Schizophrenia Research xxx (xxxx) xxx

Contents lists available at ScienceDirect

Schizophrenia Research

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

Shared multisensory experience affects *Others'* boundary: The enfacement illusion in schizophrenia

F. Ferroni [a], M. Ardizzi [a,*,1], M. Sestito [b,1], V. Lucarini [c], B.D. Daniel [c], F. Paraboschi [c], M. Tonna [d], C. Marchesi [c], V. Gallese [a,e]

[a] Department of Medicine and Surgery, University of Parma, Parma, Italy
[b] Department of Psychology, Wright State University, Dayton, OH, United States
[c] Department of Medicine and Surgery, Psychiatry Unit, University of Parma, Parma, Italy
[d] Department of Mental Health, Local Health Service, Parma, Italy
[e] Institute of Philosophy, School of Advanced Study, University of London, London, UK

ARTICLE INFO

Article history:
Received 1 August 2018
Received in revised form 15 November 2018
Accepted 16 November 2018
Available online xxxx

Keywords:
Body-illusions
Enfacement illusion
Multisensory integration
Other-other boundary
Schizophrenia
Self-face

ABSTRACT

Schizophrenia has been described as a psychiatric condition characterized by deficits in one's own and others' face recognition, as well as by a disturbed sense of body-ownership. To date, no study has integrated these two lines of research with the aim of investigating Enfacement Illusion (EI) proneness in schizophrenia. To accomplish this goal, the classic EI protocol was adapted to test the potential plasticity of both Self-Other and Other-Other boundaries. Results showed that EI induced the expected malleability of Self-Other boundary among both controls and patients. Interestingly, for the first time, the present study demonstrates that also the Other-Other boundary was influenced by EI. Furthermore, comparing the two groups, the malleability of the Other-Other boundary showed an opposite modulation. These results suggest that, instead of greater Self-Other boundary plasticity, a qualitative difference can be detected between schizophrenia patients and controls in the malleability of the Other-Other boundary. The present study points out a totally new aspect about body-illusions and schizophrenia disorder, demonstrating that EI is not only confined to self-sphere but it also affects the way we discriminate others, representing a potential crucial aspect in the social domain.

1. Introduction

> *"In perceiving the other, my body and his are coupled, resulting in a sort of action which pairs them… I make it mine; I recover it or comprehend it. Reciprocally I know that the gestures I make myself can be the objects of another's intention. It is this transfer of my intentions to the other's body and of his intentions to my own, my alienation of the other and his alienation of me, that makes possible the perception of others."*
>
> [(Merleau-Ponty, 1964, p. 118).]

Anomalies in the sense of self have been considered to be predictive for psychosis onset (Nelson et al., 2012) and occurring in all following stages of schizophrenia (Parnas et al., 2011; Schultze-Lutter et al., 2010). Various disturbances characterize this kind of disorder, like depersonalization, altered stream of consciousness or warped bodily experiences. Assuming selfhood as a multi-layered concept, the phenomenological approach (Parnas, 2000; Parnas and Handest, 2003) attributes the core aberration of schizophrenia, vividly defined by Kraepelin (1919) as an *"orchestra without a conductor"*, to the most basic level of selfhood, the 'minimal self'(Sass and Parnas, 2003). In this view, the disruption of the basic sense of self and of the implicit bodily functioning represents the clear manifestations of a disturbed bodily self, or *disembodiment* (Fuchs and Schlimme, 2009). This altered basic sense of self, which is strictly related to self-recognition and self-other discrimination impairments (Gallese and Ferri, 2014), have been traditionally associated with schizophrenia psychopathology and seems to be linked to deficits in multisensory integration mechanisms (Postmes et al., 2014).

One of the basic experiences of self concerns the sense of body-ownership as the "the perceptual status of one's own body, which makes bodily sensations seem unique to oneself"(Tsakiris et al., 2007). This basic self experience contributes to a structured sense of self and it is considered as a developmental basis for a psychological identity (Gallagher, 2000). Body ownership has been mainly investigated by studies applying the Rubber Hand Illusion protocol (Botvinick and Cohen, 1998). Even if at the moment under debate (e.g., for a review see Shaqiri et al., 2018), schizophrenia patients seem to show a greater

* Corresponding author at: Via Volturno, 39/E, 43121 Parma, Italy.
E-mail address: martina.ardizzi@unipr.it (M. Ardizzi).
[1] These authors contributed equally to this work.

https://doi.org/10.1016/j.schres.2018.11.018
0920-9964/

Please cite this article as: F. Ferroni, M. Ardizzi, M. Sestito, et al., Shared multisensory experience affects *Others'* boundary: The enfacement illusion in schizophrenia, Schizophrenia Research, https://doi.org/10.1016/j.schres.2018.11.018

malleability of the sense of ownership over body-parts than healthy controls (Ferri et al., 2014; Peled et al., 2000; Peled et al., 2003; Thakkar et al., 2011). Besides the criticisms, studies demonstrated specific relations between body-ownership deficits and the psychopathology of schizophrenia. Indeed, a weak sense of ownership over body-parts is associated to both positive and negative schizophrenia symptoms (Ferri et al., 2014; Peled et al., 2000; Thakkar et al., 2011). Also the well-known Schneiderian first-rank symptoms (i.e., thought-insertion, thought-broadcasting, somatic passivity, delusional perception) were found associated to altered sense of ownership in this clinical sample (Fourneret et al., 2001; Waters and Badcock, 2008).

