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# **Mental Representations of the Body and Malleability of the Sense of Body Ownership in Schizophrenia within the Embodied Subject Model**

## **Abstract**

The presented study was intended to shed some new light on the disturbance of body experience in persons with schizophrenia in reference to the Embodied Subject Model. The model proposes to complement theoretical linkages between concepts related to bodiness – body self and mental representations of the body (body schema, body image, body awareness) and a relatively new concept of body identity. The main research questions were: Given that persons with schizophrenia are characterised by the painful experience of their body as an external object, would they also manifest i/ weakened sensorimotor integration mechanisms, ii/ disordered mental representations of the body, iii/ weakened sense of body ownership? 41 individuals with schizophrenia and 41 matched controls participated in the Rubber Hand Illusion procedure. Body representations were measured with a Battery of Tests of the Body Self Representations. The individuals with schizophrenia showed lower scores in three body representations and greater susceptibility to the rubber hand illusion. It suggests that the explanation of susceptibility to disturbances in the sense of body ownership should be focused on the deficient structure of mental representations of the body.

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mental body representations, body self, schizophrenia, body ownership, rubber hand illusion

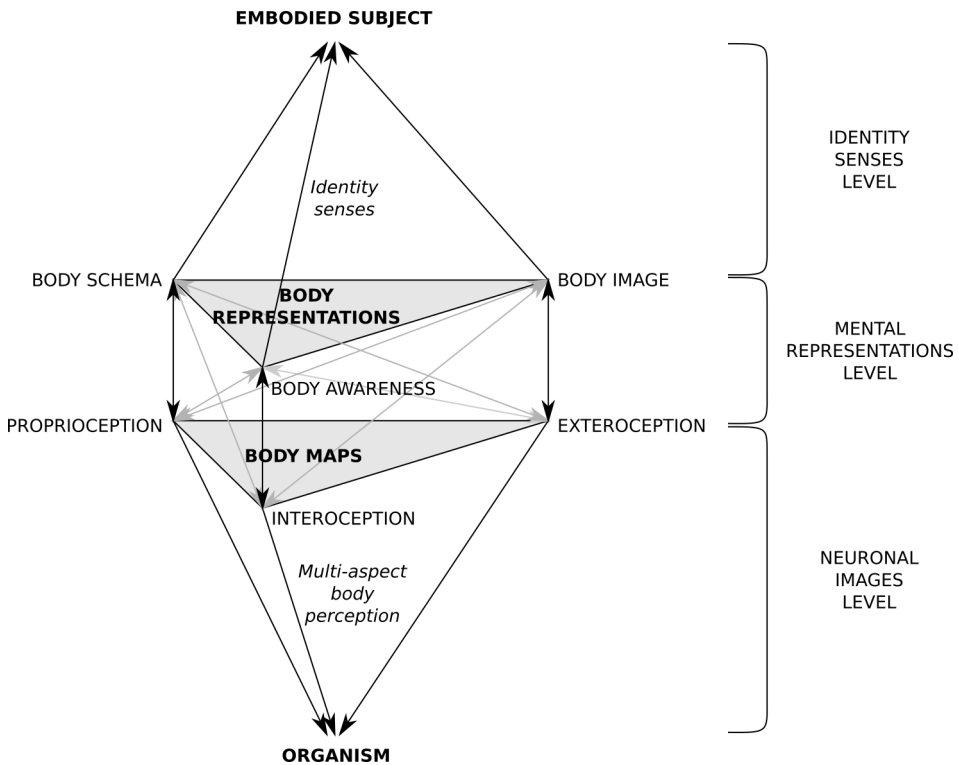
## 1. INTRODUCTION

Based on clinical evidence, schizophrenia can arguably be regarded as manifesting Descartes' error, i.e., the mental separation of body and mind (cf. Damasio, 1999). In schizophrenia, the body is experienced mainly as an external object rather than an integral dimension of an embodied subject (Sass & Parnas, 2003). Persons with schizophrenia demonstrate some typical disturbances in experiencing their own body: their sense of being alive is reduced (e.g., the body is experienced as dead, numb or insensitive), they perceive their bodies as deformed, unreal or dismembered (Rohricht et al., 2010; Rohricht & Priebe, 2002) and they demonstrate weakened sensorimotor integration mechanisms (Bittencourt et al., 2022; Carter et al., 2017). Additionally, they show disruptions in the processing of information in the attention monitoring system, leading to many disruptions in the experience of their own body, such as abnormal body awareness manifesting itself in motor inhibition and disruption of the sense of self (McGhie & Chapman, 1961). Hence, schizophrenia can be defined as a self-disorder (Parnas, 2011; Sass & Parnas, 2003) which is manifested on the most primitive level of the so-called minimal sense of self (Nelson et al., 2014), rooted in the pre-reflexive and pre-verbal bodily experience (Legrand, 2007; de Vignemont, 2011). Therefore, the disturbance of self in persons with schizophrenia (Bercovich et al., 2020; Lysaker et al., 2020) may involve difficulty with body-mind integration, which is significant in a mature self-experience of the embodied subject.

