

# Psychopathology of the Bodily Self and the Brain: The Case of Schizophrenia

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## Key Words

Bodily self · Embodied simulation · Ipseity · Mirror neurons · Neuroscience · Psychopathology · Schizophrenia · Self-disturbances

## Abstract

In the present paper, we review the recent empirical evidence on the neurobiological basis of a minimal notion of the self, the bodily self. We show the relationship between the body, its motor potentialities and the notion of minimal self. We argue that this approach can shed new light onto self-disturbances and social deficits characterizing schizophrenia. We discuss our approach with other views on the neural correlates of self-disturbances in schizophrenia and propose that cognitive neuroscience can today address the classical topics of psychopathology by adding a new level of description, finally enabling the correlation between the first-person experiential aspects of psychiatric diseases and their neurobiological roots.

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## Introduction

The notion of ‘self’ is complex, multileveled and multifaceted. The concept of a minimal, prereflective or ‘core self’ [1] is currently under debate in cognitive neurosci-

ence, developmental psychology and philosophy of mind. However, it is not clear which empirical features such a minimal self should possess and which kind of experience concurs in shaping it. In particular, a central issue regarding the definition of the self as a minimalist level of subjective experience has brought up the potential contribution of bodily experience to its constitution. Some aspects of the minimal self proposed by contemporary philosophical and empirical research are: the notion of perspective and first-person perspective, the ‘mineness’ of the phenomenal field, the question of transparency, embodiment of point of view, and the issues of agency and ownership [2]. On the philosophical side, phenomenology emphasizes the necessity of embodiment of the self for all the above cited aspects of self-experience. As argued by Cermolacce et al. [2], in phenomenology ‘the field of experience is not yet considered to be *subjective* because this predicate already implies that there is a subject. For phenomenology, the very idea of the *subject* articulates itself in experience. In this sense, the manifestation and appearing of experience are the *conditions for* the experience of the subject in question’.

This philosophical standpoint should have important implications for empirical studies, especially for those investigating the neural correlates of self-consciousness or self-representations. Rather than searching for the neural correlates of a predefined, explicit and reflective self-knowledge, the first aim of empirical research should be

to investigate which kind of experience allows an implicit and prereflective self-knowledge to emerge and how. We think that interesting questions to be answered would be: 'What is the basic experience of ourselves as bodily selves? What enables us to implicitly distinguish ourselves, as bodily selves, from other human bodies?'

In the present paper, we review recent empirical studies that tried to answer these questions. We believe they not only help reveal the bodily bases of the minimal self but, most importantly, also enable to address some aspects of the psychopathology of schizophrenia, trying to relate crucial experiential aspects of this pathology with their neurobiological bases.

In the first part of the paper we describe the relationship between the body, its motor potentialities and the notion of minimal self. We then move to schizophrenia showing how this approach can shed new light on the self-disturbances and social deficits characterizing it. Finally, we discuss our approach with other views on the neural correlates of self-disturbances in schizophrenia. We conclude by arguing that this approach shows how contemporary cognitive neuroscience can address classic topics of psychopathology by adding a new level of description, finally enabling the correlation between the first-person experiential aspects of psychiatric diseases and their neurobiological roots.

### The Motor Roots of the Minimal Bodily Self

Contemporary research, when addressing the notion of the minimal self has focused mostly on the notions of body ownership, sense of agency and first-person perspective. Body ownership refers to 'the perceptual status of one's own body, which makes bodily sensations seem unique to oneself' [3]. Different studies on rubber hand illusion (RHI) [4] suggested that multisensory integration is the crucial mechanism leading to the experience of our body as our own. The RHI consists in watching a rubber hand being stroked together with one's own unseen hand. If the stroking of the rubber and real hands occurs synchronously, the position sense of the real hand shifts towards the location of the dummy hand. Participants report that they feel the dummy hand to be part of their body. However, as it was recently argued [5, 6], a lot of evidence shows that the multisensory integration leading to the experience of our body as our own, far from being the outcome of a mere visual-proprioceptive perceptual association [7], is conditioned by the possibility – or not – to perform actions with a given body part [8–10].

Sense of agency refers to the sense of being the one who generates an action. We recognize ourselves as agents on the basis of the congruence between self-generated movements and their expected consequences. This dominant role of action over other possible cues for self-identification is accounted for by the 'central monitoring theory' of action recognition [11, 12]. In its simplest form, this model holds that each time the motor centers generate an outflow signal for producing a movement, a copy of this command (the 'efference copy') [13] is retained and then compared with the reafferent inflow signals generated by the movement (e.g. visual, kinesthetic). A predictive component of the model anticipating the sensory consequences of the movement is such that, in the case of a self-produced movement, the actual sensory feedback will match the prediction. Otherwise, sensory signals will be referred to an external event.