Crucially, the sense of body-ownership is not only related to body parts but also to the face, which represents a fundamental cue for self-identity, allowing us to distinguish not only the self from the other (i.e., Self-Other boundary) (Zahavi and Roepstorff, 2011) but also in differentiating others (i.e., Other-Other boundary). An expanding line of research extended the multisensory integration procedure adopted in the Rubber Hand Illusion paradigm to self-face recognition in healthy individuals (Paladino et al., 2010; Sforza et al., 2010; Tsakiris, 2008). The so-called Enfacement Illusion (EI) is induced by the observation of another person's face being touched at the same time of participant's face. Synchronous, but not asynchronous, visuo-tactile stimulation between the two faces modifies the usual Self-Other boundary, shifting it toward the other's face. EI effect is conventionally measured by performance on a self-face recognition task arranged before and after the visuo-tactile stimulation and/or by ad-hoc questionnaire (i.e., Illusion Questionnaire). Similarly to what happens for body-parts submitted to body-ownership illusion, also the EI highlights the normal plasticity of self-face representation. Assuming the self specificity of the body-illusions (Tsakiris, 2008), at the moment no study has investigated the potential effect of EI on the malleability of also the Other-Other boundary.

Interestingly, even if probably affected by task design (Lee et al., 2007), evidence suggests anomalies in face processing in schizophrenia, including one's own self and others' faces recognition, self-other distinction and impairment in emotional facial expressions processing (Ameller et al., 2015; Bortolon et al., 2015; Chan et al., 2010; Maher et al., 2016; Yun et al., 2014). Furthermore, a distinctive clinical sign of schizophrenia is represented by the so-called *Mirror-related phenomena*, (Parnas et al., 2005), that has been experimentally assessed in a study showing how, by means of mirror gazing test, apparitions of strange-faces in the mirror were significantly more intense in patients with schizophrenia than in controls (Bortolon et al., 2017; Caputo et al., 2012). All these well-studied phenomena may have implications for face-to-face social interactions. Indeed, social cognition is very poor among schizophrenia patients (for a review see Gur and Gur, 2015), they underestimate the social reward of genuine others' positive facial expressions (Catalano et al., 2018) and they often show social anhedonia and/or asociality (e.g., Blanchard et al., 1998, 2001; Kalin et al., 2015; Robertson et al., 2014). Reduced social interests are evident prior to illness onset (Cannon et al., 1997; Cornblatt et al., 2011; Tarbox and Pogue-Geile, 2008) and often persist despite effective positive symptoms treatment (Blanchard et al., 2001; Horan et al., 2008).

Considering both the altered minimal sense of self and the deficit in the processing of one's own self and others' faces, this is the first study that tries to integrate these parallel lines of research with the aim of investigating EI proneness in schizophrenia. This is crucial to delineate both the extension of the bodily self malleability and the potential roots of the described psychopathological aspects connoting schizophrenia also at a social level. In the present study, we adopted the same enfacement illusion protocol used by Tajadura-Jiménez and Tsakiris (2013) in which participants were stroked on the left side of their face while they were seeing the face of an unfamiliar person being stroked in synchrony either on the specularly congruent location or on incongruent side of the face. The illusion effect was tested through the commonly used Illusion Questionnaire and Face Recognition Task. This protocol was chosen because it includes only synchronous visuo-tactile stimulation, ensuring comparable levels of attention between conditions (Tajadura-Jiménez and Tsakiris, 2013), and avoiding the effect of the inter-individual variability in temporal binding window (TBW) extension (Costantini et al., 2016; Stevenson et al., 2012), two aspects crucial when clinical and non-clinical samples are compared. Accordingly, an alteration in both TBW (Foucher et al., 2007; Tseng et al., 2015) and attentional abilities (Bleuler, 1958; Fioravanti et al., 2012; Fuller et al., 2006; Kraepelin, 1919; Young et al., 2017) have been demonstrated in patients with schizophrenia. In order to introduce a further control condition able to test also the malleability of the Other-Other boundary after a shared multisensory experience, we decided to include new non-self related supplemental trials in Face Recognition Task, where, according to the self-specificity of the body-illusions, no EI effect was expected. Coherently with the here described literature, we expected higher proneness to EI in patients with schizophrenia than in controls.

2. Methods

2.1. Participants

20 patients with schizophrenia (SCZ; mean age 37.15 years SE 3.23, 17 males) and 23 healthy control participants (HC; mean age 32 years SE 0.59, 10 males) were included in the present study (Table 1). The total sample size exceeded the minimum amount required (n. 36) estimated by means of statistical a priori sample size calculation, obtained for repeated-measures ANOVA considering both within and between interactions (1-ß $= 0.95$, $\alpha = 0.05$ and effect size $f = 0.25$). Post-hoc power estimation analysis conducted for repeated-measures ANOVA considering both within and between interactions including the actual effect size of our main interaction ($f = 0.41$) and the final sample size (n. $= 43$) confirmed the high achieved statistical power achieved (1-ß $= 0.99$). SCZ were recruited among patients seeking treatment at the Psychiatric Unit of the University Hospital of Parma. All patients were under medication during the period of the study, and medication was based on a low-medium dose of a single atypical antipsychotic drug. Please, consult Supplementary Table 1 for a detailed description of SCZ patients. HC were recruited through fliers posted in meeting places.

Inclusion criteria for SCZ were I) a diagnosis of Schizophrenia according to DSM-IV-TR criteria (First et al., 2002) and II) stable phase of recovery (i.e., with no acute symptoms for at least 6 months post morbid). SCZ patients were evaluated and recruited for the study after a clinical stabilisation to assure that they were able to participate in the study. Inclusion criterion for HC was the absence of current or past psychiatric or neurological illnesses as determined by their clinical history, assessed by means of a general psychopathology questionnaire. Exclusion criteria for all participants were I) substance abuse or dependence; II) pathological conditions likely affecting cognition or interfering with participation in the study (i.e., presence of neurological and vascular disorders, dysmetabolic syndrome and mental retardation) and III) face-recognition deficits like prosopagnosia disorder, possibly affecting participants' performance. Written informed consent was obtained from all participants after full explanation of the procedure of the study. The study was approved by Ethics Committee of the University Hospital of Parma and was in line with the ethical standards of the 2013 Declaration of Helsinki.

