Schizophrenia Research xxx (2013) xxx–xxx

Contents lists available at SciVerse ScienceDirect

Schizophrenia Research

journal homepage: www.elsevier.com/locate/schres

Upcoming tactile events and body ownership in schizophrenia

Francesca Ferri [a,b,c,*], Marcello Costantini [b,c,**], Anatolia Salone [b,c], Giuseppe Di Iorio [b,c,e], Giovanni Martinotti [b,c], Antonio Chiarelli [b,c], Arcangelo Merla [b,c], Massimo Di Giannantonio [b,c,e], Vittorio Gallese [a,d]

[a] Department of Neuroscience, University of Parma, Italy
[b] Department of Neuroscience and Imaging, University G. d'Annunzio, Chieti, Italy
[c] Institute for Advanced Biomedical Technologies — ITAB, Foundation University G. d'Annunzio, Chieti, Italy
[d] IIT (Italian Institute of Technology) Brain Center for Social and Motor Cognition, Parma, Italy
[e] Psychiatric Clinic "Villa Jolanda", Jesi, Italy

A R T I C L E I N F O

Article history:
Received 18 February 2013
Received in revised form 7 June 2013
Accepted 10 June 2013
Available online xxxx

Keywords:
Schizophrenia
Body ownership
Rubber hand illusion
Tactile expectation
Multisensory integration
Ipseity

A B S T R A C T

Schizophrenic patients may report unusual perception of their own body. Studies using the rubber hand illusion (RHI) proposed that they exhibit a distorted sense of body ownership. However, since the RHI is mostly achieved with the contribution of visuo-tactile integration, the stronger RHI observed in schizophrenic patients could reflect either a general increase of the response to multisensory stimuli or a larger influence of visual cues on the tactile sensory experience. The purpose of the present study is to investigate patients' perception of their own body by means of a behavioral paradigm that measures their proneness to the RHI without relying on multisensory integration occurring during actual experience of touch. In a previous study we demonstrated in healthy participants that expectation of touch experience arising at the sight of a human hand approaching a rubber hand is enough to induce a sense of ownership over the same hand. Here we take advantage of the same paradigm to investigate body ownership in schizophrenia. Patients observed the experimenter's hand while approaching – without touching – either a rubber hand or a piece of wood placed in front of them. The seen object could be either aligned to participant's hand or rotated by 180°. Phenomenology of the illusion revealed that schizophrenic patients exhibited sense of ownership over the rubber hand, but more weakly than healthy controls. The present study sheds new light on the experience of body ownership in schizophrenic patients, corroborating the notion that alterations of bodily self-awareness play an important role in schizophrenia.

1. Introduction

Schizophrenia-spectrum disorders have been described as psychiatric conditions critically associated with anomalies of self-experiences. Schizophrenic patients can suffer from deficits in self-recognition and self-attribution of thoughts and actions (Schneider, 1950). Unrevealing the processes that underlie these symptoms might shed some light on the human ability to make a distinction between self and non-self and on the origin of its disruption in schizophrenia. Accordingly, from the phenomenological perspective, recent investigations suggest that disturbances of basic self-experience are predictive of psychosis onset in the ultra high risk for psychosis prodromal population (Nelson et al., 2012).

Empirical research on self-recognition processes in schizophrenia mainly refer to a disruption of the sense of ownership, defined as the feeling that something is part of one's own body, and agency of action, defined as the subjective awareness that one is controlling one's own volitional actions in the world (for reviews see, for example, Cermolacce et al., 2007; Jeannerod, 2009; Moore and Fletcher, 2012). As highlighted by Waters and Badcock (2010), in general, studies on sense of body ownership and sense of agency examine specific cues contributing in their own unique way to the sense of self-recognition, such as sensory integration and body schema (body ownership processes), efferent motor signal processing and psychological binding experiences (action representation processes). In particular, previous studies investigating body ownership in schizophrenic patients used the rubber hand illusion (RHI, Botvinick and Cohen, 1998). To elicit this illusion, the participant's real hand is hidden from view while a rubber hand is placed in front of her. The experimenter generally uses two paintbrushes to stroke synchronously the rubber hand and the participant's hidden hand. After a short period (about 30 s), people have the

* Correspondence to: F. Ferri, Department of Neuroscience—Section of Physiology, University of Parma, Via Volturno 39, I-43100 Parma, Italy. Tel.: +39 0521 903881; fax: +39 0521 903900.
** Correspondence to: M. Costantini, Department of Neuroscience and Imaging, University of Chieti, Via dei Vestini 33, 66013 Chieti, Italy. Tel.: +39 0871 3556945; fax: +39 0871 3556930.
E-mail addresses: francesca.ferri@nemo.unipr.it (F. Ferri), marcello.costantini@unich.it (M. Costantini).

0920-9964/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.schres.2013.06.026

experience that the rubber hand is their own hand and that it is the rubber hand that senses the touch of the paintbrush. The experience of the illusion can be quantified by means of the proprioceptive drift. In this test participants verbally report, before and after the synchronous visuo-tactile stimulation, the perceived location of their hand (Tsakiris and Haggard, 2005). After synchronous visuo-tactile stimulation, people consider their hand to be closer to the rubber hand than it really was.

According to limited current knowledge, schizophrenia patients show higher sensitivity to the illusion as compared to healthy controls (Peled et al., 2000; Peled et al., 2003; Thakkar et al., 2011). Moreover, in patients, vividness of the illusion seems to be associated with elevated positive symptoms (Peled et al., 2000, 2003; Thakkar et al., 2011). However, sense of body ownership and its experimental proxy, that is the RHI, rely on the integration of sensory signals from different modalities (Botvinick and Cohen, 1998; Botvinick, 2004; Tsakiris and Haggard, 2005; Tsakiris, 2010; Ehrsson, 2012). Thus, when the visual and spatio-temporal signals received from a limb all match, a feeling of ownership then arises for that limb (Ehrsson, 2012).