However, as argued by Jeannerod [14], the central monitoring theory cannot explain the fact that sense of agency also arises in many situations where action representation is formed, but no movement is executed. Because circumstances where actions remain covert are frequent in our daily life, the existence of an overt behavior should not be a prerequisite for self-identification. Such circumstances occur, for example, in the case of mental motor imagery [15] or during the observation of others' actions [6, 16–18]. Starting from the concept of shared representations [19], Jeannerod [14] proposed 'the model of self/other differentiation as a rotate/simulate model: I first rotate myself at the location of the person I observe in order to specify her location in space. Then, I simulate the action I observe from that person in order to understand what she is doing'.

Finally, first-person perspective can be referred to the phenomenological idea that the world *appears* as constrained by a mobile bodily self, that is by the spatially located point of view, the orientation and the attitudes relative to the subject's sensorimotor background capacities [2]. In sum, all the notions adopted by contemporary research to answer the question of how we distinguish ourselves, as bodily selves, from other human bodies refer to a crucial role of the motor system.

In the same vein, and more radically, it has recently been proposed [5, 6] that there is a sense of body that is enactive in nature, enabling to capture the most primitive sense of self as bodily self. According to this perspective, the body is primarily given to us as source or power for action, that is as the variety of motor potentialities defining the horizon of our interaction with the world [5]. In sum, the minimal notion of the self, the bodily self, tac-

itly presupposes ownership of an action-capable agentive entity. Hence, this primitive sense of the self primarily rests on the workings of the motor system.

Let's now examine how such a notion of the bodily self is related to the brain. Neuropsychological and neuroimaging studies show that the body is a 'unique' object. Indeed, specific brain structures are involved in the visual processing of the human body [20–22]. Viewing nonfacial body parts selectively activates a lateral occipitotemporal cortex, called extrastriate body area, and an area located in the fusiform gyrus, the fusiform body area [22, 23]. Moreover, a topographically organized body part map has been described within the occipitotemporal cortex, with distinct clusters of voxels showing clear preference for different visually presented body parts [24]. In line with this evidence, a hand-selective region has been recently revealed in the left lateral occipital sulcus, partially overlapping with the extrastriate body area, which could be functionally and anatomically dissociated from it [25].

When processing a human body, a critical distinction can be made between one's own body and the body of others [26, 27]. Studies using different methods – behavioral, functional magnetic resonance imaging (fMRI), transcranial magnetic stimulation studies – have shown that the recognition of the 'self body' is independent from the recognition of other people's bodies. Interestingly, self-related body stimuli are processed faster and more accurately compared to other-related body stimuli (self-advantage [28, 29]).

The relationship between the minimal sense of self and the cortical motor system has recently been revealed. The motor experience of one's own body, even at a covert level, allows an implicit and prereflective bodily self-knowledge to emerge, leading to a self/other distinction, as measured, for example, by participants' faster responses during a mental rotation task to pictures of their dominant hand, with respect to others' hands [30]. The same study also showed that when participants were requested to explicitly discriminate between their hands and the hands of others, the self-advantage disappeared. Implicit and explicit recognition of the bodily self dissociated: only implicit recognition of the bodily self, mapped in motor terms, facilitated implicit bodily self processing.

A subsequent fMRI study by Ferri et al. [31] using a similar hand mental rotation task demonstrated that a bilateral cortical network formed by the supplementary and presupplementary motor areas, the anterior insula and the occipital cortex was activated during processing of participants' own hands. Furthermore, the contralat-

eral ventral premotor cortex (vPMC) was uniquely and specifically activated during mental rotation of participants' own dominant hands.

The vPMC might represent one of the essential anatomofunctional bases for the motor aspect of bodily selfhood, also in light of its role in integrating self-related multisensory information. This hypothesis is corroborated by clinical and functional evidence showing its systematic involvement with body awareness [32–34]. This evidence demonstrates a tight relationship between the bodily self-related multimodal integration carried out by the cortical motor areas specifying the motor potentialities of one's body and guiding its motor behavior and the implicit awareness one entertains of one's body as one's own body and of one's behavior as one's own behavior.

The vPMC is anatomically connected to visual and somatosensory areas in the posterior parietal cortex and to frontal motor areas, and for this reason it is plausible to assume that premotor cortex activity reflects the detection of congruent multisensory signals from one's own body and that this could be the mechanism responsible for the feeling of body ownership. The motor aspects of the bodily self enable the integration of self-related multimodal sensory information about the body and about the world the body interacts with. In the next section we show how such multimodal integration appears to be deficient in schizophrenia, possibly leading to both self-disturbances and social deficits.