2.2. Clinical scales and control measures

SCZ were evaluated by means of the structured clinical interview for DSM-IV Axis I disorders (SCID-I) to establish Axis I diagnoses (First et al., 2002). Patients were evaluated with the Assessment of Positive and Negative Syndrome Scale (PANSS; Kay et al., 1987) that measures symptoms severity in schizophrenia. Disturbances of subjective

Please cite this article as: F. Ferroni, M. Ardizzi, M. Sestito, et al., Shared multisensory experience affects *Others'* boundary: The enfacement illusion in schizophrenia, Schizophrenia Research, https://doi.org/10.1016/j.schres.2018.11.018

Table 1
– Demographic information and clinical scales of SCZ and HC groups.

Scales	Subscales	SCZ	HC	Between-groups differences
Age (years)		37.15; SE 3.23	32; SE 0.59	$t_{(41)} = -1.57$; $p = 0.13$
Education (years)*		11.30; SE 0.58	14.91; SE 0.48	$t_{(41)} = 4.80$; $p < 0.001$
CPM (ES)		3.37; SE 0.22	3.78; SE 0.12	$t_{(40)} = 1.64$; $p = 0.11$
Digit Span (ES)		3.2; SE 0.26	n.a	
Reaction Time (msec)		5999.27; SE 2064.27	3849.22; SE 159.42	$t_{(41)} = -1.11$; $p = 0.27$
	Self images	8.60; SE 0.14	8.74; SE 0.13	Interaction Identity by Group:
Rate of adapted digital photos	Other images	0.45; SE 0.33	0.80; SE 0.31	$F_{(1,41)} = 0.207$; $p = 0.65$
SPQ_TOT		n.a.	18.13; SE 2.26	
	Positive Factor		6.78; SE 1.23	
	Negative Factor		8.96; SE 0.99	
	Disorganized Factor		5.30; SE 0.92	
PANSS_TOT		79.30; SE 3.84	n.a.	
	PANSS positive	16.60; SE 1.41		
	PANSS negative	22.20; SE 1.48		
	PANSS general	40.50; SE 2.07		
EASE_TOT		18.80; SE 1.72	n.a.	
	EASE 1	5.80; SE 0.74		
	EASE 2	7.33; SE 0.65		
	EASE 3	1.73; SE 0.55		
	EASE 4	0.67; SE 0.25		
	EASE 5	3.27; SE 0.48		

Significant between-groups differences were estimated.
SCZ = schizophrenia patients group; HC = healthy controls group; CPM = Coloured Progressive Matrices; STAI = State-Trait Anxiety Inventory; SPQ = Schizotypal Personality Questionnaire; PANSS = Assessment of Positive and Negative Syndrome Scale; EASE = Examination of Anomalous Self-experience; EASE1 = Cognition and Stream of Consciousness domain; EASE2 = Self-awareness and presence domain; EASE3 = Bodily experiences domain; EASE4 = Demarcation/Transitivism domain; EASE5 = Existential Reorientation domain; ES = Equivalent Score; n.a. = not applicable.
* $p < 0.05$.

experience were investigated through the Examination of Anomalous Self-experience scale (EASE; Parnas et al., 2005). Furthermore, patients carried out the backward Digit Span (Wechsler, 1997) in order to control for executive deficits potentially affecting task performance. All the equivalent scores were greater or equal to 1.

HC completed the Schizotypal Personality Questionnaire (SPQ; Raine, 1991) to evaluate the individual schizotypal traits in the healthy population.

Both groups completed the Coloured Progressive Matrices (CPM; Raven et al., 1998), to assure that cognitive functionality was preserved. All the equivalent scores were greater or equal to 1, with no significant difference in the mean equivalent scores between the two groups.

We also evaluated participants' reaction times (RT) to gradually changing visual stimuli in order to assess the motor reactivity of the two groups. Participants were asked to press the space bar as soon as they perceived a change in the colour of an oval shape. The oval shape matched the dimension of the faces in the face-morphing movies (see below) and the progressive change in colour (e.g., from blue to yellow) simulated the dynamic transition of the same morphing movies. No significant difference was found between the two groups. For participants' clinical scale and control measure, Table 1 shows groups' mean scores and the results of the statistical comparisons between the two groups.

2.3. Procedure

2.3.1. Induction movies

In order to induce the Enfacement Illusion, induction movies were created displaying an unfamiliar face (Other) - matching the participant's sex, age (±5 years) and ethnic group - being stroked on the cheek with a cotton-bud at 0.33 Hz. Each stroke covered a distance of 2 cm from the zygomatic bone downwards. The side of the stroking (i.e., right cheek or left cheek) was balanced (i.e., Congruent or Incongruent stimulations, see below). For each participant, 2 different unfamiliar faces (Other) were used in the induction movies, one for the Congruent and one for the Incongruent stimulation. Each induction movie lasted 120 s.

2.3.2. Face-morphing movies

A digital photograph of each participant with a neutral facial expression was taken before the beginning of the experimental session (max. 1 week before). The participant's face in the photograph was converted to greyscale, and all non-facial attributes were removed (e.g. background, hair, ears) with Adobe Photoshop software. Abrasoft Fantamorph (www.fantamorph.com) was used to merge participant's face with Other's face (i.e., the unfamiliar face displayed in the induction movie) in proportional steps. Each movie, lasting 10 s, displayed the graded blending of the two faces in 150 frames (0.67% steps). The same procedure was followed to merge the Other face with a Stranger face. The Stranger was an unfamiliar individual - matching the participant's sex, age (±5 years) and ethnic group – not displayed in any induction movie. For each participant, 2 different Strangers' faces were used to create the face-morphing movies, one for the Congruent and one for the Incongruent stimulation. For each participant, four morphing movies were created for each stimulation. In two cases, Other was morphed into the participant's face, either from Other to Self (i.e., from 100% Other to 100% Self; Other-Self morph) or from Self to Other (i.e., from 100% Self to 100% Other; Self-Other morph) directions. In the other two cases, the Other's face was morphed into the face of the Stranger, either from Other to Stranger (i.e., from 100% Other to 100% Stranger; Other-Stranger morph) or from Stranger to Other (i.e., from 100% Stranger to 100% Other; Stranger-Other morph) directions. See Fig. 1 for an exemplificative representation of the four face-morphing movies.

