# A Philosopher's Reflections on the Discovery of Mirror Neurons

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## Abstract

Mirror neurons fire both when a primate executes a transitive action directed towards a target (e.g., grasping) and when he observes the same action performed by another. According to the prevalent interpretation, action-mirroring is a process of inter-personal neural similarity whereby an observer maps the agent's perceived movements onto her own motor repertoire. Furthermore, ever as Gallese and Goldman's (1998) influential paper, action-mirroring has been linked to third-person mindreading on the grounds that it enables an observer to represent the agent's intention. In this paper, I criticize the prevalent interpretation on two grounds. (a) Action-mirroring could not result in inter-personal neural similarity unless there was a single mechanism active at different times in a single brain during the execution and the perception of acts of grasping. (b) Such a neural mechanism is better conceived as underlying the possession of the concept of *grasping* than as a basis for mindreading.

*Keywords:* Action-mirroring; Understanding goal-directed action; Tuning-fork model of social cognition; Third-person mindreading; Simulation; Embodied cognition

## 1. Introduction

I am a philosopher of mind. In the early 1990s I was primarily addressing metaphysical issues in the philosophy of mind raised by Brentano's definition of intentionality a century earlier. My questions were: can intentionality be naturalized? Could the puzzling features of intentionality be accounted for by using concepts that would be distinctly recognizable by natural scientists? Is the content of an agent's psychological state causally efficacious in the execution of some of her actions? If so, how?[1] Fifteen

years later, my philosophical work is focusing on the significance of experimental results from cognitive neuroscience for our scientific understanding of the human mind and human cognitive processes. One question which is currently of special interest to me is: what is the significance of the cognitive neuroscientific discovery of so-called ''mirror neurons'' for human social cognition in general, and for the human capacity to perform tasks of third-person mindreading in particular?

How did I change my focus from metaphysical questions in the philosophy of mind to the conceptual analysis of experimental results from cognitive neuroscience? From 1995 to 2001, a shift occurred in my professional life when I became a member of a small interdisciplinary group whose task was to prepare the creation of the new CNRS Institute of Cognitive Science located in the Lyon area in France. The Institute was formally born in early 1998, when roughly fifty cognitive scientists moved into a brand new building in the neighborhood of the Psychiatric and the Neurological Hospitals in Bron (near Lyon). Its director was the French cognitive neuroscientist Marc Jeannerod, a well-known figure in the cognitive neuroscience of vision and action. At the beginning of 2001, I left the Lyon Institute of Cognitive Science to become the director of the Institut Jean Nicod in Paris, a newly created interdisciplinary CNRS research unit at the interface between philosophy, the cognitive and the social sciences.

For several years, Marc Jeannerod and I have been involved in collaborative work including the publication of several papers and a book, most of which devoted to an interdisciplinary assessment of the empirical evidence for, and the conceptual significance of, the so-called ''two-visual systems model'' of human vision.[2] This model arose from the discovery that the primate visual system is anatomically divided into two distinct pathways with distinct functions: the so-called ''ventral'' pathway (which projects primary visual areas onto the infero-temporal cortex) and the so-called ''dorsal'' pathway (which projects primary visual areas onto the superior parietal cortex).[3]

As I see it, our interdisciplinary collaboration in the book had two major tasks. One was the conceptual clarification of the full implications of the fact that the evidence for the two-visual systems model is not consistent with the common sense assumption accepted by much philosophy of mind and perception that human vision is a unitary psychological activity, whose purpose is to enable humans to build a unified conscious picture of the visible features of the world. The other task was the conceptual clarification of the various dimensions of the distinction between visual *percepts* and *visuomotor* representations—a distinction required by a proper formulation of the two-visual systems model itself. On our version, whereas the ventral pathway underlies what Jeannerod (1994, 1997) earlier called the *semantic* processing of visual information, the dorsal pathway underlies what Jeannerod (1994, 1997) earlier called the *pragmatic* processing of visual information.[4] Whereas the semantic processing of visual information is at the service of an individual's ''belief-box,'' the pragmatic processing of visual information is at the service of an individual's system of intentions.[5]

In chapter seven of our 2003 book, Jeannerod and I moved from the evidence for a dual model of the visual processing of objects to the evidence for a potential duality of visual processing involved when humans see other humans act. In particular, we examined the

evidence for a putative dissociation between a so-called ''mirror-neuron system,'' involving areas in the human brain (such as the premotor cortex and the inferior frontal gyrus) believed to contain mirror neurons, and a so-called ''social perception system'' involving the Superior Temporal Sulcus (STS), the amygdala and the orbito-frontal cortex. In a nut-shell, we argued that the distinction between the social perception system and the mirror-neuron system reflects the distinction between human actions that are, and human actions that are not, directed towards a conspecific.[6]

In the present paper, I wish to examine a view which, borrowing a term from Saxe (2005), I will label the *tuning-fork* model of human social cognition, which gives a central role to so-called ''processes of mirroring'' and to the activity of mirror neurons. On this model, human social cognition is a tuning-fork: it vibrates (or resonates) by directly picking up the vibrations emitted by a conspecific. (I could also have called this model the *reso-nance* model of human social cognition.) In accordance with one or another version of the so-called ''embodied cognition'' paradigm and the earlier rejection by the Phenomenologi-cal tradition of both cognitivism and representationalism, it stands in sharp contrast with ''disembodied'' computational approaches to the mind according to which cognitive pro-cesses perform operations on mental representations that could be performed by a Turing machine. Recent advocates of embodied cognition seem disposed to ground their rejection of the computational and representational paradigm for cognitive science in the Phenome-nologists' critique of intellectualism, which itself predates the cognitive revolution of the 1950s.[7]

In accordance with so-called ''simulation'' approaches to tasks of third-person mindread-ing, the tuning-fork model of social cognition emphasizes the role of psychological and neu-ral *inter-personal similarity* in achieving tasks of third-person mindreading. As I see it, this model involves the five following assumptions:

1. Mirroring is a process of inter-personal mimicry (resonance or duplication) that creates a neural and psychological similarity across two distinct individuals.
2. Instances of mirroring are or constitute instances of third-person mindreading.
3. Mirroring processes are of two kinds (a) motoric mirroring (or action-mirroring) and (b) nonmotoric mirroring (or affective mirroring).
4. Mindreading an agent's prior intention can be achieved by processes of action-mirror-ing (or motoric mirroring).
5. Mindreading an agent's affective state (pain or emotion) can be achieved by processes of nonmotoric mirroring.

In the following, I accept what I take to be the classical view (held by philosophers as well as psychologists) that tasks of human mindreading are tasks whereby a human individ-ual attributes (or ascribes) a psychological state to another or to him- or herself. A task of third-person mindreading consists in forming a belief (or judgment) about (or in metarepre-senting) another's psychological state. A task of first-person mindreading consists in form-ing a belief about (or in metarepresenting) a psychological state of one's own. Accordingly, I assume that a necessary condition for achieving a task of either third- or first-person

mindreading is that the mindreader possesses and applies to the task the *concept* of the relevant psychological state (e.g., intention, belief, desire and so on).

In this paper, I will consider only tasks of third-person mindreading; I will concentrate on action-mirroring at the expense of other putative forms of mirroring, and only assumptions (1), (2) and (4) of the tuning-fork model of social cognition will be relevant. In section 2, I will argue that the resonance model of action-mirroring embodied by assumption (1) is not fully compatible with the empirical evidence. In section 3, I will argue that the classical view of mindreading is not consistent with assumptions (1), (2) and (4). In section 4, I will examine various options open to advocates of the tuning-fork model of social cognition and suggest an alternative interpretation of action-mirroring and the significance of the discovery of mirror neurons (MNs). As it turns out, I did not merely change my focus from metaphysical questions in the philosophy of mind to the conceptual analysis of experimental results from cognitive neuroscience. I also moved up the ladder from the metaphysical puzzles raised by first-order intentionality to the exploration of the cognitive mechanisms underlying human mindreading, that is, higher-order intentionality.

