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From self-modeling to the self model: agency and the representation of the self

Commentary by Vittorio Gallese and Maria Alessandra Umiltà

Introduction

Neurophysiology, the discipline that investigates the functional organization of the brain and its relation with behavior, has traditionally privileged the study of "simple" problems such as the organization of sensory and motor systems. During the last two decades, however, issues such as attention, intention, and ultimately even consciousness, traditionally fields of investigation of the cognitive and philosophical sciences, have progressively become the challenging targets of more and more neuroscientists. This fact certainly represents a major turn in the history of the scientific study of brain functions. Furthermore, it enables the possibility to establish a dialogue with other disciplines, such as psychoanalysis, that instead from the very beginning put some of these issues at the center of its research agenda.

In his stimulating paper Milrod is seeking to establish such an interdisciplinary dialogue, choosing as subject the concept of self and its representation. Milrod proposes that the gradual development of the self is paralleled by object representation. In the present commentary we would like to focus on some recent neuroscientific data that may contribute to shed some light on several attributes of the self. We will do so trying hard not to surrender to the temptation, common among many neuroscientists, to "reduce" the problem of the self and of its representation to the mere activity of a series of cortical networks. As quite correctly pointed out by the German philosopher Thomas Metzinger (2000), reduction is a relationship between theories, and not between phenomena. Neurophysiology instantiates a sub-personal level of description, that of neurons. However, by doing so we may acquire knowledge that can be used to better characterize all the other possible levels of description, the personal ones included.

Our limited scope here will be to provide evidence in favor of a possible bridge between agency and representation in different self-related domains such as spatial cognition, action on objects, and action observation. From there we will move on to submit that the self is just one—probably the most sophisticated one—of the many possible modeling ways that an organism may instantiate to achieve a better control of its dynamic interplay with the environment.

The Self-world Relationship: Space

When we speak of subjective experience we refer to a set of properties that we assign to an entity that we call *the self*. Within the camp of the cognitive sciences it has been recently proposed that the self can be conceived as a *theoretical construct* (see Baars, 1997; Metzinger, 1993, 2000)

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of the phenomenological experience of being a well identified "I". This construct can be viewed as a *model*—the Phenomenal Self Model (PSM)—(see Metzinger, 1993, 2000, 2003) that is articulated into three main phenomenal properties: *mineness* (I consciously experience *my* body as having always phenomenally belonged to me); *selfhood* (I am directly acquainted with the contents of my self-consciousness); and *perspectivalness* (phenomenal space is organized around a center, a supramodal point of view).

The notion that the self can be described—and de-constructed—as a *model* becomes immediately appealing because it provides a functional architecture that can be investigated by neuroscience at the neural level. We will briefly focus on how the issue of *perspectivalness* can be addressed from a neuroscientific point of view.

Our apparently unitary model of the world relies on the possibility to switch from one frame of representational reference to the other. Egocentric and allocentric perspectives coexist within the conscious self and at the same time define it. Our body is made of different parts, and indeed the neurophysiological literature on non-human primates has shown that different parts of the body (e.g., the eyes, the head, the hand) rely on different spatial frames of reference supported by specific, distinct neural circuits (see for review Colby and Goldberg, 1999). Some recent results of neurophysiological investigation clearly provide strong empirical evidence in favor of the existence of multiple neural "representations" of space. Far from supporting the view of a highly redundant system, this evidence points to the existence of distinct and specialized neural circuits whose "representational rules" vary along the dimension of the frame of reference.

Cortical areas integrating multiple sensory modalities such as area VIP and sectors of area PF in the posterior parietal cortex, and area F4 in the ventral premotor cortex, code the presence of objects within a limited space sector, peripersonal space (Gentilucci et al., 1988; Fogassi et al., 1996; Rizzolatti et al., 1997; Duhamel et al., 1998; Graziano and Gross, 1998). Peri-personal space is by definition a motor space, its outer limits being defined by the working space of the different body effectors. This spatial coding relies on an egocentric, often body parts-centered, frame of reference. Lesion of the ventral premotor cortex produces neglect in the near peripersonal space while leaving intact the awareness of far extrapersonal space (for review, see Rizzolatti, Berti and Gallese, 2000). What is relevant in the spatial coding implemented within these brain sectors is thus the location, with respect to the living body, of "something" that will eventually become the target of a purposeful action.