The adapted digital photographs used to create the Self-Other and the Other-Self morphs were previously rated by participants to make sure that they recognized their faces as belonging to the Self and that they distinguished their faces from those of unfamiliar Others. The adapted digital photographs of Self and Others were rated one at a time according to the sentence "Does this face represent yourself?" using a 0–9 Likert scale (0 = "strongly disagree"; 9 = "completely agree"). Both groups were able to distinguish the images of the Self from those of the unfamiliar Others (Self: 8.67 SE 0.09, Other: 0.63 SE 0.22; $F_{(1,41)} = 1155.53$, $p < 0.001$; $\eta^2_p = 0.97$). No significant differences were estimated between the two groups (Main effect of Group:

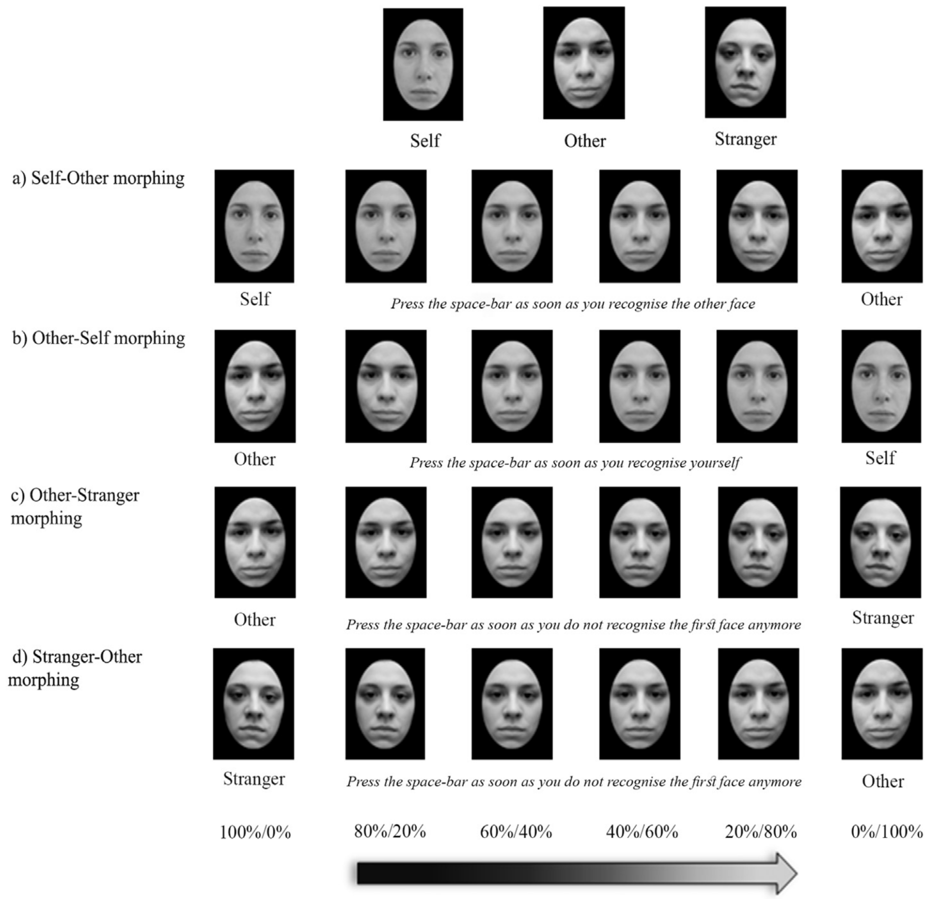

Fig. 1. Face-morphing movies. A qualitative representation of the four video-morphing movies. Panels a), b), c) and d) display the direction of each morphing and the associated questions of the Face-recognition task.

$F_{(1,41)} = 0.94$; $p = 0.34$; $\eta^2_p = 0.02$; Interaction Identity by Group: $F_{(1,41)} = 0.207$; $p = 0.65$; $\eta^2_p = 0.005$; see Table 1 for means and SE).

2.3.3. Illusion Questionnaire

After each stimulation session (see the Experimental session), participants were asked to complete the Italian version of the Illusion Questionnaire (Sforza et al., 2010) in order to evaluate their subjective experience of the illusion (see Table 2 for the English translation of IQ). Specifically, item 1 and 2 describe the experience of being touched on the same side of the face of the other person touched (i.e., referred sensation); item 3 codes the feeling of identification with the other's face; while item 8 describes the feeling of similarity in visual features with the observed face (Bufalari et al., 2014). The other questions were control items. Participants indicated their response on a Visual Analogic Scale (10 cm) ranging from "completely false" to "completely true".

Table 2
IQ's items that describe the experience of the EI.