## 2. What is action-mirroring?

Mirror neurons were first recorded in area F5 of the ventral premotor cortex of macaque monkeys by a team of Italian cognitive neuroscientists from the university of Parma led by Giacomo Rizzolatti in the early 1990s.[8] MNs are sensorimotor neurons that fire both when an agent performs a transitive action directed towards a physical target (e.g., grasping a peanut) and also when the animal observes another agent perform the same kind of transitive action. MNs are so-called on the grounds that their activity in an observer's brain seems to *mirror* (reflect, match or duplicate) MN activity in the agent's brain. As they were first discovered in the ventral premotor cortex of nonhuman primates by single-cell recording, MNs were also recorded in the inferior parietal lobule of monkeys.

The discovery of MNs first in ventral premotor cortex and later in the inferior parietal lobule of monkeys came as a surprise in light of earlier results of single-cell recording in a relevantly neighboring area of the monkey brain, namely the Superior Temporal Sulcus (STS) by a group of cognitive neuroscientists from the university of Edinburgh led by David Perrett.[9] In the monkey brain, the STS is reciprocally connected to the inferior parietal lobule, which is in turn reciprocally connected to the ventral premotor cortex (cf. Keysers & Perrett, 2004). Cells in the monkey STS respond to the perception of a much broader class of performed actions than MNs, including actions with a clear social significance (such as eye- and head-movements, some of which are signs of an agent's attention, and others of social submission and/or dominance). But, unlike MNs (recorded in either the ventral premotor cortex or the inferior parietal lobule), cells in the STS have only perceptual properties, no motor properties: they fire only when the recorded animal observes another's action, not when it executes an action. Unlike MNs, they are not sensorimotor neurons.

Subsequent application of Transcranial Magnetic Stimulation and brain imaging experiments in humans have been widely reported in support of the existence of a so-called

''mirror-neuron system'' in the human brain that responds to the execution and the perception of a broader range of actions, including both transitive actions (as in the monkey brain), but also intransitive actions (not directed towards a physical target).[10] In addition, more recently, brain-imaging experiments involving different brain areas in humans (e.g., the insula and the amygdala) have been reported suggesting the additional existence of so-called ''mirroring processes,'' not just for the execution and the perception of overt motor acts, but also for the first-personal experience of *affective* states (e.g., pain and emotions such as disgust) and the third-personal recognition of others' affective states. But the evidence for nonmotoric mirroring is not relevant to the present paper, in which I restrict myself to motoric mirroring (or action-mirroring).

The prevailing view of action-mirroring has emphasized the congruency between the motor and the perceptual properties of MNs (and the mirror-neuron system activity). In other words, it emphasizes the fact that MN activity is at work in both action execution and action observation. Assuming that the ability to execute a transitive action (of e.g., grasping) directed towards a physical target (e.g., food) is necessary to the survival of primates, it seems as if no mechanism for understanding an observed transitive action performed by another could be more basic (or more primitive) than the very mechanism that would enable the observer (were the observer the agent) to execute the action in question. Thus, this emphasis on the congruency between the motor and the perceptual properties of MNs in the monkey ventral premotor cortex raises the intriguing prospect that a fairly elementary mechanism in the motor cognition of primates might constitute an instance of mental simulation, that is, a process of motor simulation, whereby the observer mentally rehearses (without executing) the agent's observed movements.

As Rizzolatti, Fogassi, and Gallese (2001) have stressed, depending on an observer's motor resources (or repertoire), there are perceived actions that can be mapped onto the observer's motor repertoire and there are perceived actions that cannot be so mapped. Brain-imaging studies conducted by Buccino et al. (2004) have revealed greater activations of motor (and premotor) areas when human observers see without hearing a video-clip displaying a human being produce silent speech (or even a monkey produce silent lip-smacking) than when they see a video-clip displaying a dog bark. In another brain-imaging study by Calvo-Merino, Glaser, Grezes, Passingham, and Haggard (2005), capoeira and ballet dancers saw short films displaying dance steps by either capoeira dancers or classical dancers. They found enhanced activations in the mirror-neuron system of dancers observing movements belonging to their own dancing repertoire. So perceptual responses to an agent's observed movements seem to reflect the observer's motor expertise and motor familiarity with the executed movements.

On this basis, Rizzolatti et al. (2001: 666) and Rizzolatti and Craighero (2004: 179) have drawn a contrast between two ways an action might be understood (or recognized): either through a purely visual (or perceptual) analysis of the agent's bodily movements or by mapping the agent's perceived movements onto the observer's motor repertoire. If and when an observer cannot map a perceived action onto his own motor repertoire, then, according to Rizzolatti et al. (2001), the observer's understanding of the perceived action cannot be grounded in ''motor resonance.'' As a result, there is something about the perceived action

that the observer fails to understand: the action can only be categorized on the basis of its visual properties.[11] For example, as a primate cannot map a bird's wing movements onto its own motor repertoire, it can only categorize a bird's flight through a visual analysis.

Now, there is a weaker and a stronger version of the dual pathway thesis for action understanding. The weaker version is just the claim that perceived actions can be understood in two different ways. The stronger version, which deserves to be called the ''direct-matching model of action-understanding,'' is the further claim, endorsed by Rizzolatti et al. (2001: 662), that ''the results of the visual analysis of an observed action […] are devoid of meaning […]'' and that motor involvement provides a distinctive kind of action understanding, which a purely visual analysis is unable to secure: ''the main weakness of the visual hypothesis is that it does not indicate how the ''validation'' of the meaning of the observed action is achieved'' (*Ibid*: 666).[12]

Clearly, the direct-matching model of action-understanding is a version of a simulation-based model of action-understanding. Action-mirroring is described as a process of motor simulation (or motor resonance) whereby the observer's perception of the agent's act causes him or her to internally rehearse the agent's observed movements without executing them. By enabling the observer to map the agent's observed movements onto his or her own motor repertoire, motor mirroring is supposed to constitute a basic neural similarity between the agent and the observer whereby both entertain a *shared* motor representation of the action executed by the agent (insert Fig. 1 around here.) This neural similarity (or shared motor representation) is supposed to supply the observer with a special understanding of the meaning of the executed action (i.e., a representation of the goal of the action), which a purely visual analysis is allegedly unable to provide.

Interestingly, the direct-matching model of action-understanding is frequently advertised by its cognitive neuroscientific advocates under the authority of the following quote from the French phenomenologist Merleau-Ponty (1945: 225):[13]

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
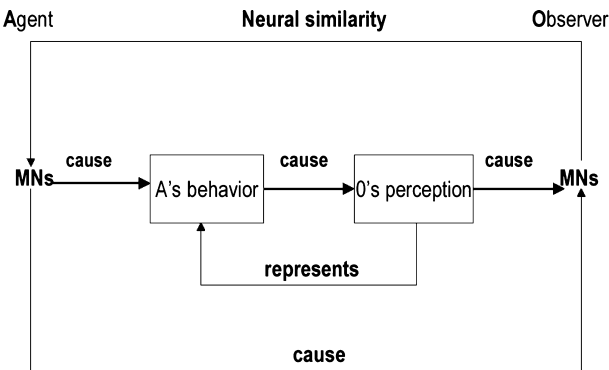


Fig. 1. Action-mirroring.

with a cognitive operation. The communication or comprehension of gestures comes 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.