### **Bodily Self and Schizophrenia: Loss of Implicit Self-Knowledge and Self-Other Differentiation**

Self-disturbance [35] is a complex notion including disturbed sense of presence, corporeality, stream of consciousness, self-demarcation and existential reorientation. All of these types of self-experience disturbance are evident in the prodromal period and are closely interrelated [36]. Such a complexity of the notion of self-disturbance in schizophrenia, however, somehow reflects the multileveled and multifaceted concept of self-experience.

Schizophrenia spectrum is described as a condition associated with disorders affecting the functioning of the 'minimal' or 'core self' [37], which is also referred to as 'ipseity' [38–40]. The notion of 'self-disorder' in schizophrenia indicates that the minimal self is fragile and unstable, being affected in its basic phenomenological aspects: phenomenality (appearing), first-person perspective and self-presence [2]. In line with this account, 'self-disorder' in schizophrenia has been elsewhere de-

scribed as a disembodiment of the self [41, 42]. As argued by Fuchs [41] the schizophrenic patient does not inhabit her body any more, in the sense of using as taken-for-granted its implicit structure as a medium for relating to the world.

More generally, the phenomenological approach to schizophrenia proposes the notion of embodiment as central to understand different symptoms, such as loss of self, loss of common sense and intentionality disorders. According to this approach, the coherence between such heterogeneous symptoms can be caught only if their common bodily roots are deemed [43]. Furthermore, the loss of the implicit functioning of the body in everyday life would lead also to the inability to interrelate with others [41, 44]. It has been proposed that social dysfunctions in schizophrenic patients would primarily spring from disturbances of bodily self-experience [40, 45, 46] rather than primarily concerning the intersubjective domain. It should be added, though, that the debated primacy either of the self or of intersubjectivity in social cognition is probably a sort of chicken-egg question. A distinctive feature of mammals in general, and of primates in particular, is to be born inside the other and with the other. Self and other are two self-contrasting notions: there is no self without the other and vice versa. Self and other are linked by means of a chiasmatic relation.

In a clinical case reported by Fuchs [41], a young schizophrenic patient experiences a progressive alienation from her bodily feelings, a sense of increasing difficulty in recognizing the way she moves or behaves. This sense of disembodiment leads her to rationalize this state by relying on a delusional explanation (others manipulated her brain). It is clear from this example that one of the first signs of schizophrenia consists in disturbances of the bodily self.

According to the notion that the experience of oneself as a bodily self likely relies on different body feelings and perceptions, various aspects of the bodily self have been found to be altered in schizophrenia, such as pain perception [47–50] and somatosensory processing [51, 52]. However, here we will not discuss about these specific deficits of the perception of the body. Instead, we will focus on the possible role of motor functions in a more general and basic disturbance of the bodily self in schizophrenia.

In a recent study [53] we showed that implicit knowledge about the bodily self is impaired and that self-other discrimination is problematic in first-episode schizophrenia patients that were submitted to the same experimental protocol employed by Frassinetti et al. [54]. In this

study implicit and explicit knowledge about the bodily self was assessed in two separate experiments. The two experiments employed as stimuli the participant's own and other people's body effectors (hands and feet) or the participant's own and other people's inanimate objects (shoes and mobile phones). In the first experiment the participants had to decide which of two images of body parts or objects matched a target image portraying the same body part or object. In the second experiment they had to explicitly determine which of two images of the same body part or object belonged to them. In both experiments half of the images portrayed the patients' own body parts, while the remaining half portrayed strangers' body parts. Results by Frassinetti et al. [54] showed that participants were more accurate in the implicit task with their own rather than with others' body effectors. In contrast, the self-advantage was not found when an explicit recognition of one's own body effectors was required. Moreover, when processing inanimate objects, both self/other and implicit/explicit effects were absent.

First-episode schizophrenic patients, at a difference from healthy controls, did not show the self-advantage effect in the implicit task. When explicitly required to recognize their own body parts, they did not show a self-advantage but showed a higher percentage of self-misattribution errors with respect to control participants [53]. These results show that first-episode schizophrenic patients suffer from a disturbed implicit sense of their bodily self. Self-other discrimination impairments in schizophrenia are already present at the very basic level of an implicit processing of body stimuli. When instead required to explicitly discriminate whether body parts presented on the screen were their own or not, schizophrenic patients beside failing in recognizing their own body parts compared to those of other people, as healthy controls, also tended to misattribute other people's body parts to themselves. On the basis of what was shown in the previous section, it is possible to hypothesize that the lack of the self-advantage effect in first-episode schizophrenic patients is mainly due to a disruption of their awareness of the bodily self as power for action.