Such constitutive role of the integration of actual multisensory signals in the RHI makes its use problematic to investigate sense of body ownership in schizophrenic patients. There is, indeed, enough evidence suggesting that multisensory integration is altered in schizophrenia (Foucher et al., 2007; de Jong et al., 2009; Seubert et al., 2010; Ebisch et al., 2013). For example, it has been demonstrated that schizophrenia patients show reduced McGurk effects (Pearl et al., 2009). The McGurk effect is a phenomenon where an auditory syllable is presented simultaneously with a silent video showing a model articulating an incongruent syllable which results in fused or combined syllable perception (McGurk and MacDonald, 1976). Schizophrenia patients also show reduced interference effects when detecting the emotional content of voices paired with facial expressions of a different emotion (de Jong et al., 2009), and patients benefit less from seeing the visual articulation of words when combined with noisy vocal presentations of the same words (Ross et al., 2007). It was suggested that these deficits result from impairments in higher-order speech processing and biological motion perception networks (Ross et al., 2007; Szycik et al., 2009); however, a more general disturbance of multisensory integration may also contribute to the phenomena. Accordingly, Williams, Light, Braff, and Ramachandran (Williams et al., 2010) recently revealed that schizophrenia patients show impairments in basic audio–visual integration. This observation was made by using a simple target detection task without a speech component.

We think that multisensory integration deficits should be carefully considered before reaching the conclusion that schizophrenic patients "might have a weaker or more flexible internal model of their body, making them more susceptible to the illusion" (Thakkar et al., 2011). Indeed, the stronger RHI observed in these patients (Peled et al., 2000; Peled et al., 2003; Thakkar et al., 2011) could reflect either a general increase of the response to multisensory stimuli (e.g., Stone et al., 2011), or a larger influence of visual cues on tactile sensory experience, compared to healthy participants. This would be also consistent with possible alterations of proprioception and somatosensory processing (Chang and Lenzenweger, 2005).

In the present study we explore the extent to which visuo-tactile integration contributes to susceptibility to the RHI in schizophrenia, by using a procedure in which no tactile stimulation is applied and multisensory integration is elicited only by anticipation of touch experience. Indeed, we want to rule out the possibility that the stronger RHI observed in schizophrenic patients, compared to controls, is due to an imbalanced contribution of vision and experience of touch. To this aim we take advantage of a new induction procedure of the RHI (Ferri et al., in 2013), that is, without delivering synchronized visuo-tactile stimuli. In this new induction procedure, participants observe a rubber hand being approached but not touched, while their own hand is out of sight. Obtaining the same results as with the classic RHI induction procedure would mean that higher susceptibility to "classic" RHI in patients does not rely either on actual stimulation nor on the overweighting of visual over tactile information, but it likely reflects a more flexible internal model (Thakkar et al., 2011). However, one could also hypothesize different scenarios. 1) Patients might experience RHI as much as control participants, which would indicate that higher susceptibility to "classic" RHI in patients does rely on actual stimulation and overweighting visual information so that when actual stimulation is absent, visuo-tactile integration seems generally unimpaired. 2) Patients might experience RHI less than control participants, which would indicate that higher susceptibility to "classic" RHI in patients does rely on actual stimulation and that anticipation, rather than actual experience of touch, is not sufficient to create ownership over the rubber hand in schizophrenic patients. In this case, it would be also possible that altered self experiences, that is, disturbed body ownership manifesting itself as lower susceptibility to RHI, could be differently related to symptomatology. In particular, it could be associated with negative symptoms, whereas higher susceptibility to RHI could be associated with positive symptoms.

2. Methods

2.1. Participants

21 schizophrenic patients (SCZ; 11 inpatients, 10 outpatients) and 17 control participants (HC) were included in the present study (Table 1). Patients were diagnosed according to the structured clinical interview for DSM-IV. Exclusion criteria for all participants comprised significant medical or neurological illness, substance abuse or dependence in the previous six months, IQ < 85, and, for the HC group, a personal history of Axis I/II disorders or a history of psychosis in first-degree relatives. SCZ and HC groups were matched for age, gender and education. SCZ patients were recruited from outpatient services at Chieti mental health department and from inpatients at the psychiatric clinic "Villa Jolanda". The mean illness duration was 12,16 ± 9,33 years. The SCZ group had intellectual capacities in the range of the average healthy population (IQ mean scores = 104.7 ± 6.5). Chlorpromazine equivalents were calculated (Woods, 2003) for antipsychotics (Table 1). The study was approved by the Ethics Committee of Chieti University. Written informed consent was obtained from all participants after full explanation of the procedure of the study, in line with the Declaration of Helsinki.

2.2. Evaluation scales

SCZ patients were evaluated by the structured clinical interview for DSM-IV Axis I disorders (SCID-I) (First et al., 1996b) to establish axis I diagnoses. They were rated for symptom severity using the brief psychiatric rating scale (BPRS; Overall and Gorham, 1962), the scale for assessment of positive symptom (SAPS) and the scale for assessment of negative symptom (SANS; Andreasen, 1984a, b) (Table 1). Patients' intelligence quotient (IQ) was evaluated by means of the Raven standard progressive matrices (SPM).

HC participants were evaluated by means of the structured clinical interview for DSM-IV for Axis II personality disorders (SCID-II) (First et al., 1996a). All the evaluation scales were administered by trained psychiatrists.