An ingenious experiment reported by Umiltà et al. (2001) is supposed to further corroborate the direct-matching model of action-understanding. In this experiment, Umiltà et al. (2001) recorded a single MN in area F5 of the monkey premotor cortex that fired when an observer saw an agent reach and grasp a target even when the target and the end of the agent's arm movement were hidden behind an occluder, but the monkey knew that there was a target behind the occluder because he had seen it prior to observing the agent's partly occluded act. On the other hand, the same MN failed to discharge when the observer saw the agent perform the same arm and hand movement, but there was no target and the observer knew it. Rizzolatti et al. (2001), Rizzolatti and Craighero (2004) and Rizzolatti and Sinigaglia (2008) argue that this finding is evidence for the direct-matching model of action understanding: in accordance with the quote from Merleau-Ponty, they take it that only by enabling the observer to map the agent's observed action onto the observer's motor repertoire can MN activity in the observer's brain generate understanding of the ''meaning'' (i.e., goal) of the observed action. As a mere pantomime of a reach-to-grasp action not directed towards a physical target lacks meaning in a nonhuman primate's mind, MNs don't fire when the animal perceives such a meaningless act.

However, two related questions jointly arise. The first question is: what is the evidence in favor of the stronger version of the dual pathway thesis of action-understanding, against the weaker version of this thesis? On the stronger version, only by mapping the agent's observed movements onto his or her own motor repertoire can the observer properly understand what Rizzolatti et al. (2001), Rizzolatti and Craighero (2004) and Rizzolatti and Sinigaglia (2008) call *the meaning* of the agent's act.[14] On the weaker version, there are at least two ways an observer can understand an agent's act: by motor resonance or by a purely visual (or perceptual) analysis. Ever since Jeannerod introduced me to the evidence in favor of the two-visual systems model of human vision, I have been fascinated by the empirical discovery of the existence of dual pathways in the brains of human or nonhuman animals that seem to underlie two separate and dissociable responses to one and the same stimulus. With respect to understanding what action-*understanding* consists in, I confess to being a contextualist and, as I am about to argue by considering the second related question, I think that the evidence does not obviously favor the stronger version of the dual pathway over the weaker version.

Furthermore, in developmental psychology, there is a lively empirical debate between two views about how human infants come to understand others' goal-directed actions during ontogeny. On the one hand, there is evidence that human infants develop understanding of others' goal-directed actions through their own performance of similar actions. For example, Sommerville, Woodward, and Needham (2005) report evidence that 3-month olds, whose accuracy in the execution of actions of grasping and reaching is enhanced by means of a Velcro glove, are better able to understand similar actions performed by others than 3-month

olds who are not allowed to use a Velcro glove. On the other hand, there is evidence that infants interpret a perceived action as goal-directed when they recognize it as an efficient means to achieve an end (cf. Csibra, Biró, Koós, & Gergely, 2003; Gergely & Csibra, 2003; Gergely, Nadasdy, Csibra, & Biro, 1995; Southgate, Johnson, & Csibra, 2008). On the face of it, the very existence of this empirical debate over the ontogeny of the human ability to understand goal-directed actions lends support to the weaker version of the dual pathway thesis of action-understanding over the stronger version.[15]

The second related question is: Does MN activity in the observer's brain *generate* understanding of the meaning (or goal) of the observed action? Or instead does it *reflect* a prior understanding of the meaning (or goal) of the observed action? As Csibra (2007) has argued, there are two conspiring empirical problems for the direct-matching model (or the stronger version of the dual pathway thesis) of action-understanding. First of all, the experimental result reported by Umiltà et al. (2001) is consistent with the possibility that MN activity in the ventral premotor cortex of an observer of another's transitive action *results* from a prior representation (if any) of the agent's goal that derives from the observer's knowledge of the presence of a hidden target. On this alternative interpretation, the lack of MN activity when the observer watches a pantomime of an act of reaching-to-grasp and knows that a physical target is missing (whether the act is partially occluded or not) simply shows that in the known absence of a physical target, the observer fails to assign any representable goal to the agent of the observed act. Until this alternative interpretation of the experimental result reported by Umiltà et al. (2001) is ruled out, the direct-matching model (or the stronger version of the dual pathway thesis) of action-understanding lacks a crucial piece of evidence.

The second empirical problem is that there is neurophysiological, behavioral and brain imaging evidence showing MN activity during observation of *nonexecutable* actions. Ferrari, Rozzi, and Fogassi (2005) report a series of experiments in which they recorded MNs in area F5 of the ventral premotor cortex of monkeys after they had been exposed for a period of two months to the visual observation of human transitive actions made with tools such as picking up pieces of food with sticks and grasping them with pliers. They found MNs that fire both when the monkey executes some transitive hand and mouth actions and when the monkey observes actions performed by a human with a tool, which the monkey could *not* use. For example, they recorded one neuron that fires when the monkey grasps a small piece of food and when the monkey sees a human pick up a small piece of food with a stick, but not when the human mimes the action with the stick in the absence of food. They recorded another neuron that fires when the monkey grasps a piece of food with his hand and holds it. The same neuron also fires when the monkey sees a human agent grasp and hold the piece of food with a pair of pliers and when he sees the human pick up the piece of food and hold it with a stick. The response of this neuron is weaker when the monkey sees the experimenter grasp the piece of food and hold it with his hand. These are clear instances of MNs that are active when the monkey sees actions that he cannot execute himself. So strictly speaking, these are MNs that fire even though the monkey is unable to map the perceived action onto his motor repertoire. This shows that the fact that an act belongs to one's motor or behavioral repertoire is not a necessary condition for action-mirroring.

Furthermore, Wood, Glynn, Philips, and Hauser (2007) and Wood, Glynn, and Hauser (2007) report behavioral evidence in nonhuman primates showing some (behavioral) under-standing of human actions, for example, throwing, that nonhuman primates cannot perform (cf. Wood & Hauser, 2008). Schubotz and Van Cramon (2004) report brain-imaging evidence in humans showing activations in the human ventral premotor cortex for observation of static arrays of geometrical objects when subjects were requested to extract regularity of patterns. Costantini et al. (2005) report equally strong activation of the human ventral premotor cortex for the observation of bio-mechanically possible *and* impossible movements. Finally, Romani, Cesari, Urgesi, Facchini, and Aglioti (2005) report motor facilitation effects during the observation of bio-mechanically *impossible* finger movements.

Taken together, this evidence is hard to square, not only with the strong thesis that MN activity generates a representation of the goal (and meaning) of an observed action, but also with the view that MN activity consists in mapping an agent's observed movements onto the observer's own motor repertoire. I now turn to the direct examination of assumptions (2) and (4) of the tuning-fork model according to which third-person mindreading can be constituted by action-mirroring by virtue of the fact that the former alone could enable an observer to represent an agent's intention.

## 3. Why can't mindreading an agent's intention be constituted by action-mirroring

In 1998, Vittorio Gallese (one of the co-discoverers of MNs) and Alvin Goldman (one of the early philosophical advocates of the simulation-based approach to tasks of third-person mindreading) published an influential paper, which was the first to explicitly consider a possible link between action-mirroring and the simulation-based approach to third-person mindreading. In that paper, Gallese and Goldman (1998: 495) ''explored [the] possibility […] that MNs underlie the process of ''mindreading,'' or serve as precursors to such a process […] and that] MNs are part of […] the folk psychologizing mechanism.'' They further conjectured that ''MNs represent a primitive version, or possibly a precursor in phylogeny, of a simulation heuristic that might underlie mindreading'' (*Ibid*: 498). More specifically, Gallese and Goldman (1998: 497) hypothesized that the ''external'' (or exogenous) activation of MNs might enable an observer to *retrodict* the agent's mental (or psychological) state (i.e., his *intention*) ''by moving backwards from the observed action.'' On this view, exogenously caused MN activity would presumably take as input the perception of the agent's movements and retrodictively compute a representation of the agent's intention, that is, the psychological cause of the agent's movements.[16] Now, as Goldman (2008, in press) has recently pointed out, there are at least two different ways that action-mirroring could contribute to third-person mindreading: instances of the former could either *constitute* or *cause* instances of the latter.

