MIRRORING AND UNDERSTANDING ACTION
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Abstract. Though the existence of a mirror system for action is widely accepted, its mechanism and function are still controversial. It was originally held that the primary function of the mirror mechanism is to enable an individual to understand the actions performed by others, by directly matching the sensory with the motor representations of those actions. Recently, however, Gergely Csibra (2007) has proposed that mirror activation cannot be construed in terms of a mechanism that directly matches observed and executed motor acts, but must be based on a purely visual reconstruction of action, so that the primary mirror function would not be to understand other's actions, but to emulate them. The aim of this paper is to refute Csibra's arguments, showing that they are mostly based on a partial reading of the functional properties of mirror neurons as well as on a biased construal of both action and action understanding.

1. Introduction

Mirror neurons are a specific class of neurons that respond when an individual performs a given action and when s/he observes a similar action performed by others. There is now a general consensus that there are at least two mirror neuron systems, one located on the lateral convexity on the brain, the other in the insula and in the cingulate cortex. The first translates observed actions devoid of any emotional content into the corresponding motor representations, while the second converts emotional behaviours into the corresponding viscero-motor responses (Rizzolatti and Sinigaglia 2008a).

It was originally held that the primary function of the mirror mechanism is to enable an individual to understand the actions performed by others, by directly matching the sensory with the motor representations of those actions (di Pellegrino et al., 1992; Rizzolatti et al. 1996; Gallese et al. 1996). A similar interpretation has been offered for the understanding of the emotions of others, since the observation of an emotional expression or context determines the activation of the same cortical sites as the direct experiencing of the same emotion (Wicker et al. 2003; Gallese et al. 2004).

Whereas mirroring in the emotional system has been mostly accepted, mirroring for action has recently become a target of criticisms. Of these, the critical account proposed by Gergely Csibra (2007) is particularly worthy of mention. Not only does it constitutes the basis of the majority of the objections raised against action mirroring, starting from those formulated by Pierre Jacob (2008) and Justin Wood and Mark Hauser (in press), but more than any other it insists on the relation between the mechanism and the function of mirror neurons, with the objective of demonstrating that interpreting the former in terms of a direct matching must inevitably be in conflict with the interpretation of the latter as critical for action understanding.

The paper aims to refute these criticisms by arguing that they are mostly due to a partial reading of mirror neuron properties and to a biased construal of both action and action understanding. In the next sections I shall give a brief outline of Csibra's argument and then focus on analyzing functional properties of mirror neurons, starting with the motor ones. I will use this analysis to counter Csibra's objections, illustrating how they presuppose a restricted conception of the directedness of mirror matching and how the latter leads to a misapprehension of the exact nature and range of mirror-based action understanding.

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2. What are mirror neurons for?

According to the direct-matching hypothesis (DMH), the observation of an action performed by others evokes, in the observer's brain, a motor activation that is alike to that which spontaneously occurs during the planning and effective execution of that action. The difference is that while in the latter case the motor activation becomes an *overt* motor act, in the former it remains at the stage of a *potential* motor act, thus enabling the observer to immediately understand the witnessed motor act. DMH does not exclude that other more complex mechanisms, such as those that are supposed to be at the basis of many inferential or meta-representational processes, may be at work and play a role in this function. It simply maintains the primacy of a direct matching between observation and execution of action, pointing out that observer's ability to understand the actions of others primarily capitalizes on the same 'motor knowledge' that underpins her/his own ability to act (Rizzolatti et al. 2001; Rizzolatti and Sinigaglia 2007).

Recently, however, DMH has been challenged by objections and alternative proposals. Of these the most stimulating challenge was undoubtedly that raised by Gergely Csibra, who proposed that "action mirroring cannot be direct but must be based on some kind of interpretation of observed action", on an "emulative action reconstruction", arguing that this implies that action understanding cannot be the primary function of action mirroring, because the former "may precede, rather than follow," the latter (Csibra 2007: 436).