2.3. Procedure

Participants sat in front of a table. The right arm was placed on the table in a relaxed position at a fixed point inside a frame. A smaller table, measuring 80 by 30 cm and 20 cm in height, was positioned over the table where the real hand was placed (see Fig. 1). This table was used to both hide participants' hand and to support the object (i.e. the rubber hand or the piece of wood, see the Experimental design section). The participants' hand and the viewed object were aligned on the vertical axis and were positioned at 20 cm from each other. The experimenter stood at the participant's right side, hidden behind a black curtain. She moved her hand towards the viewed object (which varied according to the experimental condition, see the Experimental design section) with a velocity of 0.02 m/s, starting from a distance of 70 cm from the viewed object and stopping at 15 cm away from the viewed object. The experimenter's hand never touched the viewed object. The experimenter, previously trained, followed audio instructions by earphones to perform controlled movements during the experiment. The consistency of movement direction and speed across trials was allowed by four pairs of switches fixed onto two vertical rods 70 cm in height, enabling to record experimenter's movements, speed and position. The 4 switches were positioned on each rod at 60, 45, 30, 15 cm from the object, respectively. A further switch was positioned at the starting point (70 cm). Each switch fed a signal to the PowerLab (ADinstrument), thus allowing post-hoc validation of experimenter's hand movements.

2.4. Experimental design

The experimental design was 2 × 2 factorial. The two factors were: the object (Rubber hand vs. Piece of wood) and the Position of the object (Congruent vs. Incongruent) relative to the participant's hidden arm. The rubber hand was a realistic prosthetic hand. The piece of wood was a plain wooden block, pale and beige in color, with a thumb-like feature and with one end tapered into a wrist-like shape. The four conditions were: i) Rubber Hand Congruent — the rubber hand was aligned to the participant's own hand and the experimenter moved her hand towards the rubber hand; ii) Rubber Hand Incongruent — the rubber hand was rotated 180° relative the participant's own hand and the experimenter moved her hand towards the rubber hand; iii) Wood Congruent — the piece of wood was aligned to the participant's own hand and the experimenter moved her hand towards the wood; and iv) Wood Incongruent — the piece of wood was rotated 180° relative the participant's own hand and the experimenter moved her hand towards the wood. Stimuli had comparable overall size.

The experiment consisted of four blocks, one for each of the four experimental conditions, whose presentation order was counterbalanced between participants. Each block lasted 2 min during which 4 approaching movements were performed. At the beginning of the experimental session, participants were instructed to pay attention to the experimenter's hand moving towards either a rubber hand or a piece of wood placed in front of them. After receiving instructions participants wore earphones through which white noise was delivered for the entire duration of each block. After each block participants took off earphones and were required to complete the RHI questionnaire.

2.5. RHI questionnaire

We adopted a total of 15 questions from Longo et al. (Longo et al., 2008). The questions referred to two different components of the experience of embodiment during the RHI paradigm: (a) Ten statements referring to the embodiment of rubber hand. These comprised items relating to the feelings that: the rubber hand belonged to the participant, the participant had control over the rubber hand, the rubber hand and real hand were in the same location, and the rubber hand had taken on features of the actual hand. (b) Five statements referring to the experience of loss of one's hand. These comprised items relating to the feelings of: being unable to move one's hand, one's hand disappearing, and one's hand being out of one's control. Participants completed four versions of the questionnaire, one for each experimental condition. Participants answered each statement by choosing a number from a 7-point Likert Scale, from "-3 being strongly in disagreement", and "+3 being strongly in agreement". The questions appeared

Table 1
Demographic information about schizophrenia group (SCZ) and healthy control group (HC).

	SCZ (n° = 21)	HC (n° = 17)
DSM-IV schizophrenia type		
Paranoid, n° (%)	10 (47.6%)	n.a.
Disorganized, n° (%)	6 (29%)	n.a.
Catatonic, n° (%)	0 (0%)	n.a.
Undifferentiated, n° (%)	4 (19.05%)	n.a.
Residual, n° (%)	1 (4.7%)	n.a.
Age (mean ± SD)	41.1 ± 11.4	46.6 ± 13.9
Female sex (n°)	0	0
Handedness		
Right, n° (%)	21 (100%)	17 (100%)
Left, n° (%)	0 (0%)	0 (0%)
Education (mean ± SD)	11.5 ± 3.5	12.0 ± 3.3
Illness duration (mean ± SD)	12.2 ± 9.3	n.a.
SCID-II	n.a.	Negative
BPRS (mean ± SD)	42.7 ± 9.2	n.a.
SAPS (mean ± SD)		
Hallucinations	4.7 ± 5.4	n.a.
Delusions	8.0 ± 7.3	n.a.
Bizarre behavior	2.6 ± 3.4	n.a.
Formal thought disorders	7.0 ± 6.8	n.a.
SANS (mean ± SD)		
Affective flattening	10.9 ± 8.2	n.a.
Alogia	4.5 ± 4.7	n.a.
Avolition–apathy	6.3 ±3.3	n.a.
Anhedonia–asociality	10.6 ± 4.4	n.a.
Attention	3.2 ± 2.7	n.a.
Chlorpromazine equivalent (mg/die)	404.0 ± 268.2	n.a.
Typical antipsychotic, n° (%)	2 (9.5%)	n.a.
Haloperidol	1 (4.8%)	
Levopromazine	1 (4.8%)	
Atypical antipsychotic, n° (%)	13 (61.9%)	n.a.
Clozapine	1 (4.8%)	
Risperidone	8 (38.1%)	
Quetiapine	3 (14.3%)	
Atypical + typical antipsychotic, n° (%)	6 (28.6%)	n.a.
Quetiapine + haloperidol	3 (14.3%)	
Risperidone + haloperidol	2 (9,5%)	
Risperidone + chlorpromazine	1 (4.8%)	

in random order. The mean ratings (see Fig. 2) for each component (Embodiment, Loss of own hand) of the experience of embodiment per condition were submitted to two separate multivariate ANOVA for repeated measures with object (Rubber hand vs. Piece of wood) and Position of the object (Congruent vs. Incongruent), as within-subject factors, and Group (SCZ vs. HC) as between-subject factor. In a further analysis we focused on the two sub-components distinguished by Longo et al., (Longo et al., 2008) within the "embodiment of the rubber hand" general component, namely (a1) ownership and (a2) location, to assess whether they were equally involved during the induction of the RHI in both HC and SCZ. Post-hoc comparisons were performed using the Newman–Keuls methods when necessary.