According to assumption (2) of the *tuning-fork* model of human social cognition, instances of action-mirroring are (or constitute) instances of third-person mindreading. A particular instantiation of assumption (2) is embodied by assumption (4) according to which mindreading an agent's prior intention can be achieved by action-mirroring. A couple

of remarkable experiments using single-cell recording in the monkey and brain-imaging in humans have been respectively designed by Fogassi et al. (2005) and by Iacoboni et al. (2005) to support assumption (4).

In an experiment in which a single motor act of grasping was embedded into one of two more complex actions, Fogassi et al. (2005) recorded MNs in the monkey inferior parietal lobule in both executive and perceptual tasks. After training, the monkey had learned to grasp either food or some nonedible target for the purpose of either eating the food or placing either the food or the nonedible target into a container that could be located near either the target or the monkey's mouth.[17] In the perceptual task, Fogassi et al. (2005) found that different MNs in the monkey inferior parietal lobule fire in response to the perception of a single act of grasping according to whether it is embedded within two distinct more complex actions, one of which was eating and the other was placing the food into a container.

In order to accommodate their results, they introduced a novel model of *chains of logically related MNs* with the basic property that the MNs in an observer's brain that fire in response to the perception of an act of grasping would *not* govern the execution of the same act of grasping (were the observer the agent), but instead of a different act of either bringing to the mouth or locating into a container. This model of chains of logically related MNs, which suggests that the function of MN activity in an observer's brain is *prediction* of the agent's next motor act, constitutes a sharp departure from the earlier *resonance* (or direct-matching) model of action-mirroring. On the direct-matching model, MN activity in an observer's brain *mimics* MN activity in the agent's brain. But on the novel model of chains of logically related MNs, MN activity in the observer's brain *anticipates* the agent's next most likely act.

Fogassi et al. (2005) went on to claim that MN activity in an observer's brain ''not only codes the motor act but also allows the observer to understand the agent's intentions'' (*Ibid*: 662). Arguably, it is controversial whether monkeys do represent and attribute intentions to conspecifics.[18] But Iacoboni et al. (2005) did conduct a brain-imaging study in humans with the same design as the single-cell recording study conducted by Fogassi et al. (2005) in monkeys. They showed healthy human adults a single motor act embedded into one or the other of two more complex actions by means of pairs of films divided into three conditions. In the Context condition, subjects saw objects (a tea-pot, a mug, cookies, etc.) arranged as if either before tea (the ''drinking'' Context) or after tea (the ''cleaning'' Context), but they saw no action. In the Action condition, subjects saw a human hand grasp a mug using either a precision grip or a whole-hand prehension, with no contextual elements present. In the Action condition, subjects saw either one or the other of the two acts of prehension embedded in either the drinking Context (Intention to drink condition) or the cleaning Context (Intention to clean condition). In other words, in perceiving one or the other of the single acts constitutive of the Action condition embedded into two different Contexts in the Intention condition, the observer could represent it as part of two distinct complex actions. The perception of the Context condition cannot trigger MN activity as in this condition, there are affordances (i.e., opportunities for action), but there is no action to be seen.[19] Viewing the Intention condition led to a significantly stronger activation in the right inferior frontal areas

(believed to be rich in MNs) than viewing the Action condition (which in turn was stronger than viewing the Context condition without any action).

Iacoboni et al. (2005: 529) take their experiment to demonstrate that ''premotor mirror neuron areas—areas active during the execution and the observation of an action—previously thought to be involved only in action recognition are actually also involved in understanding the intentions of others,'' which (on the view that the agent's relevant intention is the agent's *prior* intention to either drink or clean, not just the *motor* intention to grasp a mug), is equivalent to assumption (4) of the tuning-fork model. If so, then, in accordance with assumption (2), the human mirror neuron system could be said to perform tasks of third-person mindreading.

The experimental results reported by Iacoboni et al. (2005) raise at least two problems, the first of which is parallel to the problem raised by the result reported by Umiltà et al. (2001) and Fogassi et al. (2005), namely Csibra's (2007) problem of whether these experimental results show that MN activity in the observer's brain *generates* a representation of the agent's goal or prior intention. The alternative interpretation is that MN activity in the observer's brain *results from* an independent representation of the agent's goal or prior intention, which is based on the perceptual processing of contextual cues. If we apply the predictive model of chains of logically related MNs to the experimental design of Iacoboni et al.'s (2005) brain-imaging study, the chain leading to the prediction that the agent will either drink from the mug or clean the mug must be selected by processing contextual cues.

Secondly, given the tension between the resonance or direct-matching model of action-mirroring and the new model of chains of logically related MNs, the question whether action-mirroring could *constitute* third-person mindreading should be examined separately for each model. In fact, both the Fogassi et al. (2005) study and the Iacoboni et al. (2005) study leave it open whether they advocate the replacement of the simulation-based direct-matching model of action-mirroring by the new predictive model of chains of logically related MNs or the coexistence of the two models.[20]

Let us first consider the direct-matching model of action-mirroring. On this model, as a result of action-mirroring exogenously triggered by the perception of a motor act of grasping a mug, an observer could at best *form* the intention to grasp a mug without executing the act. Clearly, to form the intention to grasp a mug (without executing the act) is not the same psychological state as *believing* of an agent (distinct from self) that she intends to grasp a mug. Given the classical definition of mindreading (from the Introduction), only the latter, not the former, constitutes an instance of third-person mindreading. Furthermore, whereas one can *form* the intention to grasp a mug and lack the concept *intention* (something that, on the resonance model, action-mirroring enables an observer to do when he or she perceives another perform an action), one cannot *believe* that another intends to grasp a mug (and thus ascribe to him the intention) unless one possesses the concept *intention*. If so, then on the direct-matching or resonance model, action-mirroring falls short of third-person mindreading.

Now consider the new model of chains of logically related MNs. Fogassi et al. (2005: 666) write that chains of logically related MNs ''allow the monkey to predict what is the goal of the observed action and, thus, to ''read'' the intention of the acting individual.'' Similarly, according to Iacoboni et al. (2005: 535), ''to ascribe an intention is to infer a

forthcoming new goal, and this is an operation that the motor system does automatically.'' However, as Goldman (in press, pp. 4–5 of manuscript) insightfully notices, the notion of a *goal* is equivocal: it may refer to a physical *target* (e.g., a mug), to an *act* to be performed on a physical target (e.g., the agent's bringing the mug to his mouth) or to an agent's *intention* (e.g., the agent's motor intention to grasp a mug or his prior intention to drink). Now, unlike both the target and the agent's act, only either the agent's motor intention to grasp a mug or his prior intention to drink counts as a genuine mental representation (of a possible, nonactual state of affairs): either one of these is a psychological cause of the agent's perceived act of grasping the mug.[21]

On the model of chains of logically related MNs, the selection of a chain must depend on contextual information. So the perception of an act of grasping a mug triggers the *prediction* of the next most likely motor act, given contextual cues (e.g., the agent's bringing the mug to his mouth). On this model, action-mirroring takes as input a perceived act of grasping and the output it delivers is a motor representation of another *act* (the agent's bringing the mug to his mouth). On this model, action-mirroring could not deliver a representation of the agent's prior intention to drink, because action-mirroring is supposed to be a *predictive* device. Given that the agent's prior intention to drink is the *cause* of the agent's perceived act, action-mirroring could not *predict* the cause of the agent's perceived act from the perception of the act (i.e., the effect of the intention). It could only retrodict the agent's prior intention to drink from the perception of the act; what it can *predict* is the agent's next most likely *act*.[22] Thus, on the model of chains of logically related MNs, contrary to assumption (4) of the tuning fork model of human social cognition, mindreading an agent's prior intention could not be achieved by action-mirroring alone. Nor could instances of action-mirroring *constitute* instances of third-person mindreading, in accordance with assumption (2) of the tuning-fork model. At least, it could not, if one accepts the classical conception of third-person mindreading.