Item 1	*It seemed as if I were feeling the touch of the cotton bud in the location where I saw the other's face touched.*
Item 2	*It seemed as though the touch I felt was caused by the cotton bud touching the other's face.*
Item 3	*I felt as if the other's face was my face.*
Item 4	*It felt as if my face were drifting toward the other's face.*
Item 5	*It seemed as I might have more than one face.*
Item 6	*It seemed as if the touch I was feeling came from somewhere between my own face and the other's face.*
Item 7	*It appeared as if the other's face were drifting toward my own face.*
Item 8	*The other's face began to resemble my own face, in terms of shape, skin tone, or some other visual feature.*

2.3.4. Experimental session

Participants sat comfortably, approximately at 50 cm from a screen. *E*-Prime 2.0 software (Psychology Software Tools, Inc.) was used for stimuli presentation. A training session consisting of a series of face morphing movies with famous faces was administered before the first stimulation to assure that participants understood the instructions. The experimental protocol consisted of two sessions: Congruent stimulation and Incongruent stimulation. The order of sessions was balanced between participants and there was a 15 min break between them. Each session contained three phases: the Pre-IMS Face Recognition Task (Pre-Test), the interpersonal multisensory stimulation (IMS) phase, and the Post-IMS Face Recognition Task (Post-Test). In the Pre-Test, the 4 face-morphing movies were presented in random order. For the Other-Self morph, participants were asked to press the spacebar as soon as they perceived the face to look more like Self than Other. For the Self-Other morph, participants were asked to press the same key when they perceived the face to look more like Other than Self. As soon as the participants pressed the key, the movie stopped and the number of frames at which the movie was stopped was recorded each time. For Other-Stranger and Stranger-Other morphs, participants had to stop the movie as soon as they perceived that the identity of the first face was not detectable anymore (see Fig. 1). The Other-Stranger and Stranger-Other morphs were used as control condition to test the Other-Other boundary malleability in which no EI effect was expected, since EI challenges specifically the self-face recognition (Porciello et al., 2018).

Please cite this article as: F. Ferroni, M. Ardizzi, M. Sestito, et al., Shared multisensory experience affects *Others'* boundary: The enfacement illusion in schizophrenia, Schizophrenia Research, https://doi.org/10.1016/j.schres.2018.11.018

In the IMS phase, participants were stroked, synchronously, on the left side of their face with a cotton bud while they saw, in the induction movie, the face of the Other being stroked either in a specularly congruent location (i.e. Congruent stimulation), or in the incongruent side of the face (i.e. Incongruent stimulation) (see Fig. 2). After IMS phase, participants performed the Post-Test consisting in the same procedure of the Pre-Test. At the end of each block, participants completed the IQ. Lastly, a subjective rating of the perceived physical similarity between the Other and the Self, as well as, the trustworthiness and attractiveness attributed to the Other were measured along a 0–7 Likert scale (0 = "not at all"; 7 = "a lot").

2.4. Statistical analyses

Studies demonstrated that Self-Other discrimination is not influenced by the direction of face-morphing movies (Heinisch et al., 2011; Payne and Tsakiris, 2017). In order to assure that also in our dataset the direction of movies did not affect the results, we performed two independent repeated-measures ANOVAs, one for each group, which showed neither a main effect of Direction nor any significant interaction between Direction and the experimental manipulations. See supplemental results (section 1.1) for a detailed description. For these reasons, similarly to the procedure followed by previous studies (Panagiotopoulou et al., 2017; Tajadura-Jiménez et al., 2012), the analyses were conducted on the global number of frames attributed to the Self by considering Self-Other and Other-Self morphs altogether (Self-frames). The same procedure was followed to calculate the global number of frames attributed to the Other by considering Other-Stranger and Stranger-Other morphs altogether (Other-frames). EI effect on Self-Other boundary was estimated calculating the changing score for Self-frames in the Post-Test relative to the Pre-Test (Δ Self frames). The potential EI effect on Other-Other boundary was assessed by calculating the changing score for Other-frames in the Post-Test relative to the Pre-Test (Δ Other frames). To clarify, the Other's face was present in all morphs. The name attributed to the Δ frames (and to the Morphing factor in the subsequent statistical analyses), was chosen to stress the different measures obtained from the morphs (i.e., the number of frames attributed to the Self or the number of frames attributed to the Other). If EI occurred, we expected a higher number of frames attributed to the Self in the Post-Test than in the Pre-Test (positive Δ Self frames significantly higher than zero) in the Congruent stimulation. No difference was expected for the Incongruent stimulation (no changes in the Δ Self frames resulting not significantly different from zero). Differently, regardless of the inter-individual susceptibility to the illusion, no difference between the number of frames attributed to the Other in the Post-Test with respect to the Pre-Test, both in Congruent and Incongruent stimulations, were expected (no changes in the Δ Other frames resulting not significantly different from zero). Lastly, we expected an increment of the score of the IQ selected items, with a significant increment different from 50 (i.e., neutral evaluation), only after Congruent stimulation.

Due to the new conditions added to the standard EI protocol, we run a series of analyses only on the control group to verify the effectiveness of the procedure followed. First, the performance at Face Recognition Task was investigated. Controls' Δ frames were submitted to a repeated measures ANOVA. In this case, Morphing (i.e., Self and Other) and Stimulation (i.e., Congruent and Incongruent) were entered as within-subjects factors. Secondly, based on the significant interaction Morphing by Stimulation, the expected significant and not-significant differences from 0 of both Δ Self and Δ Other frames after the two stimulations were tested by 4 independent one sample *t*-tests against 0. Regarding the scores at the Illusion Questionnaire, we run a repeated-measures ANOVA with Statement (1–3,8) and Stimulation (i.e., Congruent and Incongruent) entered as within-subjects factors. Lastly, to test if among controls, the selected statements of Illusion Questionnaire differs from a rating of 50 (indicating a consistent deviation from a neutral explicit evaluation of EI), one sample *t*-tests against 50 were conducted on the scores of Statement 1–3 and 8 for both Congruent and Incongruent stimulations.