The study presented in this paper was intended to shed some light on how the disturbance of body experience works in persons with schizophrenia in reference to the Embodied Subject Model (Mirucka, 2018). The model points to philosophical theory, mainly phenomenological (e.g., F. Chirpaza, M. Merleau-Ponty), neurocognitive (e.g., S. Gallagher, A. R. Damasio, D. F. de Vignemont) and psychodynamic-developmental (e.g., D. W. Krueger, J. Bowlby, H. Kohut, D. W. Winnicott). It proposes to complement theoretical linkages between concepts related to bodiness – body self and mental representations of the body (body schema, body image, body awareness) and a relatively new concept of body identity.

## 2. THE EMBODIED SUBJECT MODEL (ESM)

According to the hypothetical embodiment model adopted here (Mirucka, 2018), the progression of body experience involves three principal phases: the first and the most basic level is that of neuronal maps, the second is the level of mental representations (including body schema, body image and body awareness), and the ultimate third phase consists in bodily identity senses (cf. Figure 1). Each of the three phases contributes uniquely and significantly to the embodiment process of a subject and the shaping of his individuality. The differentiation into three stages is motivated by the nature of the developmental function that predominates in each phase and the type of the resulting representation (structure). The subject, while making the transition to the next level of embodiment, builds the awareness of his own body (body as an object) and the consciousness of self as a corporeal entity (body as a subject): from pre-reflexive (non-verbal) self-awareness to symbolic (linguistic) consciousness of self (cf. Bucci, 2002).



**Figure 1**  
*The Embodied Subject Model*

The first and basic level of embodiment relies on complex neuronal mechanisms of perception: interoception, proprioception and exteroception that command precise and comprehensive signalling of bodily states. These comprise a neuronal somatosensory system that subjects the organism to multifaceted perceptions (continuous mapping). In other words, the organism – its state and various movements, is being registered in time-consistent neuronal patterns (or maps) that are not directly accessible to consciousness (Damasio, 1999). According to Damasio (1999), the sets of interlinked neuronal maps should be considered as a pre-conscious, biological predecessor of ‘I’, which is described as ‘proto-I’. Its chief task is to ceaselessly map the state of the organism’s multidimensional, physical structure. At this stage, the brain is indeed a ‘captive viewer’ of the organism (Damasio, 1999), and the sense of ‘I’ reflects the state of body function.

The neuronal body maps provide the foundation for shaping the second embodiment level. It comprises complex mental representations of the body, of which three are the most manifest: body schema, body image and body awareness. The key difference between the first level of embodiment (neuronal body maps) and the second (mental representations of the body) consists of the subject’s attitude to the information about its body. It means that all mental representations of the body reflect not an objective state of the organism but rather the subject’s emotional attitude toward it. The transition to the second stage of embodiment reveals a special ‘I – body’ relationship in which ‘I’ (body self), while receiving and processing bodily sensations, gives them an emotional tint, thus shaping them into a personal (subjective) experience. The type and strength of the emotions released in the process probably affect the quality of mental representations of the body in the most significant manner and, importantly, their mutual integration into a complex structure. The relationship between the subject and his body (or, more precisely, the information concerning his body) opens up space for bodily self-awareness that first emerges from a subtle connection between somatic information and a sensational aspect of emotions (i.e., pre-cognitive, pre-reflexive self-awareness), and then from complex mentalisations of body states (reflexive self-awareness: both pre-verbal and verbal).

The third and key stage of body subjectivisation sees an important role played by complex mental operations (including emotional, cognitive and volitional) that jointly process and modify body experience into even more complex mental structures, i.e., meta-representations. The difference between meta-representations and mental body representations is qualitative and derives from two distinct relations in mentalisation: i/ body – body self (for body representations), and ii/ body self – I (for meta-representations). In other words, the structure of body identity, in

contrast to mental representations of the body, pertains to the experience of higher order, which is produced in a reflexive-affective and, more importantly, valuational reference to body self (cf. Dempsey-Jones & Kritikos, 2014). The last stage of subjectivised embodiment appears to see valuational processes becoming the pivotal developmental mechanisms. Continually evaluating one's body experience for relevance to 'I' (self-esteem) constitutes a key motive in developing body identity (cf. Breakwell, 2010). Therefore, body identity, as an intra-mental dynamic system, constitutes a holistic experience of body self, whereby the 'I – my body' relation is superseded by the embodied subject manifesting in a complex structure of identity senses, which are key in self-determination. The most important of these include the sense of being, continuity of body self in time and space, inner consistency, separateness and bodily limits, self-acceptance as an embodied entity (Mirucka & Sakson-Obada, 2012), as well as the senses of body ownership (Giurgola et al., 2022) and agency (Carruthers, 2015).

According to ESM, body experience in normal development is inseparably linked to a holistic sense of self as a corporeal subject, which is assured by normative body processes on three levels: neuronal, mental and identity-related. The following question seems relevant in this regard: Given that persons with schizophrenia are characterised by the painful experience of their body as an external object, would they also manifest i/ weakened sensorimotor integration mechanisms, ii/ disordered mental representations of the body, iii/ weakened identity senses, and especially the sense of body ownership?