Pearson's correlation coefficients were used to evaluate the association between the vividness of the illusion and the severity of positive and negative symptoms in SCZ.

3. Results

(a) Embodiment questions
The main effects of Object ($F(1,36) = 41.0$ $p < 0.001$; $\eta^2_p = 0.53$) and Position of the object ($F(1,36) = 68.5$ $p < 0.001$; $\eta^2_p = 0.65$) were significant, as well as their interaction with the group (object by Group: $F(1,36) = 9.0$ $p < 0.01$; $\eta^2_p = 0.20$; Position of the object by Group: $F(1,36) = 5.1$ $p < 0.05$; $\eta^2_p = 0.12$). The interaction between the two within-subject factors was also significant ($F(1,36) = 56.5$, $p < 0.001$ $\eta^2_p = 0.61$). Post hoc comparisons showed higher mean rating for the Hand Congruent (0.35) condition as compared to all the

Please cite this article as: Ferri, F., et al., Upcoming tactile events and body ownership in schizophrenia, Schizophr. Res. (2013), http://dx.doi.org/10.1016/j.schres.2013.06.026

other conditions (−2.0, −1.6, and −2.1 for Hand Incongruent, Wood Congruent, and Wood incongruent, respectively; all p-values < 0.001; see Fig. 2). Importantly, there was also a significant Group by Object by Position of the object interaction ($F(1,36) = 8.7$, $p < 0.01$ $\eta^2_p = 0.20$). Both groups showed higher mean rating for the Hand Congruent condition as compared to all the other conditions (all p-values < 0.001), however HC (1.05) showed higher mean rating for the Hand Congruent condition as compared to SCZ patients (−0.21; $p < 0.01$). The other experimental conditions did not differ between HC and SCZ (all p-values > 0.40).

(b) Loss of one's hand questions

The main effects of Object ($F(1,36) = 17.4$ $p < 0.001$; $\eta^2_p = 0.33$) and Position of the object ($F(1,36) = 9.7$ $p < 0.001$; $\eta^2_p = 0.21$). The interaction between the two within-subject factors was also significant ($F(1,36) = 4.8$, $p < 0.05$ $\eta^2_p = 0.12$). Post hoc comparisons showed higher mean rating for the Hand Congruent (−0.4) condition as compared to all the other conditions (−1.21, −1.27, and −1.4 for Hand Incongruent, Wood Congruent, and Wood incongruent, respectively; all p-values < 0.01; see Fig. 2). Importantly, there was also a significant Group by Object by Position of the object interaction ($F(1,36) = 5.6$, $p < 0.05$ $\eta^2_p = 0.14$). The interaction was explained by the HC showing higher mean rating for the Hand Congruent (−0.1; all p-values < 0.001) condition as compared to all the other conditions (see Fig. 2). The same difference was not observed in SCZ patients (all p-values > 0.41).

Fig. 1. Experiment setup to evaluate rubber hand illusion. The experimenter moved her hand towards the viewed object (which varied according to the experimental condition, see the Experimental design section) with a velocity of 0.02 m/s starting from a distance of 70 cm from the viewed object and stopping at 15 cm away from it. The experimenter's hand never touched the viewed object. White noise was delivered through the headphones. EH: Experimenter's Hand; RH: Rubber Hand.

(a1) Ownership questions

The main effects of Object ($F(1,36) = 66.5$ $p < 0.001$; $\eta^2_p = 0.65$) and Position of the object ($F(1,36) = 71.4$ $p < 0.001$; $\eta^2_p = 0.62$) were significant, as well as their interaction with the group (object by Group: $F(1,36) = 10.7$ $p < 0.01$; $\eta^2_p = 0.23$; Position of the object by Group: $F(1,36) = 4.4$ $p < 0.05$; $\eta^2_p = 0.11$). The interaction between the two within-subject factors was also significant ($F(1,36) = 49.5$, $p < 0.001$ $\eta^2_p = 0.58$). Post hoc comparisons showed higher mean rating for the Hand Congruent (0.28) condition as compared to all the other conditions (−2.1, −2.3, and −2.5 for Hand Incongruent, Wood Congruent, and Wood incongruent, respectively; all p-values < 0.001; see Fig. 2). Importantly, there was also a significant Group by Object by Position of the object interaction ($F(1,36) = 6.7$, $p < 0.05$ $\eta^2_p = 0.16$). Both groups showed higher mean rating for the Hand Congruent condition as compared to all the other conditions (all p-values < 0.001), however HC (1.08) showed higher mean rating for the Hand Congruent condition as compared to SCZ patients (−0.37; $p < 0.01$). The other experimental conditions did not differ between HC and SCZ (all p-values > 0.54).

(a2) Location questions

The main effects of Object ($F(1,36) = 6.8$ $p < 0.05$; $\eta^2_p = 0.16$) and Position of the object ($F(1,36) = 77.3$ $p < 0.001$; $\eta^2_p = 0.68$) were significant. The interaction between the two within-subject factors was also significant ($F(1,36) = 13.0$, $p < 0.001$ $\eta^2_p = 0.26$). Post hoc comparisons showed higher mean rating for the Hand Congruent (1.2) condition as compared to all the other conditions (−1.5, −0.12, and −1.4 for Hand Incongruent, Wood Congruent, and Wood incongruent, respectively; all p-values < 0.001; see Fig. 2). The interaction Group by Object by Position of the object was not significant ($p > 0.1$).

