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# Intentional Attunement. The Mirror Neuron system and its role in interpersonal relations

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## Introduction

The dominant view in cognitive science puts most efforts in clarifying what are the formal rules structuring a solipsistic, representational mind. Much less investigated is what triggers the sense of social identity that we experience with the multiplicity of “other selves” populating our social world. Is the solipsistic type of analysis inspired by folk-psychology, the exclusive explanatory approach to social cognition? In particular, does it do full justice to the phenomenal aspects of our social intentional relations? My answer is no to both questions.

Instead of Mr. Spock, the famous alien character of the Star Trek series, our social mental skills are not confined to a declarative, conceptualized, and objective perspective. Usually, we are not alienated from the actions, emotions and sensations of others, because we are *attuned to the intentional relations of others*. By means of intentional attunement, “the others” are much more than being different representational systems; they become *persons*, like us.

In this paper I will show that the same neural circuits involved in action control and in the first person experience of emotions and sensations are also active when witnessing the same actions, emotions and sensations of others, respectively.I will posit that the mirror neuron systems, together with other mirroring neural clusters outside the motor domain, constitute the neural underpinnings of embodied simulation, the functional mechanism at the basis of intentional attunement.

## The mirror neuron system for actions in monkeys and humans: empirical evidence

About ten years ago we discovered in the macaque monkey brain a class of premotor neurons that discharge not only when the monkey executes goal-related hand actions like grasping objects, but also when observing other individuals (monkeys or humans) executing similar actions. We called them “mirror neurons[1]” (Gallese et al. 1996; Rizzolatti et al. 1996a). Neurons with similar properties were later discovered in a sector of the posterior parietal cortex reciprocally connected with area F5 (PF mirror neurons, see Rizzolatti et al. 2001; Gallese et al. 2002).

The observation of an object-related hand action leads to the activation of the same neural network active during its actual execution. Action observation causes in the observer the automatic activation of the same neural mechanism triggered by action execution. We proposed that this mechanism could be at the basis of a direct form of action understanding (Gallese et al. 1996; Rizzolatti et al. 1996a; see also Gallese 2000, 2001, 2003a, b, 2004; Gallese et al. 2004; Rizzolatti et al. 2001; Rizzolatti and Craighero 2004).

Further studies carried out in our lab corroborated and extended our original hypothesis. We showed that F5 mirror neurons are also activated when the final critical part of the observed action, that is, the hand-object interaction, is hidden (Umiltà et al 2001). In a second study we showed that a particular class of F5 mirror neurons, “audio-visual mirror neurons” can be driven not only by action execution and observation, but also by the sound produced by the same action (Kohler et al 2002).

We recently explored the most lateral part of area F5 where we described a population of mirror neurons related to the execution/observation of mouth actions (Ferrari et al. 2003). The majority of these neurons discharge when the monkey executes and observes transitive, object-related ingestive actions, such as grasping, biting, or licking. However, a small percentage of mouth-related mirror neurons discharge during the observation of intransitive, communicative facial actions performed by the experimenter in front of the monkey (“communicative mirror neurons”, Ferrari et al. 2003).

Several studies using different experimental methodologies and techniques have demonstrated also in the human brain the existence of a mirror neuron system matching action perception and execution. During action observation there is a strong activation of premotor and parietal areas, the likely human homologue of the monkey areas in which mirror neurons were originally described (for a review, see Rizzolatti et al. 2001; Gallese 2003a; Rizzolatti and Craighero 2004; Gallese et al. 2004). Furthermore, the mirror neuron matching system for actions in humans is somatotopically organized, with distinct cortical regions within the premotor and posterior parietal cortices being activated by the observation/execution of mouth, hand, and foot related actions (Buccino et al. 2001).

A recent brain imaging study, in which human participants observed communicative mouth actions performed by humans, monkeys and dogs showed that the observation of communicative mouth actions led to the activation of different cortical foci according to the different observed species. The observation of human silent speech activated the pars opercularis of the left inferior frontal gyrus, a sector of Broca’s region. The observation of monkey lip-smacking activated a smaller part of the same region bilaterally. Finally, the observation of the barking dog, activated only exstrastriate visual areas. Actions belonging to the motor repertoire of the observer (e.g., biting and speech reading) or very closely related to it (e.g. monkey’s lip-smacking) are mapped on the observer’s motor system. Actions that do not belong to this repertoire (e.g., barking) are mapped and henceforth categorized on the basis of their visual properties (Buccino et al. 2004).

The involvement of the motor system during observation of communicative mouth actions is also testified by the results of a TMS study by Watkins et al. (2003), in which they showed that the observation of communicative, speech-related mouth actions, facilitate the excitability of the motor system involved in the production of the same actions.

## Action observation as action simulation

The mirror neuron system for action is activated both by transitive, object-related and intransitive, communicative actions, regardless of the effectors performing them. When a given action is planned, its expected motor consequences are forecast. This means that when we are going to execute a given action we can also predict its consequences. The action model enables this prediction. Given the shared sub-personal neural mapping between what is acted and what is perceived – constituted by mirror neurons – the action model can also be used to predict the consequences of actions performed by others. Both predictions (of our actions and of others' actions) are instantiations of embodied simulation, that is, modeling processes.