A further proof of the close relationship among self-disturbance, defective sense of bodily self and social impairments in schizophrenia comes from an fMRI study on social perception of touch [55]. Twenty-four first-episode schizophrenic patients and 22 healthy control participants underwent fMRI during a social perception task requiring them to watch videos depicting other individuals' inanimate and animate/social tactile stimulations, and a tactile localizer condition in which the participants'

hand was touched. Activation in the vPMC for observed bodily tactile stimulations was reduced in the schizophrenic group and negatively correlated with self-experience disturbances as assessed with the Bonn Scale of Basic Symptoms. The vPMC could be a key structure underlying the breakdown of self-monitoring. Such an alteration could reasonably lead to the blurring of boundaries of the self and confusion in the interrelationship with others.

A second interesting finding of this study was the absence of blood oxygenation level-dependent suppression in the posterior insular cortex (pIC) observed in schizophrenic patients during the observation of touch in another individual. This finding indicates an impaired differentiation between self and other during social perception in first-episode schizophrenic patients that may reflect a deficit of the prereflective suppression of self-oriented affective arousal, likely normally contributing to the differentiation between self and other. Disturbances of bodily self-experience may have a primary role in schizophrenia and they may – at least partly – account for social deficits in schizophrenic patients.

A further element relating altered self-experience in schizophrenia with defective multisensory integration carried out by the vPMC comes from a recent study where we investigated sense of body ownership in schizophrenic patients by adopting a new way to induce the RHI [56]. In a previous study carried out on healthy volunteers [57], participants were seated with their right arm resting upon a table just below another smaller table. Thus, the real hand was hidden from the participant's view and a life-sized rubber model of a right hand was placed on the small table in front of the participant. The participant observed the experimenter's hand while approaching – without touching – the rubber hand. Phenomenology of the illusion was measured by means of skin conductance response and questionnaire. Both measures indicated that the participants experienced the illusion that the experimenter's hand was about to touch their hidden hand rather than the rubber hand, as if the latter replaced their own hand. This did not occur when the rubber hand was rotated by 180° or replaced by a piece of wood. This illusion indicates that our brain does not build a sense of bodily self in a merely reactive way, via perceptual correlations; rather it generates predictions on what may or may not belong to itself. Since embodiment of the rubber hand only occurred when the approaching experimenter's hand entered the participant's peripersonal space, the authors hypothesized that it depended on recruitment of the vPMC where body-related sensory information (i.e. tactile, visual and auditory) is integrated by neurons map-

ping the motor potentialities and controlling the actual movements of the same body parts [58], specifically by recruitment of the human homologue of macaque monkey area F4 [59, 60].

The very same experimental protocol was used to test schizophrenic patients [56]. Previous studies using the induction procedure described by Botvinick and Cohen [4] demonstrated an association between RHI and positive symptomatology in schizophrenia [61, 62]. They suggested that the underlying mechanisms responsible for positive symptoms in schizophrenic patients could have common features with the mechanisms causing the enhancement of the RHI [61]. Such mechanisms were subsequently shown to be related to alterations in associative higher-level neuronal activity [63], supporting the idea of spurious reconciliation between brain processes (e.g. vision, touch and proprioception) as a mechanism of brain pathology in schizophrenia. In our study [56] we induced RHI on schizophrenic patients by using the new procedure above described, which relies on tactile expectation, rather than on actual visuotactile integration. For this reason, it is not surprising that we found different results. Indeed, when submitted to the new version of the RHI, schizophrenic patients showed a sense of ownership over the rubber hand, although more weakly than healthy controls [50]. Furthermore, susceptibility to the RHI correlated with negative symptoms, since the self-reported strength of the illusion was related to an increased score on the anhedonia subscale of the Scale for the Assessment of Negative Symptoms. Anhedonia – the inability to experience pleasure – is a symptom of several psychiatric disorders. However, authors in the tradition of phenomenological psychiatry considered it as a fundamental manifestation of self-disturbance in schizophrenia [40]. These authors argued that anhedonia might be viewed as a facet of the core disturbance of self-experience in schizophrenia rather than as an independent dysfunction. Since, according to the same authors, the core abnormality in schizophrenia is a disturbance of sense of self or 'ipseity', and because ipseity is believed to be a necessary condition for the experience of many forms of pleasure, anhedonia has also been viewed as the outcome of a more profound alteration of self-experience [40]. In sum, the negative symptom of anhedonia would reflect a basic alteration of the mineness of experience and, as such, it seems to positively correlate with the patient's ownership over the rubber hand.