### 3. MENTAL REPRESENTATIONS OF THE BODY

Literature in the field lacks a shared understanding of the basic mental representations of the body. The most frequently used is the division into two major representations, i.e., body image and body schema, first introduced by Head and Holmes (1911) and upheld by contemporary scholars (Gallagher, 2005b). In Gallagher's understanding of embodiment, body image is regarded primarily as a perceptual image together with the representations of emotions (*body affect*) and convictions (*body concept*; Gallagher, 2005a). Although he does not explain the relationship between these elements, the omission seems to amplify the perceptual nature of body image. Thus, Gallagher sustains the tradition Schilder started in 1935, which defined body image by strong reference to the perceptual nature of the phenomenon. Presumably, Gallagher's representational dimension of body image (*body percept*) constitutes the axis around which other representations are built up and

are shaped into a multimodal structure which manifests more personal reference to the body, e.g., sensations, emotions, attitudes or convictions held about one's body (cf. Krueger, 2002; Mirucka & Sakson-Obada, 2012; Slade, 1994). In this expanded understanding of the notion, body image manifests as a complex and multidimensional phenomenon. Consequently, as Seymour Fisher suggested in 1986, we may be dealing with different images of the body self, not just one holistic body image. Thomas Pruzinsky and Thomas F. Cash (2002) firmly rejected the existence of one body image in favour of many different and often conflicting body representations.

Body schema plays a unique role in using and monitoring one's body. This pragmatic goal of body movement and control presents body schema as a basic neuronal matrix (Stamenov, 2005) that organises somatosensory sensations (interoceptive, proprioceptive, kinesthetic and tactile) and provides data on muscle tone, static positioning of the body, its balance and posture, skin stretch, homeostasis, mood, fatigue, and physical exertion (Pollio et al., 1997). Body schema is manifested on the mental level as i/ a sense of self as an object having specific characteristics (size, weight, density, temperature, complexity, etc.), located in three-dimensional space, and ii/ a sense of self in movement, performing various fine and gross motor activities.

Body awareness is a mental representation that arose from own body experience as the source of various bodily sensations, gradually formed into complex structures (bodily perceptions and states). The reception of basic body information – cardio-vascular, gastro-intestinal or osteoarticular ensures a fundamental form of contact with one's body, i.e., the awareness of the subjectivised body or body self (Krueger, 2002; Mirucka & Sakson-Obada, 2012). This awareness is shaped during the perception of bodily states, processes and actions that come mainly from interoception and proprioception (Damasio, 1999) but also from exteroception (de Vignemont, 2014; Mehling et al., 2009). Body awareness is multimodal by nature and relies on multisensory information, not just interoception or proprioception (de Vignemont, 2014). It means that body awareness ultimately takes the form of multimodal images that are more or less accessible to consciousness, depending on the intensity of the subject's attention afforded them.

Four key dimensions of body awareness are typically distinguished in operational definitions (Mehling et al., 2009). The first one is regarded as the most central and concerns the perception of somatic sensations or discerning subtle changes in bodily processes (e.g., muscular tension, fatigue, pain, etc.). The second concerns the attention paid to sensations, processes and body states. The third dimension has been defined as an attitude toward body information, i.e., how somatosensory

sensations are used. The fourth and ultimate domain concerns the relations between body sensations, on the one hand, and emotions and self-awareness as mind-body unity on the other, which is why it was termed the awareness of mind-body integration (Mehling et al., 2009). According to ESM, body awareness, body schema, and image make up an indissoluble triad of mental representations, which is invariably present in the subject's body experience.

#### **4. THE RHI PROCEDURE: EXPERIMENTAL TESTING OF THE SENSE OF BODY OWNERSHIP**

The possibility of carrying out experimental research on changes in body self-consciousness was offered by the Rubber Hand Illusion (RHI) procedure proposed by Botvinick and Cohen (1998). It involves the manipulation of the sense of body ownership in a manner which, in effect, causes the illusion of the incorporation of an external object and initiates an important trend of research regarding the sense of body ownership. Studies of this type became a part of the body transfer illusion (BTI) paradigm (Baum et al., 2022). A short, 10-minute synchronous tactile stimulation of two upper limbs: one artificial, placed in front of the person, the other being the participant's own limb hidden from his vision, is sufficient for the person to start perceiving the artificial hand as their own. Hitting the rubber hand with a hammer or pricking it with a pin demonstrates that the illusion proves sufficient to produce a very strong emotional reaction: the fear of being hurt, which is expressed by crying out, and an elevated galvanic skin response (Braithwaite & Brogna, 2014). Functional MRI detects the insula and anterior cingulate cortex (ACC) activation. Changes in interoceptive signals are also detected concerning fear and the sense of danger, which indicates that the rubber hand is structurally and emotionally incorporated into body representation (Ehrsson, 2007). At the same time, the subject's own hand, mentally separated from the body, manifests a disturbance in temperature control, which may indicate a slowdown in the processing of somatosensory information in that limb (Moseley et al., 2008).

The study employed the RHI procedure for two reasons, the first being related to its theoretical assumptions. Experimental induction of RHI provides a new manner of capturing and investigating body experience that is not limited to body image alone but constitutes, in fact, a multimodal body self-awareness, relying on exteroception, proprioception and interoception (de Vignemont, 2011). Thus, applying the procedure allowed for monitoring bodiness in its multiple aspects related to mental representations and the sense of body identity, such as body

ownership. The other reason reported in the literature is the effect that studies conducted on groups of patients with schizophrenia have shown their greater susceptibility to the rubber hand illusion (Germine et al., 2013; Peled et al., 2000, 2003; Thakkar et al., 2011).