4. Correlation analysis

In patients, we explored the relationship between self-reported illusion vividness, as revealed by the ownership questions in each experimental condition and subscales of the SAPS and SANS. Self-reported RHI strength in the rubber hand congruent, but not in all the other experimental conditions was related to increased score on the anhedonia subscale of the SANS (Pearson's $r = 0.67$, $p = 0.001$, see Fig. 3).

5. Discussion

We investigated the malleability of body ownership in schizophrenic patients by taking advantage of a new induction procedure of the RHI that relies on tactile expectation rather than proper visuo-tactile stimulation (Ferri et al., in 2013). This paradigm allowed us to explore the extent to which visuo-tactile integration contributes to susceptibility to the RHI in schizophrenia.

Schizophrenic patients and healthy controls viewed the experimenter's hand approaching either a rubber hand or a non corporeal object located just above their hidden real hand. Phenomenology of illusion was measured by questionnaires adapted from Longo et al. (Longo et al., 2008). Results indicated that both schizophrenic patients and healthy 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° with respect to their own hand or replaced by a piece of wood. Importantly, schizophrenic patients showed lower mean rating for the Rubber Hand Congruent condition, as revealed by the embodiment statements, compared to healthy controls. The mean rating for the other conditions did not differ between groups.

Please cite this article as: Ferri, F., et al., Upcoming tactile events and body ownership in schizophrenia, Schizophr. Res. (2013), http://dx.doi.org/10.1016/j.schres.2013.06.026

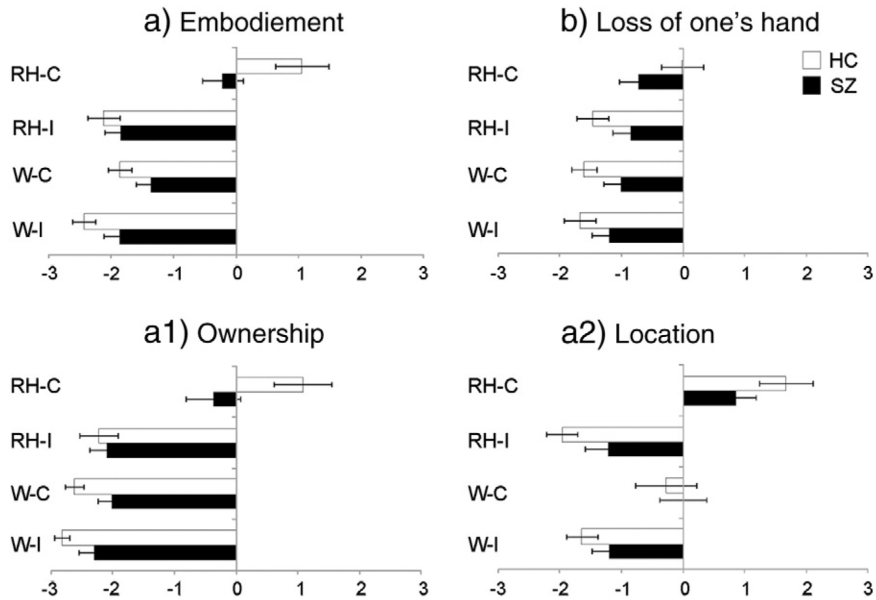

Fig. 2. Mean ratings for the Embodiment statements, for the Loss of one's hand statements, for the Ownership statements and for the location statements. RH-C: Rubber Hand Congruent; RH-I: Rubber Hand Incongruent; W-C: Wood Congruent; W-I: Wood Incongruent. Error bars indicate standard errors.

Interestingly, to further elucidate the experience of the body during the rubber hand illusion, an additional ANOVA was conducted on the sub-components of embodiment statements, namely ownership and location. This ANOVA revealed that schizophrenic patients and healthy controls differed in terms of ownership of the Rubber hand, but not in terms of location of the rubber hand. In the words of Longo et al. (2008), patients would seem to have a deficit in the "me-ness" of experience, but not the "here-ness" of experience.

We also found that sense of ownership over a rubber hand positively correlates with negative symptomatology. Previous studies using the induction procedure described by Botvinick and Cohen (1998) demonstrated an association between RHI and positive symptomatology in schizophrenia (Peled et al., 2000; Thakkar et al., 2011). 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 (Peled et al., 2000). Such mechanisms were subsequently shown to be related to alterations in associative higher-level neuronal activity (Peled et al., 2003), supporting the idea of spurious reconciliation between brain processes (e.g., vision, touch and proprioception) as a mechanism of brain pathology in schizophrenia. In the present study we induced RHI by using a new procedure (Ferri et al., 2013) relying on tactile expectation, which likely involves a different set of brain processes. Briefly (see Ferri et al., 2013, for extensive discussion), we believe the evidence we provide that expectation of a rubber hand being touched is enough to induce a sense of ownership over the same rubber hand supports the hypothesis that our brain does not build a sense of bodily self in a merely reactive way, via perceptual correlations, but rather it generates predictions on what could be ours or not. For this reason, it is not surprising that we found enhancement of RHI being positively related to negative, rather than positive, symptoms in schizophrenic patients. In particular, SANS ratings of anhedonia significantly correlated with patients' reports of sense of body ownership over the rubber hand. Despite anhedonia – the inability to experience pleasure – is a symptom of several psychiatric disorders (i.e., depression, drug and alcohol dependence), authors in the tradition of phenomenological psychiatry regard it as one manifestation of self-disturbance that is fundamental in schizophrenia (Sass and Parnas, 2003). They argue that anhedonia may be viewed as a facet of the core disturbance of self-experience in schizophrenia, rather than as an independent dysfunction. According to the same authors (Sass and Parnas, 2003), the core abnormality in schizophrenia is a disturbance of sense of self or "ipseity", which refers to a crucial sense of being the subject of experience (Ricoeur, 1992). In general, normal ipseity is believed to be a necessary condition for the experience of many forms of pleasure. Consequently anhedonia, as the attenuation or even disappearance of various forms of pleasure, has been also viewed as an outcome of a more profound alteration of self-experience (Sass and Parnas, 2003). In sum, the negative symptom of anhedonia would reflect a basic alteration of the mine-ness of experience and, as such, it seems to positively correlate with patients' ownership over the rubber hand.