Starting point of Csibra's argument is the assumption that the intuition behind DMH is that action interpretation during mirroring occurs at a relatively low-level (i.e. kinematics) and that it contributes to action understanding by means of a bottom-up motor activation allowing the observer to estimate "what higher level sub-goals and goals might have generated the observed action" (Csibra 2007: 441). He counters such intuition with the idea that mirroring can be achieved at a higher level of action interpretation and therefore that observed actions can be interpreted to the highest possible level before they are passed, *via* a top-down activation, on to the motor system for their kinematical reconstruction. Some basic mirroring phenomena (e.g. automatic imitation of simple transitive and intransitive movements, motor interferences, and so on) can be considered as highly consistent with low-level action interpretation for mirroring. However, Csibra remarks, while these mirror phenomena can be also construed as generated by emulative action reconstruction, there are several findings that seem incompatible with DMH and can be accounted for *only* by an emulative model of action mirroring.

First of all, single cell recordings showed that monkeys' mirror neurons responded to the observation of hand grasping actions even when the final part of these actions, consisting in the effective object-hand interaction, were hidden behind a screen, whereas they did not respond to the observation of the same hand movements when the experimenter mimed to grasp something in absence of any objects (Umiltà et al. 2001). As Csibra writes, "this finding is puzzling if action mirroring is performed by low-level direct matching because the low-level kinematics of a mimicked action is presumably similar to that of an object-directed action, and is available for mirroring" (Csibra 2007: 443).

Similarly "puzzling" to Csibra would be the finding that mirror neurons might respond to motor acts that the observer is unable to perform (Ferrari et al. 2005) or even to biologically impossible actions (Costantini et al. 2005): how does DMH explain such mirroring? There is no matching action in the observer's repertoire, so that the only possible interpretation appears to be that on the basis of which "observed actions are interpreted outside the motor system and then fed into the observer's action control system for reconstruction" (Csibra 2007: 446).

Finally, Csibra cites the papers by Fogassi et al. 2005 and Iacoboni et al. 2005 that showed how mirror neurons respond differentially to the individual motor acts according to the overall intention with which it is thought they were carried out. Because both experiments were designed to unable the observer to figure out the intention underlying

the observed motor acts from mere kinematical cues, it would be difficult to explain the differential motor activations by appealing to low-level mirroring: how and to what extent should such a mirroring allow the observer to understand further goals or intentions of witnessed motor acts? In contrast, as Csibra held, "these results fit perfectly with the emulation model of action mirroring", since intention understanding would be based on no-motor information (object semantic, contextual cues) processing, so that mirror activation would reflect the motor emulation of an observed action whose underlying intention is coded outside the motor system.

To sum up, the above-mentioned data would be incompatible with DMH as they would show that the fact that an observed motor act belongs to the observer's own motor repertoire can be neither sufficient nor necessary for mirror activation, because the latter can be determined by a high-level interpretation of the observed action, based on no motor and contextual information, or even by the sight of non executable movements, whose goal relatedness could be estimated from visual information only. To quote Csibra, these findings would actually undermine DMH insofar as they would reflect "two conflicting claims about action mirroring" implied by DMH: "The claim that action mirroring reflects low-level resonance mechanism, and the claim that it reflects high-level action understanding. The tension arises from the fact that the more it seems that mirroring is nothing else but faithful duplication of observed actions, the less evidence it provides for action understanding; and more mirroring represents high-level interpretation of the observed actions, the less evidence it provides that this interpretation is generated by low-level motor duplication" (Csibra 2007: 446).

3. Motor goals and action mirroring

But is really there such a "tension"? Does the directness of matching truly imply that action mirroring occurs at relatively low-level? In other words: is only the kinematics of an observed motor act that can be directly matched in the case of mirror activation? Does goal (and intention) coding really require leaving motor the motor system? In addition: does the direct matching mechanism, by definition, actually involve the same or similar effectors and biological constrains between actor and observer? What is the effective role of observer's motor repertoire?

To answer to these questions, it is useful to begin with the functional properties mirror neurons share with other motor neurons from the ventral premotor cortex (area F5) and infero-parietal lobule (IPL). Single cell recordings showed that most F5 and IPL motor neurons code goal-related motor acts (such as grasping, holding, manipulating, etc.) and not the individual movements that compose these acts. Indeed, many F5 and IPL motor neurons discharge when the monkey performs a motor act such as grasping a piece of food, irrespective of whether it uses its right or left paw or even its mouth. Others motor neurons are more selective, discharging only for a specific effector or grip. However, even when selectivity is at its highest, the motor responses cannot be interpreted in terms of single movements: neurons discharging during certain movements (the flexing of a finger, for example) performed with a specific motor goal, such as grasping an object, discharge weakly or not at all during the execution of similar movements that compose a different motor act such as scratching (Rizzolatti et al. 1988; Rizzolatti et al. 2000).