## **5. THE EXPLANATIONS OF BODY OWNERSHIP DISTURBANCE IN THE RHI PROCEDURE**

The explanations of experimental disruption in the sense of hand ownership revealed two standpoints. The first one is represented by Botvinick and Cohen (1998) and strongly supported by Armel and Ramachandran (2003). These authors reject a unimodal source of the sense of body ownership. Their theory states that a person can only identify their own body through a combination of inputs picked up by three or more of their senses (vision, touch, kinesthesia); this process is known as multisensory integration. At the same time, one's mind produces the illusion from various stimuli: predominantly visual and, to a much lower extent, tactile. Sight takes over touch and makes adjustments to the tactile information. As a result, the source of proprioceptive sensations and the sense of ownership are displaced to the artificial hand. The rubber hand is thus experienced as one's own, even though the person knows it is not the case (de Vignemont, 2011). This explanation of susceptibility to the illusion relies on cross-modal matching between the visual and the tactile and the mechanism of bottom-up processing. During the RHI experiment, the participant's perception is completely immune to their knowledge about their own body (Armel & Ramachandran, 2003).

The second approach to susceptibility to the RHI indicates the importance of top-down processes, i.e., the significant influence of body representations (body schema or body image) on the emerging sense of rubber hand ownership. Researchers (Tsakiris & Haggard, 2005; Tsakiris et al., 2010) demonstrated in many experiments that the mere combination of sensory information (bottom-up processing) is insufficient for the illusion to appear. They argued in favour of the significance of top-down processes. In their interpretation, it is the knowledge about one's own body, i.e., the already developed, stable structure of mental representations of the body, that determines one's susceptibility to the rubber hand illusion.



According to the proposed ESM, both hypotheses appear equally valid and are not mutually exclusive. Patients with schizophrenia are probably equipped with a weak structure of mental representations of the body. This structure is central to body self-awareness and is affected by top-down processes expressed in meta-representations (or identity senses) and the bottom-up influence of neuronal maps formed by somatosensory functions. The following research hypotheses were adopted to verify, at least partially, the ESM:

H1 Persons with schizophrenia (SPR) are distinguished from persons with no SPR by inferior body representations.

H2 Persons with SPR show greater susceptibility to the rubber hand illusion than persons with no SPR, which is indicative of a/ weakened somatosensory integration, and b/ an inferior sense of body ownership.

## 6. MATERIALS AND METHODS

### PARTICIPANTS

The sample consisted of two groups, each with 41 participants aged from 19 to 49: a group of patients with SPR ( $M = 30.24$ ,  $SD = 7.03$ ) and a healthy control (HC) group ( $M = 25.44$ ,  $SD = 4.12$ ). Demographic data for each group are shown in Table 1. Participants for the group with SPR were recruited from outpatient therapy centres and for the HC group via advertisements placed at universities and in local community clubs. Diagnosis by ICD-10 criteria was based on medical records. The HC participants had no history of mental illness or neurological injury. In the group with SPR, 37 persons had been diagnosed with paranoid schizophrenia, and the remaining four – disorganised schizophrenia. All participants with SPR were receiving pharmacological treatment. Data collection procedures were approved by the Ethical Review Committee of the Faculty of Education, University of Białystok. All procedures performed in studies involving human participants followed the ethical standards of the institutional and national research committee, and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

**Table 1.** Demographic data

Demographic data	SPR group (n = 41)	HC group (n = 41)
Sex:		
female	18 (43.9 %)	19 (46.3 %)
male	23 (56.1 %)	22 (53.7 %)
Place of residence:		
village	6 (14.6 %)	3 (7.3 %)
town < 100 000	16 (39.0 %)	17 (41.5 %)
city > 100 000	19 (46.3 %)	21 (51.2 %)
Education:		
primary	1 (2.4 %)	
lower secondary	4 (9.8 %)	
basic vocational	5 (12.2 %)	4 (9.8 %)
upper secondary	21 (51.2 %)	18 (43.9 %)
higher	10 (24.4 %)	19 (46.3 %)
Marital status:		
single	38 (92.7%)	39 (95.1 %)
married	3 (7.3%)	2 (4.9 %)
	Mean SD	
Age of onset due to schizophrenia		
Duration of illness (years)	20.84 4.99	
Number of hospitalisations	7.58 5.06	
	2.61 2.7	

## MEASURES

Two declarative methods have been employed in the study: i/ A Battery of Tests of Body Self Representations (Mirucka, 2017), and ii/ the RHI procedure with subjective measurement using the RHI Questionnaire (Botvinick & Cohen, 1998).