The same functional logic that presides over self-modeling is employed also to model the behavior of others: to perceive an action is equivalent to internally simulating it. This enables the observer to use her/his own resources to experientially penetrate the world of the other by means of a direct, automatic, and unconscious process of simulation.

Embodied simulation automatically establishes a direct experiential link between agent and observer, in that both are mapped in a neutral fashion. The stimuli whose observation activates mirror neurons, like a grasping hand, its predicted outcome, and the sound it produces, all consist of the specific interaction between an agent and a target. It is the agentive relational specification to trigger the mirror neurons' response. The mere observation of an object not acted upon indeed does not evoke any response. Furthermore, the effector-target interaction must be successful. Mirror neurons respond if and only if an agentive relation is practically instantiated by an acting agent, regardless of its being the observer or the observed. The agent parameter must be filled. Which kind of agent is underspecified, but not *unspecified*. Indeed, not all kinds of agents will do. The abovementioned brain imaging experiment on communicative actions shows that only stimuli consistent with or closely related to the observer's behavioral repertoire are effective in activating the mirror neuron system for actions (Buccino et al. 2004).

To summarize, action observation constitutes a form of embodied simulation of action. This, however, is different from the simulation processes occurring during motor imagery. The main difference is what triggers the simulation process: an internal event – a deliberate act of will –in the case of motor imagery, and an external event, in the case of action observation. This difference leads to slightly different and non-overlapping patterns of brain activation (see Gallese 2003a, b). However, both conditions share a common mechanism: the simulation of actions by means of the activation of parietal and premotor cortical networks. I submit that this simulation process also constitutes a basic level of experiential understanding, a level that does not entail the explicit use of any theory or declarative representation.

## Mirroring emotions and sensations

Emotions constitute one of the earliest ways available to the individual to acquire knowledge about its situation, thus enabling to reorganize this knowledge on the basis of the outcome of the relations entertained with others. The coordinated activity of sensory-motor and affective neural systems results in the simplification and automatization of the behavioral responses that living organisms are supposed to produce in order to survive. The integrity of the sensory-motor system indeed appears to be critical for the recognition of emotions displayed by others (see Adolphs 2003; Adolphs et al. 2000), because the sensory-motor system appears to support the reconstruction of what it would feel like to be in a particular emotion, by means of simulation of the related body state.

We recently published an fMRI study showing that experiencing disgust and witnessing the same emotion expressed by the facial mimicry of someone else, both activate the same neural structure – the anterior insula – at the same overlapping location (Wicker et al. 2003). This suggests, at least for the emotion of disgust, that the first- and third-person experiences of a given emotion are underpinned by the activity of a shared neural substrate. When I see the facial expression of someone else, and this perception leads me to experience *that* expression as a particular affective state, I do not accomplish this type of understanding through an argument by analogy. The other's emotion is constituted, experienced and therefore directly understood by means of an embodied simulation producing a shared body state. It is the activation of a neural mechanism shared by the observer and the observed to enable direct experiential understanding. A similar simulation-based mechanism has been proposed by Goldman and Sripada (2004) as "unmediated resonance".

Let us focus now on somatic sensations as the target of our social perception. As repeatedly emphasized by phenomenology, touch has a privileged status in making possible the social attribution of lived personhood to others. "Let's be in touch" is a common clause in everyday language, which metaphorically describes the wish of being related, being in contact with someone else. Such examples show how the tactile dimension be intimately related to the interpersonal dimension.

New empirical evidence suggests that the first-person experience of being touched on one's body activates the same neural networks activated by observing the body of someone else being touched (Keysers et al. 2004). Within SII-PV, a multimodal cortical region, there is a localized neural network similarly activated by the self-experienced sensation of being touched, and the perception of an external tactile relation. This double pattern of activation of the same brain region suggests that our capacity to experience and directly understand the tactile experience of others could be mediated by embodied simulation, that is, by the externally triggered activation of *some* of the same neural networks presiding over our own tactile sensations. A similar mechanism likely underpins our experience of the painful sensations of others (see Hutchison et al. 1999; Singer et al. 2004)

## The varieties of simulation

The notion of simulation is employed in many different domains, often with different, not necessarily overlapping meanings. Simulation is a functional process that possesses a certain representational content, typically focusing on possible states of its target object. For example, in motor control theory simulation is characterized as the mechanism employed by forward models to predict the sensory consequences of impending actions. According to this view, the predicted consequences are the simulated ones.

In philosophy of mind, on the other hand, the notion of simulation has been used by the proponents of Simulation Theory of mind reading to characterize the pretend state adopted by the attributer in order to understand others' behavior (see Gordon 1986, 1995, 2000, 2004; Goldman 1989, 1992a, b, 1993a, b, 2000, 2004; Gallese and Goldman 1998; Goldman and Gallese 2000).