After the assessment of the EI protocol among controls, the same statistical analyses were run again comparing the performance of the two groups. All participants' Δ frames were submitted to a repeated

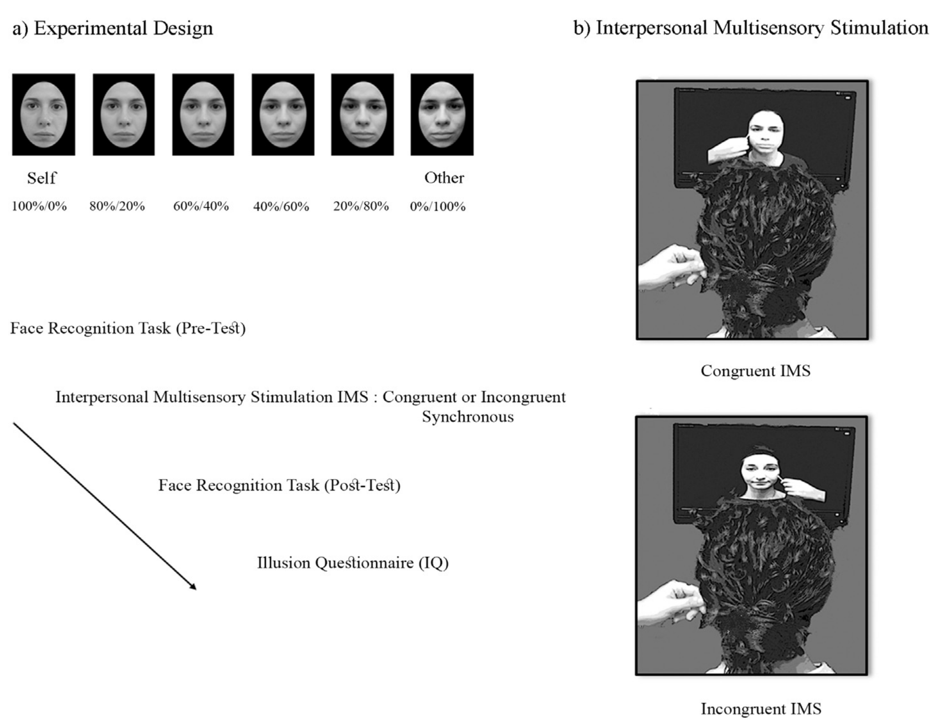

Fig. 2. Experimental protocol and visuo-tactile stimulation. a) (top panel): Exemplificative frames taken from Self-Other morphing. The percentage of Self and Other of each frame are reported below the image. a) (bottom panel): Design of the experimental phases: Pre-Test, Interpersonal Multisensory Stimulation phase (IMS), Post-Test and Illusion Questionnaire. b): Experimental set-up during IMS phase, for Congruent and Incongruent stimulation, respectively.

measures ANOVA with Morphing (i.e., Self and Other) and Stimulation (i.e., Congruent and Incongruent) as within-subjects factors, whereas Group (i.e., SCZ and HC) was entered as between-subjects factor. Again, the significant interaction Morphing by Stimulation was further investigated throughout 4 independent one sample *t*-tests against 0 performed on the whole sample (due to the absence of the significant three-ways interaction Morphing by Stimulation by Group). The Illusion Questionnaire scores were again submitted to a repeated-measures ANOVA with Statement (1–3,8) and Stimulation (i.e., Congruent and Incongruent) included as within-subjects factors, whereas Group (SCZ and HC) was entered as between-subjects factor. Lastly, one sample *t*-tests against 50 were conducted on the scores of the entire sample (due to an absence of a Group main effect) of Statement 1–3 and 8 for both Congruent and Incongruent stimulations.

Whenever appropriate, significant within- and between-group differences were explored performing Tukey HSD post-hoc comparison. Partial eta square (η^2_p) was calculated as effect size measure.

Supplementary analyses were performed on the ratings of Attractiveness, Similarity and Trustworthiness, please refer to Supplementary results (Section 1.2). Supplementary Pearson's correlations analyses were performed on SCZ group between the psychopathological measures and the performance at the EI paradigm, please refer to Supplementary results (section 1.3).

A qualitative graphical representation of Δ Self frames and Δ Other frames displayed group by group are showed for each stimulation (i.e., Congruent and Incongruent) in Fig. 3. For sake of clarity, in the graph Δ frames are expressed in percentage values calculated on the total number of frames (300). An additional more comprehensive supplemental figure (Supplemental Fig. 1) was included showing the graphical representation of Δ Self frames and Δ Other frames in function of Group, Stimulation and Morphing direction.

3. Results

3.1. Enfacement illusion in controls

3.1.1. Face recognition task

Repeated-measures ANOVA, performed only among controls on Δ frames, revealed a main effect of Morphing ($F_{(1,21)} = 35.74$, $p < 0.001$, $\eta^2_p = 0.63$) as well as a significant interaction Morphing by Stimulation ($F_{(1,21)} = 22.32$, $p < 0.001$, $\eta^2_p = 0.51$). Tukey HSD post-hoc comparison conducted on the significant main effect of Morphing revealed a significantly higher number of Self frames than Other frames, regardless of Stimulation (Δ Self frames = 9.29 SE 3.13; Δ Other frames = −8.36 SE 3.02 $p < 0.001$). Crucially, post-hoc comparisons conducted on the significant interaction Morphing by Stimulation (see Fig. 4) revealed the expected EI effect for the Self and not for Other only in the Congruent stimulation. Indeed, the number of frames was significantly higher after the Congruent than after the Incongruent stimulation only for the Self (Δ Self Congruent = 22.73; SE 4.54; Δ Self Incongruent = −4.14; SE 3.92; $p < 0.001$) and not for the Other (Δ Other Congruent = −13.82; SE 3.49; Δ Other Incongruent = −2.91; SE 5.93; $p = 0.25$).