### *A Battery of Tests of Body Self Representations (BT-BSR)*

Using this method, we can measure subjects' mental perceptions of their body self. A series of three separate tests encompasses the test kit: The Body Schema Test (BST), The Body Image Test (BIT) and The Bodily Awareness Test (BAT). The data are measured unidimensionally, individually for each sex and coded via deductive analysis. The responses are measured on a 7-point Likert Scale (starting at *I totally disagree* and going up to *I totally agree*). The formulation process of the BT-BSR involved several stages and followed guidelines for constructing

such psychological data collection tools. The BST comprises six Likert items that gauge the subject's range of perceived control over their own body and their ability to coordinate their movements. Subjects who scored high on this scale feel in control of their own bodies and do not struggle to control them. On the other hand, those who scored low feel exactly the opposite; their grasp over their bodies is weaker. A sample question from the BST test: "I think that my movements are not coordinated". The BIT questionnaire, like the previous test, comprises six questions. Unlike the previous test, however, it deals with the subject's exteroception, particularly their physical appearance perception. Subjects who score low on this scale are likely to have strong self-image issues and experience their appearance as a hindrance in their social interactions. High scores, conversely, reflect the subject's positive body image. A sample question from the BIT test: "I would like to have a different body build". Lastly, 15 questions make up the final questionnaire in the kit, the BAT test. This test is used to gauge the subject's interoception and proprioception. Subjects who score high on the scale are likely to exhibit high awareness of various signals originating from different body areas. However, those who scored low on this test have trouble processing and understanding such information. A sample question from the BAT test: "I feel tense most of the time". The BT-BSR shows satisfactory psychometric properties: good validity (construct and diagnostic) and high reliability. The reliability of the TB-BSR (Cronbach's alpha) in the present study is high: BST = .91, BIT = .88, and BAT = .87.

### *The RHI Questionnaire*

As an explicit measure of the embodiment illusion, the questionnaire is a self-reported method that captures the conscious experience of ownership. It consists of 9 statements describing specific perceptual effects that can be experienced to varying degrees during the RHI procedure (Botvinick & Cohen, 1998). All the statements are endorsed on a seven-point Likert scale ranging from -3 (*totally disagree*) to 3 (*totally agree*), and with 0 indicating uncertainty (*neither agreement nor disagreement*). The first three statements ("illusion-specific statements") describe sensations related to the illusory embodiment of ownership. They capture: i) an illusory localisation of touch on the rubber hand ("It seemed as if I was feeling the touch of the paintbrush in the location where I saw the rubber hand touched"), ii) a causal link between vision and touch ("It seemed as though the touch I felt was caused by the paintbrush touching the rubber hand"), and iii) an illusory feeling of ownership ("I felt as if the rubber hand was my hand"). The remaining six items (called control statements), even if similar to the illusion-specific statements, do not capture the phenomenological experience of ownership (e.g., "I felt as if my real hand were turning rubbery" or "The rubber

hand began to resemble my own hand in terms of shape, skin tone, freckles, or some other visual”). They served as controls for a participant’s compliance with the task (Botvinick & Cohen, 1998; Ehrsson et al., 2004).

To analyse the RHI Questionnaire data, first, the averages of the scores for 1) three illusion-specific statements, and 2) six control statements were computed to obtain a single ownership statement and single control statement scores, respectively. Second, the two single scores (illusion-specific and control statements) were compared. The experienced illusory rubber hand ownership criterion has an average rating  $\geq +1$ . It indicates that on the group level, the participants affirmed the statements (Ehrsson et al., 2004; Petkova & Ehrsson, 2008).

## PROCEDURE

An individual study was conducted according to the RHI paradigm. It consisted of three stages: 1) filling in a questionnaire with demographic data and BT-BSR, 2) the RHI procedure, 3) completing the RHI Questionnaire (Botvinick & Cohen, 1998). The total duration of the experiment did not exceed 40 minutes.

The conducted RHI procedure was similar to that introduced by Botvinick and Cohen (1998). Each participant was seated at a table (dimensions: 60cm x 120cm) with both hands resting on the tabletop. The left hand was hidden in a wooden box (dimensions: 21.5cm x 35cm x 50cm) so that the distance between the tips of the index fingers was 40 cm. A life-sized rubber model of a human hand was positioned in front of a participant’s left shoulder, which was covered with a piece of fabric coming out of a rubber wrist. The dummy hand was positioned within 20 cm of the subject’s right hand. The subjects would be asked not to move their hands and to pay close attention to the dummy hand next to them. The experimenter, seated opposite the subject, would then use a pair of matching paintbrushes to stroke the prosthetic hand and the subject’s obscured left hand simultaneously with identical and synchronised movements (at an approximate rate of 1Hz). The experience of body transfer illusion during the experiment was gauged through an RHI questionnaire provided to the participants. The proprioceptive drift was not evaluated for two reasons as an implicit measure of the rubber hand illusion. First, the goal was to simplify the experimental procedure for patients with schizophrenia in order to diminish their potential experimental anxiety. Second, new findings indicate that it might be invalid to use proprioceptive drift within the RHI to gauge subjects’ feelings of body ownership because different mechanisms of multisensory integration are responsible for proprioceptive drift and the feeling of ownership (Holle et al., 2011; Rohde et al., 2011).