I employ the term “embodied simulation” as an automatic[2], unconscious, and pre-reflexive functional mechanism, whose function is the modeling of objects, agents, and events. Simulation, as conceived of in the present paper, is therefore not necessarily the result of a willed and conscious cognitive effort, aimed at interpreting the intentions hidden in the overt behavior of others, but rather a basic functional mechanism of our brain. However, because it also generates representational content, this functional mechanism seems to play a major role in our epistemic approach to the world. It represents the outcome of possible actions, emotions, or sensations one could take or experience, and serves to attribute this outcome to another organism as a real goal-state it is trying to bring about, or as a real emotion or sensation it is experiencing.

Successful perception requires the capacity of predicting upcoming sensory events. Similarly, successful action requires the capacity of predicting the expected consequences of action. As suggested by an impressive and coherent amount of neuroscientific data (for a review, see Gallese 2003a; Gallese and Lakoff 2005), both types of predictions seem to depend on the results of unconscious and automatically driven neural states, functionally describable as simulation processes.

To which extent embodied simulation is a motor phenomenon? According to the use I make of this notion, embodied simulation *is not conceived of as being exclusively confined to the domain of motor control*, but rather as a more general and basic endowment of our brain. It applies not only to actions or emotions, where the motor or viscero-motor components may predominate, but also to sensations like vision and touch. It is mental because it has content. It is embodied not only because it is neurally realized, but also because it uses a pre-existing body-model in the brain realized by the sensory-motor system, and therefore involves a non-propositional form of self-representation.

## Conclusions

We have discovered some of the neural mechanisms mediating between the multi level experiential knowledge we hold of our lived body, and the *implicit certainties* we simultaneously hold about others. Such body-related experiential knowledge enables us to directly understand some of the actions performed by others, and to decode the emotions and sensations they experience. Our seemingly effortless capacity to conceive of the acting bodies inhabiting our social world as *goal-oriented persons* like us depends on the constitution of a “we-centric” shared meaningful interpersonal space. I propose that this shared manifold space (see Gallese 2001, 2003a, b, 2004) can be characterized at the functional level as embodied simulation, a specific mechanism, likely constituting a basic functional feature by means of which our brain/body system models its interactions with the world.

The mirror neuron matching systems and the other non-motor mirroring neural clusters represent *one particular* sub-personal instantiation of embodied simulation. With this mechanism 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 would be doing a similar action or experiencing a similar emotion or sensation. This proposal also opens new interesting perspectives for the study of the neural underpinnings of psychopathological states and psychotherapeutic relations (see Gallese and Migone, in preparation), and of aesthetic experiences (see http://plaisir.berkeley.edu/).

In contrast with what argued by Jacob and Jeannerod (2004, forthcoming), social cognition is not *only* explicitly reasoning about the contents of someone else's mind. Our brains, and those of other primates, appear to have developed a basic functional mechanism, embodied simulation, which gives us an experiential insight of other minds. The shareability of the phenomenal content of the intentional relations of others, by means of the shared neural underpinnings, produces intentional attunement. Intentional attunement, in turn, by collapsing the others' intentions into the observer's ones, produces the peculiar quality of familiarity we entertain with other individuals. This is what "being empathic" is about. By means of a shared neural state realized in two different bodies that nevertheless obey to the same morpho-functional rules, the "objectual other" becomes "another self".

This of course doesn't account for all of our social cognitive skills. Our most sophisticated mind reading abilities likely require the activation of large regions of our brain, certainly larger than a putative – and neo-frenologic – domain-specific Theory of Mind Module. As correctly pointed out by Jacob and Jeannerod (2004, forthcoming), the same actions performed by others in different contexts can lead the observer to radically different interpretations. Thus, social stimuli are also understood on the basis of the explicit cognitive elaboration of their contextual aspects and of previous information.

The point is that these two mechanisms are not mutually exclusive. Embodied simulation is experience-based, while the second mechanism is a cognitive description of an external state of affairs. Embodied simulation scaffolds the propositional, more cognitively sophisticated mind reading abilities. When the former mechanism is not present or malfunctioning, as perhaps in autism (see Gallese 2005b; Gallese and Migone in preparation), the latter one can provide only a pale, detached account of the social experiences of others. It is an empirical issue to determine how much of social cognition, language included, can be explained by embodied simulation and its neural underpinnings.

[1] This short paper is exclusively focused on the relationships between the mirror neuron system, embodied simulation and the experiential aspects of social cognition. A longer and more elaborate version will appear soon in Phenomenology and the Cognitive Sciences (Gallese 2005a). For sake of concision, many other issues related to mirror neurons and simulation will not be addressed here. The vast literature on the mirror neuron system in humans and its relevance for theory of mind, imitation and the evolution of language is reviewed and discussed in several papers (Gallese and Goldman 1998; Rizzolatti and Arbib 1998; Rizzolatti et al. 2001; Gallese 2003a; Metzinger and Gallese 2003; Rizzolatti and Craighero 2004; Gallese et al. 2004; Arbib 2004). For an analysis of the role played by embodied simulation in conceptual structure and content, see Gallese and Lakoff 2005.

[2] It is “automatic” in the sense that it is obligatory.

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