A very recent study has shown that this is true not only for hand- and mouth-, but also for tool-mediated motor acts (Umiltà et al. 2008). The experiment was carried out with macaque monkeys, which were trained to grasp objects using two different types of pliers, 'normal pliers', which require typical grasping movements of the hand (opening and then closing), and 'reverse pliers', which require hand movements in the opposite sequence (closing and then opening). All recorded F5 neurons discharged in relation to the goal-related action of the pliers, maintaining the same relation to the different phases of

grasping in both conditions, regardless of the fact that diametrically opposite hand movements were required to achieve the goal.

This quick review of the motor properties mirror neurons share with most of F5 and IPL neurons is enough to throw the assumption that lies at the basis of Csibra's criticism into discussion. As mentioned earlier, mirror defining functional characteristic is that these neurons become active not only when an agent performs a given motor act, but also when s/he observes it being performed by another. In the light of their motor properties, there is no reason to assume that mirror neurons "have to duplicate every minute detail of the observed act (including, for example, direction and speed of motion, angles between joints, etc.) in order to facilitate its understanding" (Csibra 2007: 437). Just as there is no reason to assume, as Csibra however does, that the directedness of matching has to be restricted to the kinematics of observed motor acts. And in fact DMH does not assume this. According to DMH, that in the observer's brain, the sight of a motor act performed by another recruits the same neurons that would become active if s/he were planning and effectively executing that act, means that mirror neurons code the motor goal-relatedness that identifies that particular motor act, independently of whether it is executed by the agent him/herself or simply observed while being carried out by another. What is directly matched is the motor-goal relatedness that characterizes both the effective observed and the effective executed motor acts (Sinigaglia 2008a; Rizzolatti and Sinigaglia 2008b).

This explains why mirror neuron activation is not strictly bound to the completeness of the sensory information or to only one sensory modality. Indeed, mirror neurons have been shown to respond to only partially seen motor acts (Umiltà et al. 2001) as well as to sound-producing motor acts (e.g. paper tearing), independently of whether they were seen, heard or both seen and heard (Kohler et al. 2002). As we have seen, Csibra regards as "puzzling" the fact that "observing a reaching act for an occluded target object elicits mirror neuron activation whereas the same movement does not trigger mirror neuron response when the monkey knows that there is no food behind the occluder" (Csibra 2007: 443). However, Umiltà et al. 2001' findings are "puzzling" only if one presupposes that sensory information directly mapped on motor neurons uniquely concern the kinematics of observed action. Only on the basis of such a presupposition it makes sense to contend, as Csibra does, that, "what [these findings] really indicate is that mirror neurons *reflect* action understanding rather than contribute to it" (Csibra 2007: 443).

There is absolutely no doubt that in Umiltà et al.'s experiment the fact that miming did not activate the mirror neurons was due to the circumstance that the monkey was fully aware that there was no object behind the screen. This however would in no way entail a top-down mechanism in which the monkey would access (how we do not know) a high level description of the observed action that would then be transmitted to the motor system for reconstruction. On the contrary, the hypothesis that the visual information relative to the presence (or absence) of the target contributes to the activation of the mirror system to the extent to which it is compatible with the animal's motor repertoire is much more economical (and plausible). In other words, the motor goal 'grasp' implies (at least for the macaque), a reference to an object which is physically present; the absence of the target entails that the observed movement cannot be matched with a corresponding motor goal, irrespective of the fact that the kinematics may be very similar in the two cases.

This can also be explained in the light of the different types of congruency that characterizes mirror neurons. In some cases this congruence can be extremely strict, pertaining not only the motor goal (e.g. grasping), but also the ways to achieve it (e.g. the type of grip). For most mirror neurons, however, the congruence is broader: though not identical, observed and executed actions are clearly connected, sharing the same goal-relatedness. For instance, a mirror neuron that is active during hand-grasping action can be activated by the observation of a mouth-grasping action.