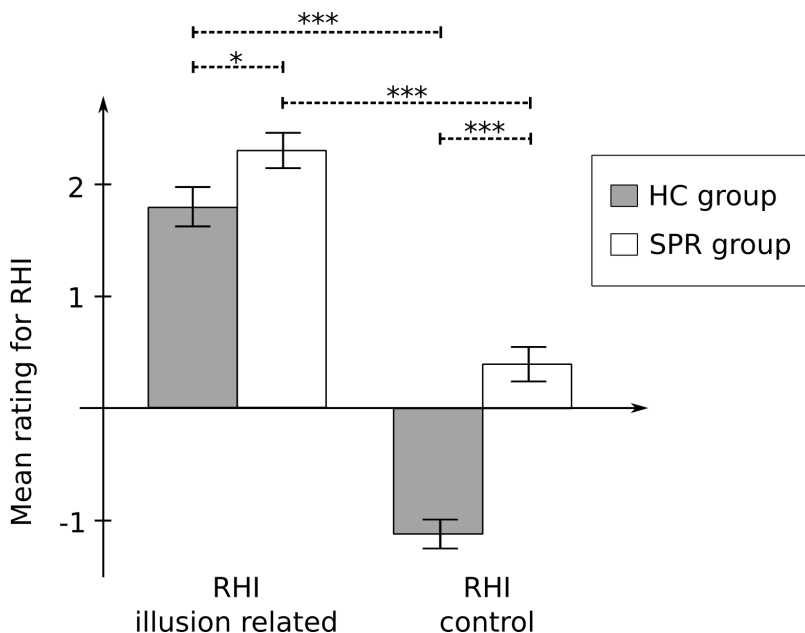
## RESULTS

First, SPR and HC research groups were compared regarding their answers to the RHI single questionnaire statements in synchronous stimulation conditions to investigate the susceptibility to disturbances in body ownership in schizophrenia. Student's t-test revealed that in each RHI statement the SPR group obtained a higher score than the HC group (Table 2). In the case of six items: S3, S5, S6, S7, S8, and S9, these differences were statistically significant. Unexpectedly, there were no significant differences between the research groups in the first two items (illusion-related statements): S1 and S2, whereas quite a large effect size was observed for the third statement, S3 (Cohen's  $d = .14$ )

**Table 2.** Questionnaire statements in synchronous stimulation in the two groups: HC and SPR, with mean and standard deviation of scores for each item: Student's t-test

Questionnaire RHI	Control group (HC) <i>n</i> = 41		Group with SPR <i>n</i> = 41		<i>t</i> (80)	<i>p</i>	Cohen's <i>d</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>			
S1. It seemed as if I were feeling the touch of the paintbrush in the location where I saw the rubber hand touched.	2.46	1.07	2.66	1.06	-.83	.41	-
S2. It seemed as though the touch I felt was caused by the paintbrush touching the rubber hand.	1.63	1.53	1.83	1.87	-.52	.60	-
S3. I felt as if the rubber hand were my hand.	1.29	1.65	2.41	1.07	-3.66	<.001	.14
S4. It felt as if my (real) hand were drifting towards the rubber hand.	-1.10	1.46	-.68	1.98	-1.08	.28	-
S5. It seemed as if I might have more than one left/right hand or arm.	-2.17	1.38	.27	2.04	-6.35	<.001	.33
S6. It seemed as if the touch I was feeling came from somewhere between my own hand and the rubber hand.	-1.24	1.39	-.32	1.69	-2.70	.01	.14
S7. It felt as if my (real) hand were turning rubbery.	-.24	1.83	1.19	1.52	-6.57	<.001	.35
S8. It appeared (visually) as if the rubber hand were drifting towards my hand.	-1.29	1.27	-.15	1.80	-3.34	.001	.12
S9. The rubber hand began to resemble my own (real) hand, in terms of shape, skin tone, freckles or some other visual feature.	.32	2.09	2.10	1.43	-4.50	<.001	.20

Second, the illusion-specific and control statement scores were compared between and in both research groups using an ANOVA test and the independent Student's t-test (Figure 2). ANOVA revealed that the HC and SPR groups differed significantly for illusion ownership  $F(1, 80) = 3.99; p < .05$ ; partial  $\eta^2 = .05$  and likewise for a control statement  $F(1, 80) = 48.07; p < .001$ ; partial  $\eta^2 = .37$ . According to the criterion of the illusory rubber hand ownership experience, it was demonstrated that on the group level, all the participants affirmed the statements. In other words, in both groups, the illusion-specific statement score was higher than the control statement score and was greater than 1. The dependent Student's t-test showed that these differences were significant both in the HC group  $t(40) = 17.94; p < .001$  and in the SPR group  $t(40) = 9.05; p < .001$ .