Space is therefore inherently dependent on the dynamic relation between agent and environment. Even more suggestive that this perspective is right are the data by Iriki and coworkers (1996, 2001). These authors discovered in a sector of the monkey posterior parietal cortex "bimodal" (visual and somatosensory) neurons that fired when a tactile stimulus was delivered to the monkey's hand and when visual objects were presented near the hand tactile receptive field. The striking characteristic of these neurons was that, during a reaching movement performed by the monkey with a rake, their visual receptive field expanded to include the entire length of the rake. In other words, the monkey's body schema changed when the tool was used: the tool was assimilated to the hand and became part of the visual hand representation. As a consequence, the far extrapersonal space reached by the rake was re-mapped as "near" peripersonal space, and the neurons that fired for near space also fired for the remapped far space.

This action-driven modulation of spatial maps has been shown also in humans. Berti and Frassinetti (2000) showed that when the cerebral representation of body space is extended to include tools that the subject uses, space previously mapped as far is treated as near. They described a patient (P. P.), who after a right hemisphere stroke, exhibited a clear neglect in near space in many different tasks such as line cancellation, reading, and line bisection. When the lines were positioned far from the body (approximately 1 m) and the patient bisected them using a laser pointer, neglect tended to disappear almost completely. However, when line bisection in far space was tested using a stick by means of which the patient could *reach* the line, neglect re-appeared and was as severe as neglect in near space. Like in monkeys, the use of a tool extended the body space of the patient up to include all the space between the body and the stimulus. As a consequence far space was remapped as near. Because near space was affected by the lesion, neglect re-appeared.

In conclusion what these studies suggest is that—both in monkeys and humans—action plays a crucial role in modifying spatial awareness. By acting differently in the world, our brain is capable—with a high degree of plasticity—to differently map sectors in space according to their relationship with the acting organism. Space is represented according to the way we act within it. The lesion of a specific part of this architecture impairs our phenomenal field of the corresponding space sector, but leaves intact other parts of space representation.

According to Metzinger (1993, 2000, 2003) *perspectivalness* anchors the viewpoint from which "the world outside" is experienced to a temporally extended, non-conceptual, supramodal, body-centered and therefore *embodied*, frame of reference. By exploring the functional properties of specific and different neural circuits, we have learned that the different parts of the body (e.g., the eyes, the head, and the hands) rely on different spatial frames of reference.

These results tell us that even one of the single features composing the self-model—perspectivalness—can be further decomposed, at the neuronal as well as at the neuropsychological level. Being a self depends on the acquired capacity: 1) to recognize the existence of multiple frames of reference, and 2) to put them in dynamic relation to each other by a continuous process of analogy and differentiation. It can be hypothesized that this capacity developed as the best adaptive solution to the powerful pressure exerted by multiple and, in principle, conflicting frames of reference.

The emergence of the self can be seen as the adaptive tool able to give coherence to these interacting levels of representation. If being a self is viewed as a particularly high level type of self-modeling, then the adaptive logic for human beings to model themselves, once rooted into an evolutionary perspective, can be traced back to more ancient mechanisms of which it may represent the sophisticated human homologue.

After reaching these tentative conclusions, however, we need a "glue" capable to give coherence to the *cubist* multiplicity of levels of descriptions produced by this deconstructivist account of some of the features of the self. Our suggestion is that a good candidate for "gluing the pieces together" might be Agency, in its double aspect of action generation and action representation (see below).