According to Csibra, it would be hard to realize "how low-level motor mirroring could produce such a mismatch"; on the contrary, this kind of mirroring would fit perfectly with the emulation model of mirroring: "If the monkey has 'understood' the

immediate goal of the action outside the motor system, from which the motor activation reconstructs the observed action, we would expect exactly this kind of correspondence between observation and execution" (Csibra 2007: 444). However, there is no reason to leave the motor system in order to account for the different degrees of mirror neuron congruency. In fact, giving their motor properties, it is no so "puzzling", as Csibra thinks, that mirror neurons visually (or acoustically) code observed motor acts with different degrees of generality.

The directedness of matching does not imply that it has necessarily to be construed in terms of one-to-one mapping, and even when this is the case, as for the strictly congruent mirror neurons, mirror mechanism does not run at the level of mere kinematics, but at a higher level, that captures the motor goal-relatedness of the observed act. Indeed, both strictly and broadly congruent mirror neurons respond to the goal-relatedness of the observed movements, even if they represent it in a different way, the former being more detailed and the latter more general. As a result, what is matched, and how it is matched, depends on the degree of generality that characterizes the motor responses of a given (set of) mirror neuron(s) as well as on its degree of congruence, and there is no need to leave the motor system to explain these differences.

4. From motor goals to motor intentions

Formulated in these terms, the question of the activation of mirror neurons during the observation of act that the observer had never executed previously or even biologically impossible acts, also takes on a difference significance to that attributed by Csibra. With regards the first point, he cites the study carried out by Ferrari et al. (2005) which showed mirror neurons that became active both when the monkey grasped a piece of food with its own paw and it watched the experimenter using a stick to pick up the food, even though the animal had never been taught how to use a stick in this way.

According to Csibra, this would be "a clear example of mirroring activation […] which is incompatible with the idea of low-level motor mirroring". Nevertheless, as he himself acknowledged, "the mirroring process was not random", since "mirror neurons responded to the sight of a non-executable action with a different action that the monkey could have used to achieve the same goal". This, however, is not sufficient to justify Csibra's conclusion that a similar activation could *only* be explained within the emulation model of action mirroring. Indeed, the hypothesis that the motor system contributes to the effective understanding of observed actions mapping them on the motor representations that underlie the animal's capacity to act is far more simple (and more plausible too). The goal coded in motor terms is (at least) as general as that which should be coded in purely visual terms, as the mirror neurons that discharge at the sight of the stick being grasped by the experimenter also fire during the execution of the hand- and mouth-grasping action. Thus, more than just representing a reconstruction of the action, the activation of the mirror neurons would reflect the way in which it is understood.

In the case in point, grasping with a stick would have the motor meaning of grasping with the hand or the mouth for the animal observing the act. The situation changes when the animal has a certain degree of familiarity with the tool. In the above-mentioned study on the use of normal and reverse pliers, Umiltà et al. (2008) have shown that part of the recorded neurons had mirror properties and that their discharging coded the distal goal of the pliers as the same (i.e. grasping), even when the observed movement of the fingers were diametrically opposite. Very recently, Rochat et al. (submitted) attempted to weigh the rootedness in the motor repertoire of observed acts and its role in the coding of visual information, comparing the mirror responses determined by the sight of hand-grasping actions, (reverse) pliers-grasping actions and stick-grasping actions in monkeys who were accustomed to using pliers but not sticks. The data indicated that

although the various types of grasping were all mapped on the observer's motor repertoire, they gave rise to different types of mirror activation, and specifically, the more the observed act was rooted in the observer's motor repertoire, the more anticipated the mirror discharge.

This shows that Ferrari et al.' findings cannot be used as an argument against the directedness of matching, but suggests that the mirror mechanism presents different degrees of generality that enable it to code, in motor terms, a wide range of observed goal-directed motor acts. Indeed, the generality of the motor coding of the mirror neurons allows them to map observed motor acts that appear to violate biological parameters as in the experiments conducted by Costantini et al. (2005) in which a number of volunteers were presented with finger movements that were outside of the normal range of such actions. Quite the opposite to what Csibra thought, there is no need to assume that the directedness of mirror matching implies that such a mechanism has to take into account the biomechanical constraints the observed movement would involve if they were actually executed. On the other hand, if we take the alternative explanation proposed by Csibra into account, according to which the motor system would try to approximate (albeit unsuccessfully) the visual action reconstruction, using the available motor programs, we have to ask why the motor system should attempt to reconstruct a similar act, or what meaning would such an emulation have, particularly as the visual system has guaranteed "appropriate description of the end-state of such an action" (Csibra 2007: 446).