To date only few studies investigated body ownership in schizophrenia. For instance, Peled and colleagues (Peled et al., 2000) submitted schizophrenic patients to a rubber hand illusion and found stronger onset of the illusion as compared to healthy controls. However, these authors only administered synchronous stimulation, thus providing only partial evidence of body ownership deficits in schizophrenic patients. The RHI is, indeed, typically measured on the basis of the difference between the ratings after synchronous and asynchronous stimulation or, alternatively, on the basis of the difference between the ratings after having observed a life-size rubber hand and a non-corporeal object (e.g. a piece of wood or a stick), as in our case. In a more recent study, Thakkar and colleagues (Thakkar et al., 2011) implemented both the synchronous and the asynchronous conditions. This study has also the merit of measuring the illusion both with subjective (e.g. questionnaire) and objective (e.g. proprioceptive drift, autonomic responses) methods. In particular, with respect to the subjective measures Thakkar and colleagues did not find a significant interaction group by synchrony, likely because schizophrenic patients' mean ratings were equally high in the synchronous and the asynchronous condition in most of the statements. With respect to the proprioceptive drift, they did find higher drift in the synchronous as compared to the asynchronous condition, but only in schizophrenic patients. This effect, which is the hallmark of the RHI, was not observed in healthy controls. Finally, with respect to the autonomic measures, the authors did not find an effect of synchrony. Based on these results, the authors, in agreement with previous investigations (Peled et al., 2000; Peled et al., 2003), proposed embodiment of the RH to be stronger in schizophrenic patients than in healthy controls.

How can we reconcile our results with those of Peled and colleagues and Thakkar and colleagues? As illustrated in the Introduction section,

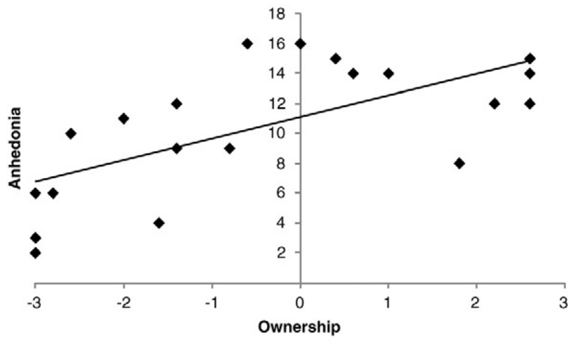

Fig. 3. Scatter plot of anhedonia scores against sense of ownership over the rubber hand.

"classic" RHI relies on the integration of actual sensory signals from different modalities (Botvinick and Cohen, 1998; Tsakiris and Haggard, 2005; Costantini and Haggard, 2007; Tsakiris et al., 2011), a process that seems to be compromised in schizophrenic patients. The comparison between results from the previous studies using the "classic" induction procedure and from the present study suggests that higher susceptibility to "classic" RHI in patients does rely on actual stimulation, likely arising from a larger influence of visual cues on the tactile sensory experience, or from a general increase of the response to multisensory stimuli (e.g., Stone et al., 2011). Indeed, in absence of actual visuo-tactile signals, like in the present study, no higher susceptibility to RHI is observed in patients, even if multisensory integration is still elicited, but through anticipation mechanisms. Furthermore, the fact that patients experience RHI less than control participants, when using the new induction procedure, indicates that anticipation of touch is not sufficient for them to experience the RHI.

A possibility is that schizophrenic patients do not anticipate the touch in the same way that controls do. Indeed, impairments in anticipating the position of a moving stimulus have been reported in schizophrenia–most extensively in the domain of smooth pursuit eye movements (Ross et al., 2000). Accordingly, investigation of the implicit processing of asynchrony by means of the Simon effect (i.e., the finding that manual responses are biased to the side of the stimulus) suggested that predictive mechanisms allowing anticipation of upcoming events are impaired in patients, who would rather rely on reactive mechanisms in order to perceive asynchrony. Indeed, patients appeared to process stimuli as if isolated rather than following each other (Lalanne et al., 2012).

When we firstly reported our anticipation-based procedure to induce the RHI (Ferri et al., 2013), we also proposed that it likely recruits activity in the ventral premotor cortex (vPMC), specifically in a region representing the human homologue of monkey F4 (Bremmer et al., 2001). This brain region, indeed, has been described as having multisensory properties (Graziano, 1999; Graziano, 2001) and being involved in the dynamic mapping of the peri-personal space (e.g., Rizzolatti et al., 1997), as well. Moreover, neuroimaging studies have recently shown that human vPMC is activated during the implicit processing of one's own hand and face (Cardini et al., 2011; Ferri et al., 2012a). Given that the vPMC appears to be hypofunctional as well as negatively correlated with self-experience disturbances in schizophrenia (Ebisch et al., 2013), and since it has been demonstrated that patients show a defective implicit sense of their bodily self (Ferri et al., 2012b), we hypothesize that the lack of anticipatory touch displayed by schizophrenic patients in the present study might share the same premotor origin (see also Gallese and Ferri, in press).

In conclusion, schizophrenic patients seem to experience the RHI differently from control subjects. This happens both when actual tactile stimuli are actually delivered, as demonstrated by Thakkar et al. (2011) and Peled et al. (2000, 2003), as well as when touch is only expected, as in the present study. However, the direction of the RHI findings in schizophrenia, compared to control participants, seems to be specifically associated with symptomatology in each case. Disturbed body ownership manifesting itself as higher susceptibility to RHI when actual multisensory stimuli are delivered has been suggested to contribute to psychotic symptoms (Thakkar et al., 2011). On the other hand, we suggest that disturbed body ownership manifesting itself as lower susceptibility to RHI when actual multisensory stimuli are absent might contribute to negative symptoms, such as anhedonia. In particular, in schizophrenic patients this could be associated with altered predictive processes allowing anticipation of touch experience.