The Self-world Relationship: Actions on Objects

When acting upon the world of inanimate things, we are phenomenally aware of the sharp distinction between ourselves and the objects that are the target of our actions. However, if we investigate the neural mechanisms by means of which our brain presides over the interactions between self and world, that distinction, phenomenally so vivid, appears to blur to a considerable extent. In fact, while studying the role of the monkey ventral premotor cortex in the mechanisms of visuo-motor control of goal-related hand movements, a discovery was made. A particular class of premotor neurons—"canonical neurons"—were selectively activated when the monkey, in the absence of any active movement, observed objects whose intrinsic features, such as size and shape, were strictly related to the type of action that the very same neurons motorically coded (see Rizzolatti et al., 1988; Murata et al., 1997; Rizzolatti, Fogassi and Gallese, 2000; Gallese, 2000a). The most interesting feature of these neurons is that the vast majority of them show a strict congruence between their motor selectivity for a particular type of prehension they control and their visual selectivity for objects that require the same type of prehension in order to be grasped.

It is hard to conceptualize these responses in purely sensory or motor terms. It is more plausible to postulate that the objects whose observation triggers the neurons' response are analyzed in *relational* terms. Object observation, even within a behavioral context not specifically requiring an active interaction on the side of the observer, determines the activation of the motor program that *would be* required, were the observer being actively interacting with the object. To observe objects is therefore equivalent to automatically evoke the most suitable motor schema required to interact with them. Looking at objects means to unconsciously "simulate" a potential action. The object-*representation is transiently integrated* with the action-*simulation* (the ongoing simulation of the *potential* action). The very same sub-personal mechanism presides over both action and target specification.

If this interpretation is correct, objects are not merely identified and recognized by virtue of their physical "appearance", but in relation with the effects of the interaction with an agent. In such a context, the object acquires a meaningful value by means of its dynamic relation with the agent of this relation. This dynamic relation is multiple, as multiple are the ways in which we can interact with the world by acting upon it. The object-*representation* ceases to exist by itself. The object *phenomenally* exists to the extent it represents the target of an action. Experimental evidence suggests that the same functional architecture be at work also in the human brain. In a PET brain imaging experiment subjects were asked to simply observe three-dimensional objects. The results showed that object observation, in the absence of any overt motor demand, activated the same cortical premotor areas normally active when subjects are engaged in actions towards the same objects (Grafton et al., 1997).

These data emphasize the *intentional* character of representation. According to this perspective, *re-presentations* (see also Grush, 1997), as we qualify them, do not primarily originate—neither phylogenetically, nor onthogenetically—with a specific *semantic* value. This feature is likely the later result of the functional reorganization of processes originally selected for a different purpose. Such a scenario can be framed within the concept of "exaptation" introduced by Gould and Lewontin (1979), that is, the emergence of new skills (behavioral, mental and the like) that developed by exploiting in a totally new way resources that had been selected for other purposes. It has been submitted (see Gallese, 2000a,b, 2001) that this purpose is to achieve a better control of the dynamic relation between an open system—the living organism—and the environment. The capacity to entertain a representation of the external world is no more than a refined way to model the interaction between the agent and its environment. The notion of an acting self cannot be distinct from the notion of the targets of her/his actions.

Even in adult humans, who can clearly set a limit between self and non-self, nonself representation nevertheless is intrinsically related to functional architectures modeling the relationship between self and non-self. In order to be acted upon and "re-presented" the external object has to be somehow "introjected" by the agent's action schemata. Self and non-self can thus be defined as contrastive notions. This will become even clearer in the next section, where the *objects* will be the actions performed by other individuals.

The Self-world Relationship: The Actions of Others

In a series of single neuron recording experiments we discovered in two reciprocally connected sectors of the monkey brain, premotor area F5 and parietal area 7b, a particular set of neurons, activated not only during the execution of purposeful, goal related hand actions, such as grasping, holding or manipulating objects, but also when the monkey observed similar hand actions performed by another individual. We designated these neurons as "mirror neurons" (Gallese et al., 1996; Rizzolatti et al., 1996a; Gallese, 1999; Gallese, 2000a, 2001; Gallese et al., 2002; Umiltà et al., 2001; see also Rizzolatti, Fogassi and Gallese, 2000, 2001).

