neural basis of such sharing.

The Developmental Course of Mirroring Mechanisms and Social Identification

One crucial issue still not clarified is how the MNS develops in the course of development. We do not know yet to which extent the mirroring mechanisms described in this paper 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. These 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 postnatal life since its very beginning. The apparent continuity between fetal and postnatal development of action and sensory-motor integration was somehow prefigured by Freud (1926) when he emphasized that there is a fundamental continuity between fetal and postnatal life.

The earliest indirect evidence available to date of a MNS in infants comes from a study by Shimada and Hiraki (2006), who demonstrated by means of near infrared spectroscopy the presence of an action execution/observation matching system in 6-month-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 nonbiological 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 Théoret (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 prefrontal 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.

EMBODIED SIMULATION AND PSYCHOANALYSIS: IMPLICIT AND LINGUISTIC DIMENSIONS OF INTERPERSONAL RELATIONS

The results of neuroscientific investigation reviewed in the present paper broaden the possibility to establish a dialogue between neuroscience and psychoanalysis. Psychoanalysis has always identified the body as the source of the energies alimenting psychic representations. Recently, Karlsson (2004) proposed that the unconscious presupposes presexual processes in the form of a body's formation of continuity, coherence, and wholeness. Interestingly, recent developments in cognitive neuroscience, as those presented here, have emphasized the role of the acting body and of sensory-motor systems in constituting the way our mind represent reality, by shaping our cognitive schemas (Gallese, 2007, 2008; Gallese & Umiltà, 2002; Rochat, Serra, Fadiga, & Gallese, 2008).

These findings support contemporary psychoanalytic developments that have shifted the analytic focus from the individual mind to the intersubjective field. These may have been suggested in prior theorizing (see Gallese, Eagle, & Migone, 2007) but have only recently become more explicit. Freud, of course, referred to the role of the analyst's empathy (Einfühlung) in understanding the patient, but he did so mainly in informal observations and comments about the treatment situation.

The present paper focused on the embodied experiential aspects of interpersonal relationships. My hypothesis is that embodied simulation is at work within the psychoanalytic setting between patient and analyst (see also Beebe et al., 2005; Gallese et al., 2007; Knoblauch, 2000; Seligman, 1999). The notions of projective identification and the interpersonal dynamic related to transference and countertransference can be viewed as instantiations of the implicit and prelinguistic mechanisms of the embodied simulation-driven mirroring mechanisms here reviewed.

It should be added that the notion of neural mirroring and the related functional mechanism of embodied simulation do not imply that what is mirrored and simulated in the observer's brain needs to be an exact replica of its object. The mirror metaphor is perhaps misleading. The more we study mirroring mechanisms the more we learn about their plasticity and dependence upon the personal history and situated nature of the "mirroring subject."

The late Mauro Mancia, a neuroscientist and psychoanalyst who pioneered the establishment of a dialogue between psychoanalysis and neuroscience, repeatedly emphasized the importance for psychoanalysis, both from a theoretical and clinical point of view, of implicit memory and of unrepressed unconscious (Mancia, 2007, 2006). I submit that the plasticity of mirroring mechanisms could play an important role in the constitution of the implicit memories that constantly accompany, as a sort of background, our relations with internal and external objects. By internalizing specific patterns of interpersonal relations we develop our own characteristic attitude toward others and toward how we internally live and experience these relations. It can be hypothesized that our personal identity is—at least partly—the outcome of how our embodied simulation of others develops and takes shape.

A second important implication for psychoanalysis must be considered. The same embodied perspective applied to implicit aspects of intersubjectivity can also be used to characterize several dimensions of language, the cognitive tool employed to organize, elaborate, narrate and self-consciously structure our own social experiences. Freud's and—more generally—psychoanalysis's canonical approach to understanding the patient's mind primarily rest on explicit theory-based interpretations of the patient's productions (i.e., free associations, dreams).

The patient's productions can be read as a "text" in need to be deciphered and interpreted in order to be truly understood. It is an open question to which extent such "text" is permeable to the influence exerted by the embodied simulation mechanisms here discussed. Viewing social cognition as an embodied and situated enterprise (see Anderson, 2003; Barrett & Henzi, 2005; Barsalou, 1999; Clark, 1997; Gallese, 2003a; Gallese & Lakoff, 2005; Lakoff & Johnson, 1980, 1999; Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005) offers the possibility of a new approach to language that is both neuroscientific and intersubjective.