**Figure 2**

Mean ( $\pm$  standard error) scores calculated for single illusion-related and control statement RHI in the two groups: HC and SPR. Significance level: \*  $p < .05$ ; \*\*\*  $p < .001$

We used the MANOVA (multivariate analysis of variance) model to explore whether there were significant differences in the three body representations and susceptibility to disturbances in body ownership (S3) between the SPR group and the HC group. Box's M test produced a value of  $p = .132$  for non-significant values, which indicated a homogeneity of covariance matrices within our

research. The results were significant: Pillai’s Trace = 0.632,  $F(4, 77) = 33.07$ ;  $p = .001$ , partial  $\eta^2 = .63$ . Furthermore, the results of the test between participants indicated that there were significant differences based on groups in body schema  $F(1, 80) = 91.64$ ;  $p < .001$ ; partial  $\eta^2 = .53$ , body image  $F(1, 80) = 30.68$ ;  $p < .001$ ;  $\eta^2 = .28$ , and body awareness  $F(1, 80) = 120.67$ ;  $p < .001$ ;  $\eta^2 = .60$ . In particular, body awareness and body schema showed a considerable effect size ( $.53 < \text{partial } \eta^2 < .60$ ). A lower – although still considerable – effect size was observed for body image representation (partial  $\eta^2 = .28$ ). The method has revealed a statistically significant main effect of illusory ownership (RHI),  $F(1, 80) = 35.13$ ,  $p < .001$ , which shows that, in contrast to HC individuals, subjects afflicted with SPR were prone to encounter perturbations in their body ownership experience to a more extreme degree (Table 3).

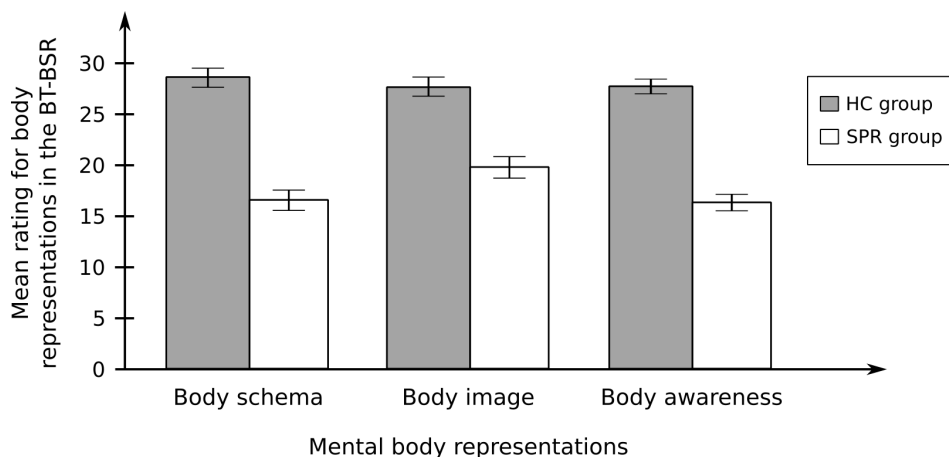
**Table 3.** A comparison of scores obtained in the BT-BSR and RHI by the group with SPR and the control group: MANOVA

Body representations	Group with SPR n = 41				Control group n = 41				Significance of differences F(1, 80)	Partial eta squared $\eta^2$
	M	SD	Min.	Max.	M	SD	Min.	Max.		
Body schema	16.54	6.03	2	30	28.58	5.34	16	37	91.64***	.53
Body image	19.83	6.87	2	35	27.73	6.01	15	36	30.68***	.28
Body awareness	16.36	4.94	7	26	27.76	4.43	19	36	120.67***	.60
RHI illusion related	49.90	9.15	18	66	38.32	8.54	12	55	35.13***	.30

Significance level: \*\*\*  $p < .001$

The mean scores obtained in both groups in three mental representations of the body showed two different structures (see Figure 3). The participants with SPR tend to score low in body schema ( $M = 16.54$ ;  $SD = 6.03$ ) and body awareness ( $M = 16.36$ ;  $SD = 4.94$ ), while at the same time they score higher in body image ( $M = 19.84$ ;  $SD = 6.87$ ). On the other hand, the configuration of body representations in the HC group is very homogeneous, which means that the mean scores in body schema ( $M = 28.58$ ;  $SD = 5.34$ ), body awareness ( $M = 27.76$ ;  $SD = 4.43$ ), and body image ( $M = 27.73$ ;  $SD = 6.01$ ) are high and very similar. Multivariate analysis of variance with two levels (groups) and three dependent variables: body image, body schema, and body awareness was conducted. There are significant

differences between the three body representations in both groups, MANOVA:  $\lambda$  Wilksa  $F(3, 78) = .04, p < .001$ .



**Figure 3**

Mean ( $\pm$  standard error) scores calculated for the body representations in the BT-BSR in the two groups: HC and SPR

## 7. DISCUSSION

The following assumptions underpinned the studies: i/ minimal sense of self are related to the disturbance of body experience, and ii/ patients with SPR fail to reach normative functioning as embodied subjects. Regarding the ESM accepted as a theoretical frame of reference, an attempt was made to partially explain the mechanism that underlies abnormal body experiences in patients with schizophrenia. Concerning this goal, three levels of body experience coming into the embodiment process were investigated in two groups populated by, respectively, patients with SPR and healthy persons: 1/ multisensory integration (i.e., the level of congruity between interoception, proprioception and exteroception), 2/ mental representations of the body (body schema, body image, body awareness), 3/ the sense of body ownership.