## 4. Three theoretical options

So far, advocates of the existence of a close link between instances of action-mirroring and instances of third-person mindreading have pursued two theoretical options. The former option is to give up the classical view of third-person mindreading. The latter option is to weaken the view that there is a *constitutive* link between action-mirroring and third-person mindreading (as required by assumptions [2] and [4] of the tuning-fork model) into a merely *causal* dependency of third-person mindreading upon action-mirroring. I briefly examine them in turn.

### 4.1. First option: rejecting the classical picture of mindreading

So far as I can see, the first option, which consists in rejecting the classical view of third-person mindreading, is explicitly advocated in a provocative paper by three of the leading cognitive neuroscientists, who discovered MNs, in a 2004 paper entitled ''A unifying view

of the basis of social cognition,'' which I take to be a manifesto of the tuning-fork model of human social cognition, and from which I extract a rather long characteristic quote:[23]

[…] the fundamental mechanism at the basis of the experiential understanding of others' actions is the activation of the mirror neuron system. A similar mechanism, but involving viscero-motor centers, underlies the experiential understanding of the emotions of others […] We will posit that, in our brain, there are neural mechanisms (mirror mechanisms) that allow us to directly understand the meaning of the actions and emotions of others by internally replicating (''simulating'') them without any explicit reflective mediation. Conceptual reasoning is not necessary for this understanding […] the fundamental mechanism that allows us a direct experiential grasp of the mind of others is not conceptual reasoning but direct simulation of the observed events through the mirror mechanism. The novelty of our approach consists in providing for the first time a neurophysiological account of the experiential dimension of both action and emotion understanding […] There is something shared between our first- and third-person experience of these phenomena [i.e., actions and emotions]: the observer and the observed are both individuals endowed with a similar brain-body system. A crucial element of social cognition is the brain's capacity to directly link the first- and third-person experiences of these phenomena (i.e., link ''I do and I feel'' with ''he does and he feels'').[24]

Leaving aside the claims about the existence of processes of nonmotoric or affective mirroring putatively involved in the recognition of others' affective states (e.g., emotions), this passage epitomizes two features of the tentative picture of mindreading, by which advocates of the tuning-fork model propose to replace the classical picture. On the one hand, their emphasis upon a direct, immediate and nonconceptual grasp of the minds of others is clearly reminiscent of the Phenomenological rejection of a cognitivist and representationalist framework exemplified by the earlier quote from Merleau-Ponty.[25] On the other hand, they endorse a view that in many of his writings, Gallese (2001, 2003) calls ''embodied simulation,'' and which stresses the role and format of shared motor representations of actions in understanding others.

However, like other versions of *embodied cognition*, Gallese's notion of *embodied simulation* leaves one question unanswered: is a cognitive process embodied in virtue of the fact that it is supported not just by the agent's brain, but also by the agent's full body? Or instead is it embodied in virtue of the fact that it could not occur unless the agent were able to form mental representations of her own bodily parts?[26] Nor is it entirely clear how one could turn a shared motor representation of another's *action* into a shared motor representation of another's *mind* or *psychological state*. It is one thing to assume that as a result of perceiving an act of grasping a mug executed by another agent, an observer is caused to form a motor intention to grasp (not followed by execution). But it is another thing entirely to claim that the observer's exogenously caused motor intention is itself a representation of the agent's mind. Arguably, in such a case, the agent and the observer of the executed act might be said to share a motor representation of the act. It just seems like a category mistake to confuse the fact that an observer forms an intention whose content is similar to the content of the

agent's intention and the fact that the observer forms the belief or judgment about the agent that he or she has an intention with a given content. On my view, these potential confusions show that the challenge of offering a coherent alternative to the classical view of mindreading is not easy to meet.

## 4.2. Second option: weakening the link between action-mirroring and mindreading

Goldman (2006, 2008, in press), one of the most eloquent advocates of the simulation approach to human mindreading over the past twenty years, agrees that action-mirroring cannot constitute third-person mindreading. He endorses instead the weaker thesis that the latter *causally* depends on the former. As Borg (2007) and Jacob (2008) have noted, unless one subscribed to behaviorism, one would not be tempted to endorse the view that the perception and mental rehearsal of an agent's motor act is a sufficient basis for forming a reliable belief about the agent's prior intention. Although the weaker thesis asserting a causal dependency (not a constitutive link) between third-person mindreading and action-mirroring is immune to this criticism, the weaker thesis faces at least two problems: the problem of the teleological stance and the problem of the gap in the causal link.

### 4.2.1. The teleological stance problem

Violation-of-expectation studies by Gergely et al. (1995), Csibra et al. (2003) and Gergely and Csibra (2003) have demonstrated that human infants as young as 12-month old both automatically interpret others' actions as goal-directed and expect agents to perform the most efficient act given the physical constraints.[27] For example, 12-month olds, who have been habituated to seeing a 2D circle jump over a 2D rectangular obstacle on a computer screen in a parabolic trajectory, are more surprised (i.e., look longer) if they see the circle jump again once the obstacle has been removed rather than if they see the circle move in a straight line (i.e., exemplify a novel trajectory that they have never seen before). According to Gergely and Csibra (2003), these experimental results show that 12-month olds ascribe goals and apply what they call the ''teleological stance'' to others' actions.

Goldman (2006, 2008, in press), who subscribes to a simulation-based approach to third-person mindreading, primarily thinks of action-mirroring as an instance of an exogenous process of motor simulation that automatically creates a neural similarity between an agent and an observer. Goldman (2006) further claims that action-mirroring causally contributes to what he calls ''lower-level'' tasks of third-person mindreading. Tasks of lower-level mindreading are ''comparatively simple, primitive, automatic and largely below the level of consciousness'' (*Ibid*: 113).[28] Now given Gergely and Csibra's (2003) findings, the adoption of the teleological stance by 12-month olds seems to be early evidence of lower-level mindreading activity of goal-ascription.[29]

The problem for Goldman's causal claim is that 12-month olds cannot jump, let alone fly, over obstacles. So the Gergely and Csibra findings strongly suggest that action-mirroring cannot be a *necessary* condition for a 12-month-old human infant to ascribe a goal to an agent. It is true that 12-month-old human infants can move their hands and feet over objects.[30] Perhaps 12-month-old human infants can map the nonbiological parabolic motion

of a geometrical stimulus over an obstacle onto the motor repertoire of their own hand and feet movements. Perhaps they can also map the nonbiological rectilinear motion of the same geometrical stimulus in the absence of any obstacle onto their own ability to produce hand and feet movements with a similar trajectory. Perhaps on the basis of this twofold mapping, they could somehow represent and ascribe goals to moving geometrical stimuli.[31]

However, further experimental data reported by Southgate et al. (2008) are more difficult to reconcile with the view that action-mirroring plays a causal role in low-level mindreading tasks of goal ascription. Using the habituation/dishabituation paradigm, Southgate et al. (2008) divided 6- to 8-month-old infants into an experimental and a control group. Infants in the experimental group were habituated to seeing a two-step goal-directed action whereby a human hand (a) removes an obstructing box and (b) retrieves an object. Infants in the control group were habituated to seeing the same sequence except that the removed box was not obstructing and therefore its removal was unnecessary for retrieving the object. Then infants from both groups saw two test events. In one, they saw a human hand (a) remove an obstructing box and (b) retrieve an object, in a way consistent with biomechanical constraints on arm movements. In the other, they saw an arm snake in between a pair of boxes and around the second box in violation of biomechanical constraints on arm movements. When Southgate et al. (2008) compared the looking times of infants in both the experimental and the control groups, they found that infants in the experimental group looked significantly longer at the biomechanically possible yet relatively less efficient goal-directed hand action than at the more efficient yet biomechanically impossible action. This result shows that only infants in the experimental condition (who had been habituated to seeing an efficient action), not infants in the control condition (who had not been habituated to seeing an efficient action), were more surprised to see a less efficient than a more efficient one in the test event. Interestingly, this result can also be taken (and is so interpreted by Southgate et al., 2008) to show that 6- to 8-month-old human infants might lack knowledge about the biological constraints on human actions performed by others and also that the perception of a biologically impossible action may trigger in such infants a perceptual *illusion* of efficiency. (Their perception is illusory because the action is biologically impossible.) It is unlikely that action-mirroring could explain why 6- to 8-month-old human infants are less surprised to see a more efficient yet biologically impossible hand action than a biologically possible yet less efficient one.