As shown in the previous section, the human vPMC is activated during the implicit processing of one's own hand [31]. Given that the vPMC appears to be hypofunc-

tional as well as negatively correlated with self-experience disturbances in schizophrenia [55], and since it has been demonstrated that patients show a defective implicit sense of their bodily self [53], we hypothesize that the defective anticipatory touch displayed by schizophrenic patients as demonstrated by the study of Ferri et al. [56] might share the same premotor origin [64].

### The Self, Schizophrenia and Brain Midline Regions

The literature we reviewed so far clearly supports the hypothesis that abnormalities of self-experience are elementary features of schizophrenic pathology. We particularly focused on empirical evidence of abnormalities of bodily self-consciousness in schizophrenia, such as the loss of the implicit recognition of self body parts, the explicit self-misattribution of the same body parts when belonging to others, the blurring of peripersonal space boundaries as well as of self-other boundaries. We discussed the association of these symptoms with dysfunctions of brain lateral cortices (i.e. vPMC and insula). At this point, however, it is fair to report also another perspective on self-disturbances in schizophrenia referring them to dysfunctions of brain midline regions involved in self-referential processes [65, 66] and the default mode network [67].

From this perspective schizophrenia has been associated with changes in functional connectivity [68] and homogeneity of the midline cortex [69], an anterior-to-posterior shift during self-reflection [70], as well as aberrant coupling within and across the default mode network and other brain networks [71]. Moreover, the PCC (posterior cingulate cortex) which is a crucial node of the default mode network [72] is commonly implicated in schizophrenia [73, 74].

Recent studies, however, suggest that these two perspectives on self-disturbances in schizophrenia, the one relating them with dysfunction of brain lateral cortices (i.e. vPMC and insula) and the other associating them with alterations of midline brain structures, are intimately interrelated [75]. As discussed above, vPMC and pIC are candidate brain regions underlying disturbances in both self-experience and self-other relationship. Results from functional interaction analysis in first-episode schizophrenia as compared to healthy controls showed aberrant functional interactions of the right vPMC and bilateral pIC with the PCC [75]. More specifically, increased functional coupling between vPMC and PCC was found to positively correlate with basic symptoms (sub-

jective self-experience disturbances). Moreover, the pIC showed reduced functional coupling with the PCC and postcentral gyrus and increased functional interactions with the anterior insula.

In sum, these data suggest that altered functional interactions of pIC and vPMC converge on the PCC. Ebisch et al. [75] interpreted these data in terms of imbalance in the processing between internally and externally guided information (pertaining to insular cortex and vPMC, respectively) and its abnormal integration with self-referential processing as mediated by the PCC. Finally, on the basis of these results it is possible to hypothesize that the complexity of the multifaceted self-disturbance in schizophrenia, including altered consciousness of the bodily self, likely relies on an imbalance in the functioning and the relationship between different brain networks, where midline structures may play a mediating role. Further studies are needed to confirm this hypothesis.

### Conclusions

The Italian psychopathologist Arnaldo Ballerini [76] in his last book on schizophrenia and subapophanic syndromes, echoing the words of Blankenburg [77], argues that the time has come to address schizophrenia starting from the 'transcendental deficit' of schizophrenic patients, which consists in their inability to simultaneously constitute the naturalness of the self and of its relationship with the world. This appears to be the fundamental ontological deficit from which the main ontic aspects of the disease, like negative and positive symptoms, derive. The constitution of the self, according to Ballerini, is intrinsically related to the constitution of the other as a self. Similarly to what happens to Meursault, the main character of Albert Camus' novel *L'Étranger* (1942), the autistic dimension of schizophrenia would be determined by the originary nuclear failure of the self in its constitutive movement towards the other.

As argued elsewhere [64], we believe that the potentiality for action our bodies normally instantiate might provide the core nucleus enabling to give form to the *bodily presence* characterizing a competent self-other relationship. The enigmatic nature of the world, particularly of the world of others, betrays the impossibility for schizophrenic patients to ground it into their defective bodily presence. We hypothesize that the empirical findings here reviewed represent preliminary evidence of the neural mechanisms underpinning defective forms of

bodily presence in schizophrenia. It is probably a useless exercise, as argues Ballerini [76, p. 142], trying to determine whether self or other constitution plays a primary causal role in the making of the natural evidence of the world, both being closely and inextricably intertwined.

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