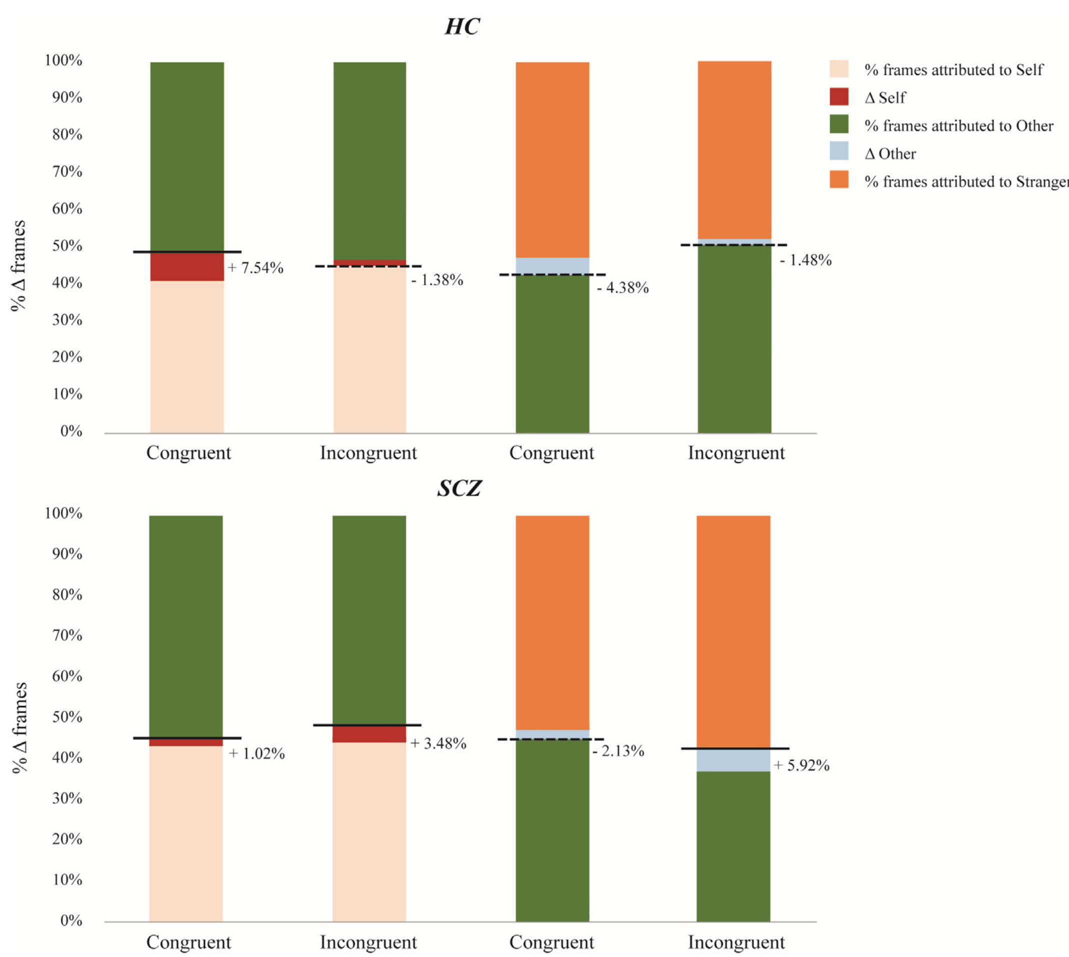

Fig. 3. Qualitative graphical representation of Δ Self frames and Δ Other frames of HC and SCZ groups. Percentage of Δ Self frames and Δ Other frames of SCZ and HC groups displayed for Congruent and Incongruent stimulations. Black continuous lines represent a higher number of frames measured in the Post-Test relative to the Pre-Test (positive Δ frames). Black dashed lines represent a lower number of frames measured in the Post-Test relative to the Pre-Test (negative Δ frames). Positive Δ Self frames denote an Enfacement Illusion effect. See Supplemental Fig. 1 for a graphical representation of the Δ frames of each morphing movie in function of both Group and Stimulation.

Please cite this article as: F. Ferroni, M. Ardizzi, M. Sestito, et al., Shared multisensory experience affects *Others'* boundary: The enfacement illusion in schizophrenia, Schizophrenia Research, https://doi.org/10.1016/j.schres.2018.11.018

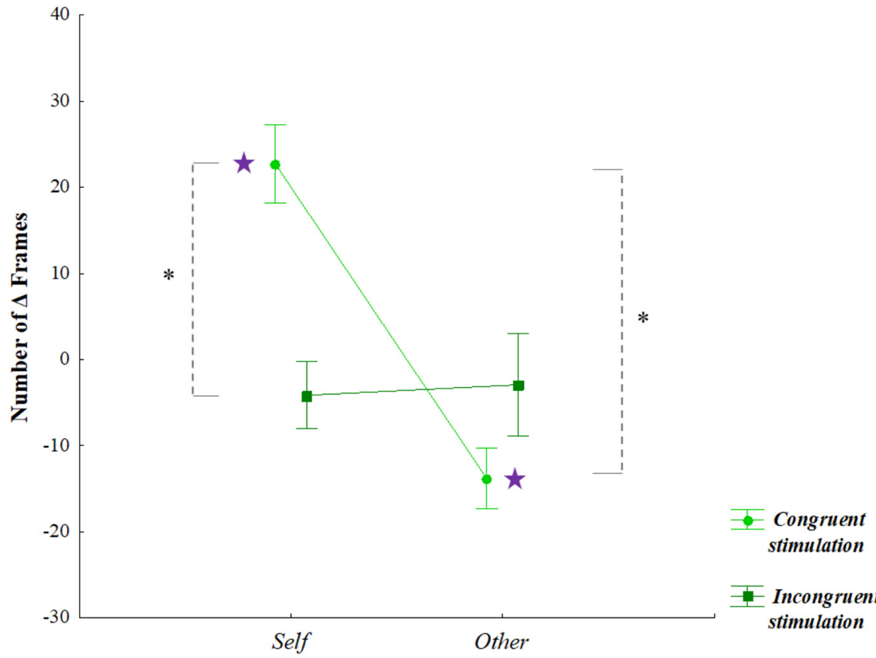

Fig. 4. Enfacement Illusion in controls. Number of Δ Self frames and Δ Other frames of Healthy Controls for Congruent (light green/circle) and Incongruent (dark green/square) stimulations. * = $p < 0.05$ of Repeated-measures ANOVA, Purple stars = $p < 0.05$ of one sample *t*-tests against zero; error bars depicted SE. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Moreover, the number of frames attributed to the Self were significantly higher than the number of frames attributed to the Other after Congruent stimulation ($p < 0.001$).