Thus, RHI is able to highlight a specific difference between patients and controls in the bodily self experience (Ferri et al., 2012b). However, to fully understand the outcome of the RHI, more systematic investigations are required. Indeed, one major limitation of our study is that only subjective reports were used and we have no indication whether patients in this sample may have been less forthcoming with reporting the illusion or subject to response bias. New investigations might help to understand under which conditions the RHI in patients is stronger or weaker than in healthy participants and, in general, how environmental inputs and specific alterations of their integration/processing differently affect the relation between self experience and symptomatology.

Role of funding source

The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Contributors

Francesca Ferri and Marcello Costantini conceived and designed the study, wrote the protocol, collected the data, undertook the statistical analyses, managed the literature searches and wrote the manuscript.

Vittorio Gallese conceived and designed the study.

Anatolia Salone selected the patients and wrote the manuscript.

Giuseppe Di Iorio, Giovanni Martinotti, Massimo Di Giannantonio selected the patients.

Antonio Chiarelli and Arcangelo Merla designed the experimental set up.

All authors contributed to and have approved the final manuscript.

Conflict of interest

The authors have no financial or ethical conflict of interest to declare.

Acknowledgment

This work was supported by the EU grant TESIS (Towards an Embodied Science of InterSubjectivity).

References

Andreasen, N.C., 1984a. Scale for the Assessment of Negative Symptoms (SANS). University of Iowa, Iowa City, Iowa.

Andreasen, N.C., 1984b. Scale for the Assessment of Positive Symptoms (SAPS). University of Iowa, Iowa City, Iowa.

Botvinick, M., 2004. Probing the neural basis of body ownership. Science 305 (5685), 782–783.

Botvinick, M., Cohen, J., 1998. Rubber hands 'feel' touch that eyes see. Nature 391 (6669), 756.

Bremmer, F., Schlack, A., Shah, N.J., Zafiris, O., Kubischik, M., Hoffmann, K., Zilles, K., Fink, G.R., 2001. Polymodal motion processing in posterior parietal and premotor cortex: a human fMRI study strongly implies equivalencies between humans and monkeys. Neuron 29 (1), 287–296.

Cardini, F., Costantini, M., Galati, G., Romani, G.L., Ladavas, E., Serino, A., 2011. Viewing one's own face being touched modulates tactile perception: an fMRI study. J. Cogn. Neurosci. 23 (3), 503–513.

Cermolacce, M., Naudin, J., Parnas, J., 2007. The "minimal self" in psychopathology: re-examining the self-disorders in the schizophrenia spectrum. Conscious. Cogn. 16 (3), 703–714.

Chang, B.P., Lenzenweger, M.F., 2005. Somatosensory processing and schizophrenia liability: proprioception, exteroceptive sensitivity, and graphesthesia performance in the biological relatives of schizophrenia patients. J. Abnorm. Psychol. 114 (1), 85–95.

Costantini, M., Haggard, P., 2007. The rubber hand illusion: sensitivity and reference frame for body ownership. Conscious. Cogn. 16 (2), 229–240.

de Jong, J.J., Hodiamont, P.P., Van den Stock, J., de Gelder, B., 2009. Audiovisual emotion recognition in schizophrenia: reduced integration of facial and vocal affect. Schizophr. Res. 107 (2–3), 286–293.

Ebisch, S.J., Salone, A., Ferri, F., De Berardis, D., Romani, G.L., Ferro, F.M., Gallese, V., 2013. Out of touch with reality? Social perception in first-episode schizophrenia. Soc. Cogn. Affect. Neurosci. 8 (4), 394–403.

Ehrsson, H.H., 2012. The Concept of Body Ownership and Its Relation to Multisensory Integration. MIT Press, Cambridge, MA.

Ferri, F., Frassinetti, F., Ardizzi, M., Costantini, M., Gallese, V., 2012a. A sensorimotor network for the bodily self. J. Cogn. Neurosci. 24 (7), 1584–1595.

Ferri, F., Frassinetti, F., Mastrangelo, F., Salone, A., Ferro, F.M., Gallese, V., 2012b. Bodily self and schizophrenia: the loss of implicit self-body knowledge. Conscious. Cogn. 21 (3), 1365–1374.

Ferri, F., Chiarelli, A.M., Merla, A., Gallese, V., Costantini, M., 2013. The body beyond the body: expectation of a sensory event is enough to induce ownership over a fake hand. Proc. R. Soc. B: Biol. Sci. 280 (1765).

First, M.B., Spitzer, R.L., Gibbon, M., Williams, J.B.W., 1996a. Structured clinical interview for DSM-IV Axis I disorders, clinician version (SCID-CV). American Psychiatric Press, Washington, DC.

First, M.B., Gibbon, M., Spitzer, R.L., First, M.B., Gibbon, M., Spitzer, R.L., 1996b. Structured clinical interview for DSM-IV Axis II personality disorders, (SCID-II, version 2.0). Psychiatric Institute. New York: Biometric Research Department, New York State.

Foucher, J.R., Lacambre, M., Pham, B.T., Giersch, A., Elliott, M.A., 2007. Low time resolution in schizophrenia Lengthened windows of simultaneity for visual, auditory and bimodal stimuli. Schizophr. Res. 97 (1–3), 118–127.

Gallese, V., Ferri, F., 2013. Jaspers, the body and Schizophrenia: the bodily self. Psychopathology (in press).