The same argument can be adopted when we consider whole motor actions, identified by determined goal hierarchies as opposed to individual motor acts, characterised by a specific goal-directedness. As Csibra himself recalls in his criticism of DMH, recent studies appear to indicate that the cortical motor system codes not only *what* an individual is doing but also *what* s/he is doing it *for*.

In particular, Fogassi et al. (2005) recorded single IPL neurons during eating and placing grasping actions. Most of the tested hand-grasping neurons appeared to be 'action constrained', forming pre-wired motor chains and discharging differentially depending on whether the grasping was a grasping to carry to the mouth or a grasping to move the piece of food from one place to another. But even more interesting is the fact that most of the recorded IPL 'action constrained' neurons showed mirror properties, responding both to eating and placing actions performed by an experimenter and discharging differentially depending on which action the single observed act of grasping was embedded into (e.g. grasping *for* eating or grasping *for* placing).

According to Csibra, this study would demonstrate, better than any other, the alleged tension between the two conflicting claims about action mirroring implied by DMH. On the one hand, indeed, it would be possible to hypothesise that monkeys' IPL mirror neurons were sensitive to kinematical parameters, so that their activation would represent a low-level mirroring phenomenon: however, Csibra remarks, "nothing in this study would then suggest that the monkeys would have understood the 'intention' behind the observed actions" (Csibra 2007: 447). On the other hand, it might be possible to accept Fogassi et al.'s (2005) argument that the mirror activation was independent of the kinematical parameters, reflecting an 'intention' understanding based on contextual cues: however, Csibra adds, "nothing in this study such an understanding is based on low-level mirroring (i.e. motor resonance)" (Csibra 2007: 447).

Now, it has already been seen that the mirror system does not run at a mere kinematical level, but is capable of coding the goal-relatedness of observed movements, thus allowing the observer to understand immediately the actions of others. Fogassi et al. 2005's data suggest that not only is the motor system sensitive to the goal-directedness that characterises an individual motor act, it also reflects the goal architecture in which that specific act may be embedded or the motor intention with which it had been carried out. In the case of first person execution of an action, the organization of the motor system explains the fluidity of action that is typical of intentional behaviour, since the final motor goal is displayed in the motor sub-goals that are suitable for its achievement from the

start: from the first launch of hand movements, grasping a piece of food is a grasping *for* bringing to the mouth or a grasping *for* placing. But the most important aspect of all is that such motor organization extends the reach of mirror mechanism, allowing the observer to understand the motor intention underlying the observed act: indeed, when 'action constrained' neurons discharge, the sight of a hang-grasping motor act evokes much more in the observer than merely a single isolated potential motor act, it evokes an entire chain of potential motor acts which actually prefigure the motor intention that underlies the movements that were observed.

There is no doubt that information processing concerning object semantics (the type of object to be grasped) and/or some relevant contextual cues (e.g. the presence or absence of containers) might play a role in the elicitation of a given motor chain (grasping *for* eating instead of grasping *for* placing). But this does not require that mirror activation had to be construed here in terms of a top-down emulative mechanism deputed to reconstruct the kinematics development of the observed action on the basis of a not very clearly defined visual-inferential understanding of the intention. Nor it does imply that the construal of mirror activation as constitutive of observer's understanding of agent's motor intention represents a behaviouristic drift "cognitive science should resist" (Borg 2007: 18; see also Jacob 2008).

I argued elsewhere (Sinigaglia 2008b) that such interpretations end up missing the specificity of mirror mechanism, that is, the fact that the sensory information concerning the observed scene is mapped onto motor neurons forming pre-wired motor chain, and that only in virtue of this motor chain organization the activation of these neurons can be functionally interpreted in term of motor intention understanding. Here I just will mention the EGM experiments carried out by Cattaneo et al. (2007), showing that motor intention understanding does not rely on a processing of mere object or contextual information, but is primarily rooted in the observer's motor knowledge.