The studies were performed in the RHI paradigm (Botvinick & Cohen, 1998). The choice of the procedure was motivated by its capacity to affect changes in body awareness that could potentially be regarded as a tool to better understand multisensory integration processes and the sense of body ownership (cf. Ramakonar et al., 2011). The results obtained in the study have revealed that patients



with schizophrenia are much more susceptible to the disturbance of own body awareness, as compared to the healthy population. Although the two groups did not manifest significant differences for statements (S1) *an illusory localisation of touch on the rubber hand*, and (S2) *a causal link between vision and touch*, the average result for patients with SPR was statistically higher (significant) for (S3) *an illusory feeling of ownership*, which demonstrated a relatively large effect size. The outcome confirms the results of earlier studies with SPR patients in the RHI paradigm (Mirucka, 2016; Peled et al., 2000; Peled et al., 2003; Thakkar et al., 2011).

The results obtained in control statements are intriguing. While both groups satisfied the criterion of the experienced illusory rubber hand ownership (Ehrsson et al., 2004; Petkova & Ehrsson, 2008), the average results in control items (except S4) were significantly higher in the group with SPR. Particularly in questionnaire statements S5, S7, and S9, patients with SPR declared experience that is indicative of quite intense experimental disturbance in body awareness, which included the sense of i/ having more than one left hand (S5), ii/ the rubber hand becoming their own hand (S7), and the rubber hand resembling their own hand (S9). The high averages obtained by persons with SPR in illusion-specific and control statements can arguably indicate the disturbance of body experience on the multisensory integration level. While the illusion of fake hand incorporation can be induced to a high degree in all study participants without exception, the disturbance of body awareness in the other aspects, reflected in control items, was manifested only in persons with SPR. The co-existence of the experimental disturbance of body ownership with a broader spectrum of induced disruptions of body experience probably points to a significant weakening of sensory integration processes – interoception, proprioception and exteroception. Also, earlier studies suggested that bottom-up processing may have been involved in the emergence of the RHI (Armel & Ramachandran, 2003; Botvinick & Cohen, 1998; Costantini & Haggard, 2007).

In conformity with the ESM, multisensory integration provides the foundation for shaping coherent mental representations of the body (Mirucka, 2018). The presented studies have demonstrated that schizophrenia is very closely linked to the manner in which somatosensory experience is organised into mental body representations. The obtained results confirmed the veracity of the second hypothesis, whereby persons with SPR, as opposed to HC persons, manifest very weak mental representations of the body – body schema, body image and body awareness. This weakness in all body representations, coupled with a relative prominence of the body in the representational dimension, may point to disruptions in the level of sensorimotor processes. The dominance of a weakened body image

over extremely feeble representations of body schema and body awareness in persons with SPR is very likely to reflect the disturbance of all functions engaged in body perception, especially interoception and proprioception, pointing to their abnormal integration (cf. Blanke, 2012; Blanke & Metzinger, 2009; Ehrsson, 2012; Jeannerod, 2006). Persons with SPR, while relying on exteroception as their chief source of sensory information, are more susceptible to the RHI and experience the illusion more intensely, which signifies the disturbance of their body ownership. It would validate the reports of interoception being distinctly weakened in SPR, which translates into a weakened sense of one's own body. Consequently, visual information gains priority and underpins body experience, which leads to the objectivisation of the body and regarding it as alien, dissociated from the self, and even hostile. It explains why the third-person perspective is adopted instead of experiencing oneself as an embodied subject (the first-person perspective). Therefore, the disturbance of the self in SPR can be described as a disembodiment of the self (Fuchs, 2005; Stanghellini, 2009). It may signify that in SPR, the body self as a basic mental function responsible for, *inter alia*, the processing of bodily information of different modalities, instead of integrating with the mental self, functions in an increasingly isolated manner and escalates the state of mental separation between body and mind (Chapman et al., 1978; Klaver & Dijkerman, 2016; Petterson-Yeo et al., 2011).

Previous research has shown the multi-aspect nature of body experience disorders in persons with schizophrenia. For example, research based on the Body Self Model (Sakson-Obada et al., 2018) revealed differences in the functions of the body-self, in the aspect of body image and the sense of body identity between the control group and persons with schizophrenia. As a result, it was empirically confirmed that various dimensions of their body experience are disturbed at the same time. Based on similar assumptions, the ESM model goes a step further and makes it possible to track the dynamics of connections between all dimensions and thus determine the embodiment stages. Hence, it is possible to check if it is possible for a subject to make the transition to the next level of embodiment, build awareness of their own body (body as an object), and the consciousness of self as a corporeal entity (the body as a subject): from pre-reflexive (non-verbal) self-awareness to symbolic (linguistic) consciousness of self (cf. Bucci, 2002), or if the process stops or disintegrates at some stage. Therefore, we propose the ESM model as a comprehensive model enabling the description of the embodiment process in persons with schizophrenia.

Nonetheless, this study has several limitations to consider when interpreting and generalising its outcomes. Due to the relatively small number of participants,

the questionnaires were always presented in the same order. In future research, it would be worth using their random order. It would also be worth collecting a larger sample. The lack of measurement of proprioceptive drift or hand temperature makes it impossible to compare the results with other reports completely. It is worth repeating the research with their measurement in the future. An important issue that is worth taking into account when describing the functioning of people with schizophrenia is the possible impact of medicines on their experience of themselves in their bodies. Further research is needed to check what is specific to SPR group and what is a side effect of medications. When examining people with schizophrenia, it is also worth keeping in mind the specificity of their cognitive functioning, especially in terms of the reliability of responses in people diagnosed with paranoid schizophrenia.

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