Graziano, M.S.A., 1999. Where is my arm? The relative role of vision and proprioception in the neuronal representation of limb position. Proc. Natl. Acad. Sci. U. S. A. 96 (18), 10418–10421.

Graziano, M.S.A., 2001. A system of multimodal areas in the primate brain. Neuron 29 (1), 4–6.

Jeannerod, M., 2009. The sense of agency and its disturbances in schizophrenia: a reappraisal. Exp. Brain Res. 192 (3), 527–532.

Lalanne, L., Van Assche, M., Wang, W., Giersch, A., 2012. Looking forward: an impaired ability in patients with schizophrenia? Neuropsychologia 50 (12), 2736–2744.

Longo, M.R., Schüür, F., Kammers, M.P.M., Tsakiris, M., Haggard, P., 2008. What is embodiment? A psychometric approach. Cognition 107 (3), 978.

McGurk, H., MacDonald, J., 1976. Hearing lips and seeing voices. Nature 264 (5588), 746–748.

Moore, J.W., Fletcher, P.C., 2012. Sense of agency in health and disease: a review of cue integration approaches. Conscious. Cogn. 21 (1), 59–68.

Nelson, B., Thompson, A., Yung, A.R., 2012. Basic self-disturbance predicts psychosis onset in the ultra high risk for psychosis "prodromal" population. Schizophr. Bull.

Overall, J.E., Gorham, D.R., 1962. The brief psychiatric rating scale. Psychol. Rep. 10 (3), 799–812.

Pearl, D., Yodashkin-Porat, D., Katz, N., Valevski, A., Aizenberg, D., Sigler, M., Weizman, A., Kikinzon, L., 2009. Differences in audiovisual integration, as measured by McGurk phenomenon, among adult and adolescent patients with schizophrenia and age-matched healthy control groups. Compr. Psychiatry 50 (2), 186–192.

Peled, A., Ritsner, M., Hirschmann, S., Geva, A.B., Modai, I., 2000. Touch feel illusion in schizophrenic patients. Biol. Psychiatry 48 (11), 1105–1108.

Peled, A., Pressman, A., Geva, A.B., Modai, I., 2003. Somatosensory evoked potentials during a rubber-hand illusion in schizophrenia. Schizophr. Res. 64 (2–3), 157–163.

Ricoeur, P., 1992. Oneself as Another. The University of Chicago Press, Chicago.

Rizzolatti, G., Fadiga, L., Fogassi, L., Gallese, V., 1997. The space around us. Science 277 (5323), 190–191.

Ross, R.G., Olincy, A., Harris, J.G., Sullivan, B., Radant, A., 2000. Smooth pursuit eye movements in schizophrenia and attentional dysfunction: adults with schizophrenia, ADHD, and a normal comparison group. Biol. Psychiatry 48 (3), 197–203.

Ross, L.A., Saint-Amour, D., Leavitt, V.M., Molholm, S., Javitt, D.C., Foxe, J.J., 2007. Impaired multisensory processing in schizophrenia: deficits in the visual enhancement of speech comprehension under noisy environmental conditions. Schizophr. Res. 97 (1–3), 173–183.

Sass, L.A., Parnas, J., 2003. Schizophrenia, consciousness, and the self. Schizophr. Bull. 29 (3), 427–444.

Schneider, K., 1950. Die psychopatischen Personlichkeiten (9th edn). Deuticke, Vienna.

Seubert, J., Loughead, J., Kellermann, T., Boers, F., Brensinger, C.M., Habel, U., 2010. Multisensory integration of emotionally valenced olfactory–visual information in patients with schizophrenia and healthy controls. J. Psychiatry Neurosci. 35 (3), 185–194.

Stone, D.B., Urrea, L.J., Aine, C.J., Bustillo, J.R., Clark, V.P., Stephen, J.M., 2011. Unisensory processing and multisensory integration in schizophrenia: a high-density electrical mapping study. Neuropsychologia 49 (12), 3178–3187.

Szycik, G.R., Munte, T.F., Dillo, W., Mohammadi, B., Samii, A., Emrich, H.M., Dietrich, D.E., 2009. Audiovisual integration of speech is disturbed in schizophrenia: an fMRI study. Schizophr. Res. 110 (1–3), 111–118.

Thakkar, K.N., Nichols, H.S., McIntosh, L.G., Park, S., 2011. Disturbances in body ownership in schizophrenia: evidence from the rubber hand illusion and case study of a spontaneous out-of-body experience. PLoS One 6 (10), e27089.

Tsakiris, M., 2010. My body in the brain: a neurocognitive model of body-ownership. Neuropsychologia 48 (3), 703.

Tsakiris, M., Haggard, P., 2005. The rubber hand illusion revisited: visuotactile integration and self-attribution. J. Exp. Psychol. Hum. Percept. Perform. 31 (1), 80–91.

Tsakiris, M., Tajadura-Jiménez, A., Costantini, M., 2011. Just a heartbeat away from one's body: interoceptive sensitivity predicts malleability of body-representations. Proc. R. Soc. B Biol. Sci. 278 (1717), 2470–2476.

Waters, F.A., Badcock, J.C., 2010. First-rank symptoms in schizophrenia: reexamining mechanisms of self-recognition. Schizophr. Bull. 36 (3), 510–517.

Williams, L.E., Light, G.A., Braff, D.L., Ramachandran, V.S., 2010. Reduced multisensory integration in patients with schizophrenia on a target detection task. Neuropsychologia 48 (10), 3128–3136.

Woods, S.W., 2003. Chlorpromazine equivalent doses for the newer atypical antipsychotics. J. Clin. Psychiatry 64 (6), 663–667.

Please cite this article as: Ferri, F., et al., Upcoming tactile events and body ownership in schizophrenia, Schizophr. Res. (2013), http://dx.doi.org/10.1016/j.schres.2013.06.026