They recorded the activation of the mouth-opening mylohyoid muscle (MH) during the execution and observation of eating and placing actions in both traditionally developed (TD) children and children with autistic spectrum disorders (ASD). Both the execution and the observation of the eating action produced a marked increase of MH activity in TD children as early as the reaching phase. On the contrary, children with ASD showed a much later activation of the MH while eating, with the muscle becoming active only during the bringing-to-the-mouth phase, and, most importantly, no MH activity was recorded during their observation of eating action. These findings suggest that TD children were able to represent the action to be executed as an organized motor chain (grasping *for* eating), while children with ASD could represent the intended action just a simple sequence of unrelated single motor acts (reaching, grasping, *and* bringing-to-the-mouth), and this prevented them from disambiguating the sensory information regarding observed actions and, therefore, from immediately grasping the motor intentions underlying those actions, even when they are able to comprehend the goals of the single observed motor acts.

As well as throwing new light on the relationship between ASD and mirror neurons (see Sinigaglia and Sparaci 2008; Gallese et al. in press on this point), this data clearly indicates that the level at which an observed act is described during action mirroring, as well as the range of such description, depends on the observer's motor knowledge: the more refined this is and the more detailed, the more the mirroring will able to capture the intentional dynamics of the observed act. Therefore, contrary to what Csibra maintains, this implies that not only there would be no tension between the level of action mirroring and the level of action understanding, but the efficacy of the latter would be lessened if the former were not present.

5. Conclusions

I have devoted the previous sections to replying to Csibra's account of mirroring and understanding action, arguing that his objections to DMH are mostly based on the (unwarranted) assumption that directedness of mirror matching would imply that action mirroring occurs at a very low-level, being confined to a mere kinematical description of action. It is only in virtue of such an assumption that Csibra can portray the mirror mechanism as follows: "The popular conception of the causal role of mirroring in understanding the 'meaning' of actions involves a direct, unmediated, automatic, mandatory, resonance-like transfer mechanism, which miraculously generates a copy of the motor command responsible for the observed action, and forms the basis of bottom-up identification of the goals (or intentions) that have guided that action" (Csibra 2007: 454).

However, once one realizes that what characterizes the cortical motor system is its coding of goal-related motor acts and actions rather than single movements, and that this motor goal-relatedness can be represented with different degrees of generality, then it becomes immediately evident that there is no reason to look elsewhere other than the motor system to account for the motor goal-relatedness that identifies a given motor as such, regardless of whether it is performed by an agent or is witnessed by someone else. In the latter case, what is directly matched, i.e. what level of action description is involved in the direct matching mechanism, depends on the motor properties and degree of congruence of the activated (set of) mirror neurons. Even when the congruence is very strict, the direct matching occurs at the level of the motor goal-relatedness that is shared by the effective observed and effective executed motor acts; it therefore follows that even in this case action mirroring cannot be reduced, as Csibra does, to a mere kinematics resonance.

Moreover, the alternative account proposed by Csibra has a number of hitches. For example, it is not clear *where* and *when* that high-level action description would occur, of which mirror activation would be a mere motor emulation. It is true that, as Csibra mentions, Perrett et al. 1989 recorded pure visual neurons in the monkey's superior temporal sulcus (STS) that responded to the sight of goal-related motor acts. Just as it is true that STS neurons project directly to IPL areas that are endowed mirror properties and are strongly connected to the ventral premotor cortex. This suggests that visual information processing contributes to mirror activation. However, this does not justify the interpretation of action mirroring as a two-step process, where the first, purely visual step would be deputed to recognising the goal of the observed movements while the second step, with its visuo-motor characteristics, would be dedicated to emulating them. Such interpretation cannot be justified because this process could in no way give rise to a top-down action reconstruction, given that, at best, the coding of the STS neurons' goal is characterised by the same degree of generality as the mirror system and is not concerned with the goal architecture which the motor system is able to code, because of its chain organization. Finally, what would be the function of such motor emulation? Monitoring of the actions of others, as Csibra seems to be suggesting? The problem here is how a similar function would be compatible with the various degrees of generality with which the mirror system codes the goals of the actions of others? And how would it be interpreted in the case of anticipation of others' intentions?

With these arguments, I am not denying that descriptions of higher level and in any case different from those based on mirror activation play a key role in action understanding. What I have attempted to do is to demonstrate that mirror-based action understanding represents a specific way of understanding the actions and intentions of others, a way which is original and primary in nature, and this in virtue of a direct matching mechanism that maps the sensory information on the observer's motor repertoire, thus facilitating the grasping of the motor goal-relatedness which makes a certain sequence of movements a given motor act, achieved with a given motor intention, regardless of whether the agent is performing the act or whether s/he is watching it being performed.

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