With the advent of language, and even more with the "discovery" of written language, meaning is amplified as it becomes independent from specific instantiations of actual experience. Language expands the meaning of individual situated experiences. Language evokes the totality of possibilities for action the world calls upon us, and structures action within a web of related meanings. If we confine language to its sole predicative use, we reify a consistent part of language's nature. Our understanding of linguistic expressions is not solely an epistemic attitude; it is a way of being. Our way of being, in turn, depends on what we act, how we do it, and how the world responds to us.

Signification arouses speech as the world arouses the body by soliciting different forms of relations. As suggested by Merleau-Ponty (1960/1964), for the speaking subject to express a meaning is to become fully aware of it. The signifying intention of the speaker can be conceived of as a gap to be filled with words. Language is a social enterprise in which action plays a crucial role. When we speak, by means of the shared neural networks activated by embodied simulation, we experience the presence of others in ourselves and of ourselves in others. Embodied simulation likely helps filling the gap (Gallese, 2007, 2008).

Overall, then, this action-related and experience-driven account of language and its intersubjective framing suggest a tight relation between language and the domain of action. Neuroscientific investigation already produced remarkable findings. When processing language, both at the visual and auditory level, humans show activation of the motor system. This activation occurs at the phonoarticulatory as well as at the semantic and syntactical levels (for review, see Gallese, 2007, 2008).

Recent evidence also shows a tight relationship between the activation of the motor system and processing of the emotional content of language. Understanding happy sentences activates muscles associated with smiling, while understanding sad and angry sentences activates muscles associated with frowning. Furthermore, because emotion simulation activates particular action systems like facial muscles, adapting those action systems (e.g., by contracting specific facial muscles during the task) affects comprehension of sentences with emotional content congruent with the adapted action system (for review, see Glenberg, Webster, Mouilso, Havas, & Lindeman, in press; Niedenthal, 2007).

As suggested by Arciero (2006), to imbue words with meaning requires a fusion between the articulated sound of words and the shared meaning of action. Embodied simulation does exactly that. Furthermore, and most importantly, embodied simulation and the MNS underpinning it, provide the means to share communicative intentions, meaning, and reference, thus granting the parity requirements of social communication.

The implications for the "talking cure" of the perspective on language offered by the results here reviewed should appear obvious. It appears that even the apparently most explicit way of relating to others—that provided by linguistic expressions—is deeply rooted in intercorporeity.

CONCLUSIONS

The model of embodied simulation can be relevant to psychoanalysis for four main reasons. First, it provides a unified account of preverbal aspects of interpersonal relations that likely play an important role in shaping the Self. Second, it can contribute to a new definition of psychopathological processes. Third, t discloses the possibility to analyze from a different perspective the specific interpersonal preverbal dynamics characterizing the psychoanalytic setting. Fourth, it sheds new light on the intimate relationship between language and the embodied experience we make of the world, thus offering new clues on the narrative identity of selves.

My proposal can be framed within the broader picture of an interactionist theory of meaning (see Gallese & Lakoff, 2005). Meaning does not inhabit a pre-given Platonic world of ideal and eternal truths to which mental representations connect and conform. The body is the main source of meaning, because it not only structures the experiential aspects of interpersonal relations, but also their linguistic representations.

This proposal can stimulate a new form of dialogue between neuroscience and psychoanalysis, based on the common goal of grounding the analysis of human experience on a multilevel and multidisciplinary approach, likely the sole capable of succeeding in the fascinating enterprise of understanding who we really are.

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CONTRIBUTOR

Vittorio Gallese, M.D., is a Neurologist and Full Professor of Physiology at the Department of Neuroscience of the University of Parma, Italy. He worked at the University of Lausanne, Switzerland, and at the Nihon University, Tokyo, Japan. He has been George Miller visiting professor at the University of California at Berkeley. He has published more than 100 papers in international peer-reviewed journals and edited books. Among his major contributions is the discovery, together with the colleagues of Parma, of mirror neurons and the elaboration of a theoretical model of basic aspects of social cognition–embodied simulation. In 2007 he received with Giacomo Rizzolatti and Leonardo Fogassi the Grawemeyer Award for Psychology for the discovery of mirror neurons.