In any case, this experimental result is hard to square with the view that either familiarity with a perceived action or action-mirroring is a causally necessary condition for representing or ascribing a goal to an agent. If so, then not all instances of lower-level mindreading can be causally dependent upon action-mirroring. In light of these new developmental findings, the advocate of the causal link between instances of action-mirroring and instances of lower-level third-person mindreading should give up the view that, as a matter of nomic psychological fact, all instances of low-level mindreading are always caused by episodes of mirroring. Instead, he should be prepared to specify the class of cases in which action-mirroring does, and the class of cases in which action-mirroring does not, play any causal role in subsequent episodes of mindreading.

*4.2.2. The gap in the causal link*

As Goldman (in press, p. 2 of manuscript) indicates, the causal link interpretation between action-mirroring and lower-level third-person mindreading is a special case of the general claim that mental simulation causally contributes to tasks of third-person mindreading. The thesis of the causal dependency of third-person mindreading upon either action-mirroring or mental simulation in general leaves a crucial gap unfilled within the putative causal chain. On the simulation-based direct-matching model, an instance of action-mirroring exogenously triggered by the perception of a motor act of grasping a mug could at best lead an observer to *form* the intention to grasp the mug without executing the act. The question is: How is the observer's tokening of an *intention* to grasp the mug is turned into the observer's *belief* that the agent intends to grasp the mug?

Consider now the standard simulation-based account of the ascription (or prediction) of another's decision (insert Fig. 2 around here). Call the other T for target. The interpreter creates in his own mind a pretend goal (or desire) g and a pretend instrumental belief to the effect that producing action m is an efficient means of achieving goal g, where both the pretend goal g and the pretend belief that producing action m is an efficient means of achieving goal g are supposed to be relevantly similar to T's actual goal and instrumental belief. Then the interpreter feeds the pretend goal and the pretend belief into his own decision-making mechanism, which in turn outputs a pretend decision, for example, the pretend decision to do m. Unsurprisingly, the standard simulation-based account of decision-ascription now faces the very same question that is faced by action-mirroring: how is the pretend *decision* to do m transformed into the interpreter's *belief* (or prediction) that target T will decide to do m?

What is distinctive of simulation-based approaches to mindreading is the appeal to interpersonal neural and/or psychological *similarity*. Further appeal to interpersonal similarity in and by itself will *not* solve this question. The response to both versions of the same question is that the output of either action-mirroring or simulation in general is being *embedded* into a higher-order (or metarepresentational) *belief*. Arguably, action-mirroring or simulation might enable a mindreader to *mimick* (or *duplicate*) another's psychological state. However, to perform a full task of third-person mindreading is to form a genuine (higher-order) *belief*
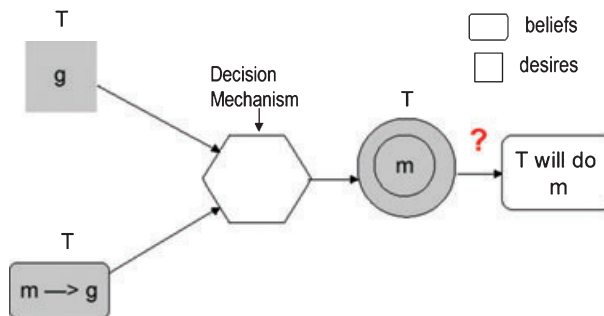
Fig. 2. The simulation-based account of the prediction of another's decision Captions.

about another's psychological state. Only by breaking out of the (hermeneutical) circle of interpersonal similarity and by shifting up to *metarepresentational ascent* can the questions be answered.[32] So far in this section of the essay, I have argued that action-mirroring is not sufficient for enabling an observer to represent an agent's intention and I have questioned the view that it is causally necessary. It is time to explore an alternative interpretation of action-mirroring.

### 4.3. *Third option: MN activity and the possession of action-concepts*

As MNs were first recorded in the ventral premotor cortex of monkeys, the prevalent interpretation of the experimental findings has been cast in terms of a process of *interpersonal simulation*, whose output is a neural and/or psychological *interpersonal resonance* or *similarity*. Clearly, however, MN activity could not achieve interpersonal resonance or similarity across the brains of *two* distinct individuals at a *single time* unless MNs fired in a *single* brain on *different occasions*.[33] Now, as Sperber (2004) has suggested, a brain mechanism that is active within a single brain in both the execution of a transitive act (e.g., grasping) and in the perception of the same act performed by a conspecific (at different times) looks very much like a neural mechanism underlying the *concept* of the act in question (i.e., *grasping*).[34]

Arguably, the conceptual representation of the act of grasping is an abstract representation that brackets the difference between the purely motor representation and the purely visual representation of the act. The view that MN activity is the neural basis of the concept of such a specific act as grasping would make sense of the variations in the statistical congruency between the motor and the perceptual properties of MNs noted by Csibra (2005, 2007). Whereas a significant proportion of MNs are generally reported as being ''strictly congruent,'' a majority is said to be ''broadly congruent'' (approximately 70% as reported by Rizzolatti & Sinigaglia, 2008, p. 84). It would also make sense of the fact that MNs have been recorded in the monkey for the perception of motor acts that the observer cannot perform (e.g., grasp food using a stick), as arguably seeing an agent perform an act of grasping food using a stick is seeing an act that falls under the concept of *grasping food*, which itself falls under the concept of *grasping*. In fact, on the basis of Rizzolatti et al.'s (2000) and Rizzolatti and Sinigaglia's (2008: 46) notion of a *motor vocabulary* (or *vocabulary of motor acts*), what I am presently calling a *conceptual representation* of the act of grasping is just what Rizzolatti et al. (2001) and Rizzolatti and Craighero (2004) call the *motor representation* commonly entertained by an agent and an observer.

If a conceptual representation of the act of grasping brackets the distinction between executive instances and perceptual representations of the act, then possession of the concept of *grasping* does not require 100% statistical congruency between the MNs that fire during respectively the execution and the perception of an act of grasping. Furthermore, the view that MN activity is the neural basis of some motor acts further helps resolve the tension between the direct-matching model and the model of chains of logically related MNs. If action-mirroring is the neural basis of the concept of *grasping*, then it does not underlie

tasks of third-person mindreading. But it makes sense that the application of the concept of *grasping* triggered by the perception of an act of grasping a mug would inferentially give rise to the related concept of, for example, *drinking* (as a function of contextual cues).