The sensorimotor integration process supported by the fronto-parietal F5-PF mirror matching system instantiates an "internal copy" of actions utilized not only to generate and control goal-related behaviors, *but also* to provide—at a pre-conceptual and pre-linguistic level—a meaningful account of behaviors performed by other individuals.

Several studies that used different methodologies have demonstrated also in humans the existence of a similar mirror system, matching action observation and execution (see Fadiga et al., 1995; Grafton et al., 1996; Rizzolatti et al., 1996b; Cochin et al., 1998; Decety et al., 1997; Hari et al., 1998; Iacoboni et al., 1999; Buccino et al., 2001). In particular, it is interesting to note that brain imaging experiments in humans have shown that during hand action observation a cortical network, similar to that present in the brain of the monkey, is activated (Grafton et al., 1996; Rizzolatti et al., 1996b; Decety et al., 1997; Decety and Grèzes, 1999; Iacoboni et al., 1999; Buccino et al., 2001).

Let us see more closely what relationship could exist between planning an action and understanding the action of others. When a given action is planned, its expected motor consequences are forecast. This means that when we are going to execute a given action we can also predict its consequences. Through a process of "equivalence" between what is acted and what is perceived, this information can also be used to predict the consequences of actions performed by others. This equivalence—underpinned by the activity of mirror neurons—is made possible by the fact that both predictions (of our actions and of others' actions) are simulation (modeling) processes. The same functional logic that presides over self-modeling is employed also to model the behavior of others. According to this perspective, to perceive an action is equivalent to internally simulate it. This *implicit*, *automatic*, and *unconscious* process of motor simulation enables the observer to use her/his own resources to penetrate the world of the other without the need of explicitly *theorizing* about it. A process of action simulation automatically establishes a direct implicit link between agent and observer (for a discussion of mirror neurons, empathy and simulation theory, see Gallese and Goldman, 1998; and Gallese, 2001, 2003a).

The developmental psychoanalytic trajectory of the self discussed by Milrod could well be translated into the language of neuroscience as a trajectory leading to more refined and sophisticated modes of self-modeling, by incorporating into the self-model the existence of other individuals. This trajectory, however, would be seriously impaired if the possibility to establish an intentional and emotional (see Gallese, 2001, 2003b) link between self and other couldn't occur. Autism could exemplify this lack of intentional and emotional link. The mirror matching system might therefore constitute a necessary ingredient for those links to be established. Indeed, it has been recently proposed within the psychoanalytic camp (see Wolf et al., 2000, 2001), that mirror neurons could ground a developmental sequence of the self similar to that proposed by Stern (1985). The mirror matching system could well be the sub-personal functional mechanism enabling the Sternian *affect attunement* to occur. Furthermore, the presence of a matching system bridging self and others could explain the *plasticity* of our notion of ourselves, constantly in balance between continuity and sameness on the one hand, and adjustment to external models, on the other.

The developmental psychoanalytic scenario proposed by Milrod emphasizes the role played by social relationships in determining the emergence of the self and its representation. These aspects are fully compatible with some of the empirical findings that we briefly summarized here. These findings provide possible sub-personal underpinnings to the analysis conducted by Milrod at the personal level.

Conclusions

Self-representation, object-representation and the representation of the actions of others appear to constitute different sides of a modeling manifold. Agency plays a crucial role in developing such a modeling manifold.

At the bottom end, even if using different perspectives and different vocabularies, neuroscience and psychoanalysis are indeed tackling the same issues. The results of neuroscientific investigation, especially some results, as those briefly summarized here, broaden the possibility to establish a dialogue between our disciplines. This dialogue seems very promising and fruitful especially on issues such as those addressed in Milrod's article. The development of interpersonal relationships and their role in shaping the acquisition of a full-blown, self-conscious self represent a perfect instantiation of possible targets for a future interdisciplinary research agenda. An interdisciplinary approach in our view is the only chance to provide an empirically firmly grounded account of the self without losing its rich connotations.

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