Conversely, evidence from brain-imaging experiments in humans reported by Brass, Schmitt, Spengler, and Gergely (2007) confirms the view that MN activity in humans is not primarily involved in tasks of third-person mindreading. Brass et al. (2007) report enhanced activity in human brain areas known to underlie the perception of social stimuli and third-person mindreading, in particular the Superior Temporal Sulcus (so far not believed to contain MNs), for the observation of an agent's opening a door with his knee when the action is *unexpected* (because his hands are free), as opposed to when it is expected (because he is using his hands to hold books). What this shows is that when the agent's observed action raises no particular puzzle in the observer's mind, action-mirroring may supply a motor representation of the agent's act. But when the agent's observed action is unexpected (or puzzling), then the observer draws automatically upon her mindreading resources to revise her hypothesis about the agent's intention (and/or other psychological states), which she might have formed on the perceptual basis of contextual cues. If this is correct, then action-mirroring might not generate at all a representation of the agent's intention. Instead, it may underlie the observer's conceptual representation of the agent's act and enable the observer to predict the agent's most likely next act, in conjunction with the perception of contextual cues, which in turn may also give rise to a representation of the agent's intention.

Nor does it follow from the conceptualist approach that there is no interesting difference between an agent and an observer. For instance, it is entirely consistent with the conceptualist approach that, unlike an observer, an agent has available information about his being the author of the act by means of a so-called ''efference copy'' of his motor instruction.[35] Insofar as the efference copy of an agent's motor instruction serves as the basis of the sense of agency, the conceptualist approach can accommodate the phenomenological difference between being an agent and being an observer of an act performed by another.

Simulation-based approaches to third-person mindreading have long emphasized the crucial role of psychological *similarity* between a target (or agent) and an interpreter. The discovery of MNs has been interpreted as a vindication of the simulation approach to mindreading by showing the existence of a neural mechanism for motor simulation (or motor resonance) in the primate brain, which would create an interpersonal neural similarity between an agent and an observer and would enable the latter to make sense of an agent's intention from the perception of the agent's movements. On the one hand, I have argued that this neural and/or psychological similarity between an agent and an observer at a time could never be exemplified via action-mirroring unless the brains of single primates were endowed with a mechanism with executive and perceptual properties that are instantiated in different tasks at different times. And as I have further argued, such a brain mechanism can plausibly be thought of as a neural mechanism underlying the relevant actions concepts. On the other hand, as showed by some of their writings, Rizzolatti and his collaborators (who discovered MNs in the first place) made room for such an interpretation of MN activity with the concept of *motor vocabulary*. However, given the prevalence of the tuning-fork model of social

cognition, this interpretation has been overridden, if not discarded, by the exclusive importance ascribed to interpersonal similarity in social cognitive tasks.

## 5. Conclusions

In this paper, I have questioned the view widely accepted among members of the cognitive neuroscientific community that action-mirroring alone (i.e., MN activity in an observer's brain) is either sufficient, or necessary, or both, for the purpose of representing an agent's intention—and thereby for the purpose of performing tasks of third-person mindreading. Instead, I have suggested that the most parsimonious account of the discovery of MNs in the brain of nonhuman primates is that MN activity underlies the possession of action concepts. In the process, I have focused on the limitations of the contribution to tasks of third-person mindreading of a mechanism of mental simulation, whose main function is to create a neural and psychological *interpersonal similarity* between an observer and an agent.

The first time the link between the simulation-based approach to third-person mindreading and action-mirroring (i.e., MN activity in an observer's brain) was explicitly put forward was in a 1998 paper whose joint authors were Vittorio Gallese and Alvin Goldman, that is, one of the co-discoverers of MNs and a leading analytic epistemologist and philosopher of mind, who happened to be one of the philosophical advocates of the simulation-based approach to mindreading in the late 1980s. It is, in my view, important to emphasize the fact that in the following ten years, Gallese and Goldman have developed their earlier conjecture in significantly different ways. So much so that, unlike Gallese, Goldman does not subscribe to what I earlier called the tuning-fork model of human social cognition.

In particular, as I noticed in section 4, Goldman (2004, 2006, 2008) accepts what I called the classical view of mindreading and he thereby rejects the view that an instance of mental simulation could constitute an instance of third-person mindreading. Instead, he accepts a weaker causal link between mental simulation and third-person mindreading. In other words, Goldman agrees that mental or neural similarity between an observer and an agent is not sufficient to allow the former to mindread the latter. Furthermore, Goldman (2006) adds a twofold distinction to the tool-kit of the simulation-based approach to third-person mindreading. On the one hand, he argues that both processes of mirroring and imaginative processes are instances of mental simulation. On his view, processes of mirroring play a causal role in so-called ''lower-level'' tasks of third-person mindreading and the imagination plays a causal role in so-called ''higher-level'' tasks of third-person mindreading. On the other hand, he argues for a distinction between two kinds of processes of mirroring: action-mirroring (or motoric mirroring) and affective mirroring (or nonmotoric mirroring).

As I understand it, in the past ten years since Gallese and Goldman published their 1998 paper, Gallese (2001, 2003, 2004) has argued that the discovery of action-mirroring vindicates a so-called ''embodied'' version of simulation, that is, a ''a basic functional mechanism of our brain [which is] an automatic, unconscious and pre-reflexive'' process. The

embodied version of simulation endorsed by Gallese stresses the role of interpersonal simi-
larity of brain and bodily structure (an embodied ''manifold of intersubjectivity'') for inter-
subjective understanding. On the one hand, Gallese's notion of embodied simulation seems
to erase Goldman's distinction between mirroring and imagination. On the other hand, it
encapsulates the idea that neural and/or psychological *similarity* is both necessary and suffi-
cient for third-person mindreading. It thereby contributes to two assumptions of the tuning-
fork model of human social cognition, that is, that action-mirroring is *constitutive* of third-
person mindreading, in virtue of the fact that action-mirroring alone enables an observer to
represent an agent's intention.[36] Arguably, Gallese's (2001, 2003, 2004) own propensity to
endorse jointly the embodied version of simulation and the core assumptions of the tuning-
fork model of human social cognition might betray his uncritical acceptance of the Phenom-
enologists' rejection of computational and representational approaches to mental processes
(prior to the cognitive revolution), which itself reflected philosophical prejudices.

In conclusion, I would like to emphasize five correlative points about the putative link
between action-mirroring and human mindreading.

1. As I already noticed, it is far from clear that there is currently any coherent alternative
   to the classical view of mindreading.
2. The current evidence about action-mirroring in either nonhuman primates or humans
   does not support the stronger view (over the weaker view) of the direct-matching
   model of action understanding. The developmental investigation of the ontogeny of
   human infants' understanding of goal-directed actions is wide open. There are cur-
   rently two main views: one emphasizes the role of familiarity and motor experience in
   understanding others' goal-directed actions. The other emphasizes the role of cues of
   efficiency in the understanding of others' goal-directed actions.
3. The experimental evidence about MN activity in both nonhuman primates and humans
   does not support the strong view that action-mirroring constitutes mindreading (in the
   sense that MN activity alone could enable an observer to figure out the agent's prior
   intention).
4. The best evidence for the view that action-mirroring causally promotes tasks of third-
   person mindreading by helping an observer figure out the agent's prior intention faces
   the following problem. Far from corroborating the resonance (or direct-matching)
   model of MN activity, the evidence for the putative causal role of action-mirroring in
   the representation of the agent's prior intention is also evidence for a novel model of
   chains of logically related MNs. But according to this model, what MN activity does is
   to enable the observer to predict the agent's most likely next act, given the context.
   Predicting the agent's next act is not to perform a task of third-person mindreading
   (classically construed). If the perceptual processing of contextual cues is required to
   select the appropriate chain of logically related MNs, then it is perfectly possible that
   it also suffices to enable the observer to form a representation of the agent's prior
   intention.
5. Finally, the prevalent interpretation according to which action-mirroring causally
   contributes to mindreading is based on the view that action-mirroring generates an

interpersonal neural and psychological similarity between an agent's and an observer's brain at the time at which the agent performs his action (of e.g., grasping). As I have argued, this synchronic interpersonal neural and psychological similarity would simply fail to arise unless action-mirroring in each individual brain were a single mechanism active in two different tasks (an executive and a perceptual task of e.g., grasping) at different times. But as I have also argued, a single mechanism in a single brain that is active in both an executive and a perceptual task of grasping suspiciously looks like a brain mechanism that underlies the concept of the act of grasping. If so, then we might do well to endorse the more parsimonious hypothesis that action-mirroring underlies the conceptual representation of the relevant motor acts and leave out any additional assumption about the role of action-mirroring in tasks of third-person mindreading.

## Notes

1. Much of this work is reflected in Jacob (1997). I do take it that the joint works of Dretske, Fodor, Millikan and others have made intentionality respectable to a metaphysical naturalist by showing deep underlying connections between it and such concepts broadly used in the natural sciences as *nomic correlation*, *information* and *function*. What is not obvious is whether this interesting metaphysical research program has generated much scientific understanding of the human mind. For a radically negative response to this question, cf. Chomsky (2000), who accepts methodological naturalism, but rejects metaphysical naturalism.
2. Cf. Jacob and Jeannerod (2003).
3. Cf. Ungerleider and Mishkin (1982). This discovery has generated much discussion about the exact functions of the two pathways.
4. One thing we argued in the Epilog of Jacob and Jeannerod (2003) and in Jeannerod and Jacob (2005) is the importance of recognizing that there are levels of complexity in the pragmatic as well as the semantic processing of visual information.
5. Cf. also Jacob (2005). I'm still working, and just completed a new paper, on this topic. Cf. Jacob and de Vignemont (2009).
6. Cf. Allison, Puce, and McCarthy (2000).
7. The Phenomenological rejection of intellectualism seems tantamount to rejecting cognitive operations or computations. For recent versions of the embodied cognition paradigm, cf. Varela, Thompson, and Rosch (1991), Clark (1997) and Gallhager (2005).
8. Cf. Di Pellegrino, Fadiga, Fogassi, Gallese, and Rizzolatti (1992).
9. Cf. Jacob and Jeannerod (2003, chapter 7) and Jacob (2008) for a detailed discussion.
10. For an extended discussion of the empirical evidence, cf. Jacob (2008).
11. Application of ''motor resonance'' to MN activity is metaphorical talk. It is best explained, I think, by the idea that MN activity is motor simulation (without execution) of an observed act enabling the observer to map the agent's observed movements onto his own motor repertoire. If so, then the alleged resonance is likely to be a subpersonal, functional (not a personal) relation holding between the agent's and the observer's

respective brain areas. This seems to fit Gallese's (2001: 45) construal of what he calls ''the shared manifold of intersubjectivity.''

12. Cf. also Rizzolatti and Sinigaglia (2008: 94–98).

13. In some respects, what this quote reveals is that the philosophical Phenomenological rejection of the role of cognitive operations in capturing what it is like to understand another's act has a cost: it promotes a view of action-understanding that seems best to fit the well-known positive symptoms of schizophrenia—a point made by Jeannerod (2004) in response to Gallese (2004).

14. Notice that the stronger version seems to make the unwarranted assumption that actions have a unique meaning, if any.

15. For further discussion, cf. section 4.2.

16. On my view, it is unlikely that by mentally rehearsing an agent's perceived movement, an observer could mentally represent its psychological cause. Cf. Jacob (2008).

17. In one of the motor tasks, the monkey brought the food to the mouth and ate it. In the other two motor tasks, the monkey was rewarded after correct accomplishment of locating both the food and the nonedible target into a container (located near either the target or his mouth).

18. According to Fogassi et al. (2005: 662), in the executive task, monkeys were trained to place food into a container by being ''rewarded after correct accomplishment of the task.'' So the selective discharge of MNs in the perceptual task may reflect *associative learning* instead of spontaneous mindreading.

19. Affordances can trigger the discharge of so-called ''canonical'' neurons, not of MNs. Cf. Rizzolatti, Fogassi, and Gallese (2000).

20. Note that on Gallese and Goldman's (1998) view, the agent's intention is *retrodictively* computed by action-mirroring from the perception of his movements. Goldman (in press, pp. 6–7 of manuscript) recognizes the tension between the two models, but he espouses the latter view and concludes from the studies that there are two kinds of mirror neurons.

21. Following Searle's (1983), Pacherie's (2000) and others' terminology, it is natural to characterize the agent's intention to drink as his *prior* intention because it is chronologically and causally prior to both the agent's acts of grasping the mug and bringing it to the mouth. Cf. Jacob (2008).

22. If one knows an agent's beliefs and desires, then arguably one can *predict* an agent's *prior* intention. For example, knowing that an agent both wants to read and believes that there is not enough light, one could presumably predict that the agent will form the prior intention to turn the light on. But clearly such a prediction is beyond the mechanism of action-mirroring.

23. Gallese, Keysers, and Rizzolatti (2004: 396).

24. Cf. Gallese et al. (2004: 396).

25. For recent analyses of the contribution of Merleau-Ponty's rejection of cognitivism and representationalism to the Phenomenological tradition, cf. Carman and Hansen (2005).

26. As phantom limb pains show, human patients may have mental representations of their own nonexistent bodily parts (at least, nonexistent when the mental representations are being formed). For further discussion, cf. Goldman and de Vignemont (in press).

27. ''Goal-directed'' does not mean directed towards a physical target, but guided by a mentally represented aim.

28. The contrast between *lower-level* and *higher-level* tasks of third-person mindreading might be drawn in terms of the amount of *inhibition* required: higher-level mindreading requires more inhibition that lower-level mindreading. For example, passing a standard false belief task requires inhibiting one's own correct representation of the location of the object in order to represent another's incorrect belief.

29. In light of Onishi and Baillargeon's (2005) and Surian, Caldi, and Sperber's (2007) evidence for the representation of others' false beliefs by respectively 15-month olds and 13-month olds, this does not seem like an unreasonable proposal.

30. Something jointly pointed out to me by an anonymous referee for this journal and by Iris Trinkler.

31. But, as I am about to argue, there is a gap between forming a goal similar to the agent's and ascribing the goal to the agent.

32. Similarly, imagination may enable one to engage into a game of make-believe required to appreciate a work of fiction. But there is a gap between imaginatively engaging in such a game and forming a metarepresentational belief, and stating a fact, about or describing, a work of fiction.

33. Arguably when an agent sees his own hand movement, MNs might fire in a single brain in a dual task (of action-execution and action-perception). If so, then it would not be strictly correct to say that MNs fire in a single brain in different tasks at different times. But it is difficult to test the hypothesis that the firing of MNs in an agent's brain also underlies the agent's visual perception of his own act.

34. On this view, the discovery of MNs in the ventral premotor cortex of monkeys might be said to vindicate the application of Fodor's (1975) hypothesis of a *language of thought* composed of concepts (or cross-modal mental symbols) to the cognition of nonhuman primates (who lack a language faculty).

35. The concept of *efference copy* was introduced by Helmholtz, who was exercised by the puzzle of how humans (and other animals) are able to discriminate the visual signals produced on their retina respectively by the motion of some external moving object and by the movements of their own eyes. The efference copy was Helmholtz's theoretical response to the puzzle: when the brain sends to the muscles of the eye a motor instruction to perform a saccade, it also generates an efference copy of the motor instruction that informs the brain that the sensory changes result have an endogenous, not an exogenous, source. Cf. Wolpert (1997).

36. In this paper, I have argued that the psychological interpersonal similarity emphasized by simulation-based approach is not sufficient for third-person mindreading. In addition, as Goldman and de Vignemont (in press) notice, it is unclear what role the embodied format of simulation could play in representing, for example, others' mathematical beliefs.

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