Results of one sample *t*-tests against 0 revealed that the Δ Self frames measured after the Congruent stimulation were significantly higher than 0 ($t_{(23)} = 5.20$ $p < 0.001$). On the contrary, the Δ Other frames measured after the Congruent stimulation were significantly lower than 0 ($t_{(23)} = -3.85$ $p < 0.001$) (see Fig. 4, purple stars). No significant differences were estimated against zero considering both Δ Self ($t_{(22)} = -1.05$ $p = 0.30$) and Δ Other frames ($t_{(23)} = -0.75$ $p = 0.46$) measured after Incongruent stimulation.

3.1.2. Illusion Questionnaire

The repeated-measured ANOVA showed a significant main effect of Statement ($F_{(3,66)} = 23.25$, $p < 0.01$, $\eta^2_p = 0.51$). Tukey post-hoc comparisons showed that the score of the Statement 1 differed from all the other scores (Statement 1 = 61.02 SE 5.41; Statement 2 = 29.37 SE 6.77; Statement 3 = 24.74 SE 5.93; Statement 8 = 19.85 SE 4.92; all $p_s < 0.00011$). All other interactions were non-significant (all $p_s > 0.14$).

Results of t-tests against 50 showed that the only Illusion Questionnaire statement that was rated significantly higher than 50 was the statement 1 when referring to the experience of EI after Congruent stimulation (66.96 SE 6.73, $t_{(22)} = 2.52$ $p = 0.019$). This was also the only statement that discriminated between Congruent and Incongruent stimulations. Indeed, no significant difference from 50 was found for statement 1 referring to the experience of EI after Incongruent stimulation (55.09 SE 7.12, $t_{(22)} = 0.71$ $p = 0.48$). All the other comparisons were significantly lower than 50 (all $p_s < 0.008$).

3.2. Between-groups differences in enfacement illusion

3.2.1. Face recognition task

The repeated measures ANOVA showed a significant main effect of Morphing ($F_{(1,35)} = 7.50$, $p = 0.01$ $\eta^2_p = 0.18$). Moreover, the interactions Morphing by Group ($F_{(1,35)} = 5.1$, $p = 0.03$ $\eta^2_p = 0.13$), Stimulation by Group ($F_{(1,35)} = 12.58$, $p = 0.01$ $\eta^2_p = 0.26$) and Morphing by Stimulation were significant ($F_{(1,35)} = 10.07$, $p = 0.01$ $\eta^2_p = 0.22$). Tukey HSD post-hoc comparison conducted on the main effect Morphing revealed a significantly higher number of frames attributed to the Self than to Other, regardless of Stimulation (Δ Self frames = 9.51; SE 2.64; Δ Other frames = −0.16 SE 3.05; $p = 0.01$). Post-hoc comparisons performed on the interaction Morphing by Group (see Fig. 5) revealed that both groups showed an equal number of frames attributed to the Self after the stimulation irrespective of the side (HC: Δ Self frames = 9.29 SE 3.37, SCZ: Δ Self frames = 9.73 SE 4.08; $p = 0.99$). Differently, only controls showed the expected EI Self specificity as demonstrated by a higher number of frames attributed to the Self than to the Other (Δ Other frames = −8.36 SE 3.88; $p = 0.002$). No significant difference was found in the same comparison for SCZ group (Δ Other frames = 8.03 SE 4.70; $p = 0.98$). Consequently, the number of frames attributed to the Other was significantly different between the two groups ($p = 0.027$). Tukey post-hoc comparisons conducted on the interaction Stimulation by Group (Supplemental Fig. 2) revealed a significant higher number of frames measured after the Incongruent stimulation than after the Congruent stimulation only for SCZ group (Congruent stimulation: - 1.37; SE 4.00; Incongruent stimulation: 19.13 SE 5.20; $p = 0.011$). Moreover, the number of frames measured after the Incongruent stimulation for SCZ group was also significantly higher than the number of frames measured in the same condition for HC (HC: Incongruent stimulation = −3.52 SE 4.29; $p = 0.002$). Post-hoc comparisons performed on the significant interaction Morphing by Stimulation (Supplemental Fig. 3) revealed a significantly higher number of frames attributed to the Self than to the Other after the Congruent stimulation (Self: 12.63 SE 3.21, Other: -9.54 SE 3.52; $p > 0.001$). This effect was not found after the Incongruent stimulation (Self: 6.40 SE 3.67, Other: 9.21 SE 5.29; $p = 0.97$). Comparing the two stimulations, only the number of frames attributed to the Other were significantly different ($p = 0.016$).

Results of one sample *t*-tests against 0, performed on the whole sample, revealed that the Δ Self frames measured after the Congruent stimulation were significantly higher than 0 ($t_{(37)} = 4.28$ $p < 0.001$). Differently, the Δ Other frames measured after the Congruent stimulation were significantly lower than 0 ($t_{(37)} = -2.95$ $p = 0.005$). No significant differences were estimated against zero considering both Δ Self ($t_{(36)} = 1.11$ $p = 0.27$) and Δ Other frames ($t_{(37)} = 1.04$ $p = 0.30$) measured after Incongruent stimulation.

Please cite this article as: F. Ferroni, M. Ardizzi, M. Sestito, et al., Shared multisensory experience affects *Others'* boundary: The enfacement illusion in schizophrenia, Schizophrenia Research, https://doi.org/10.1016/j.schres.2018.11.018

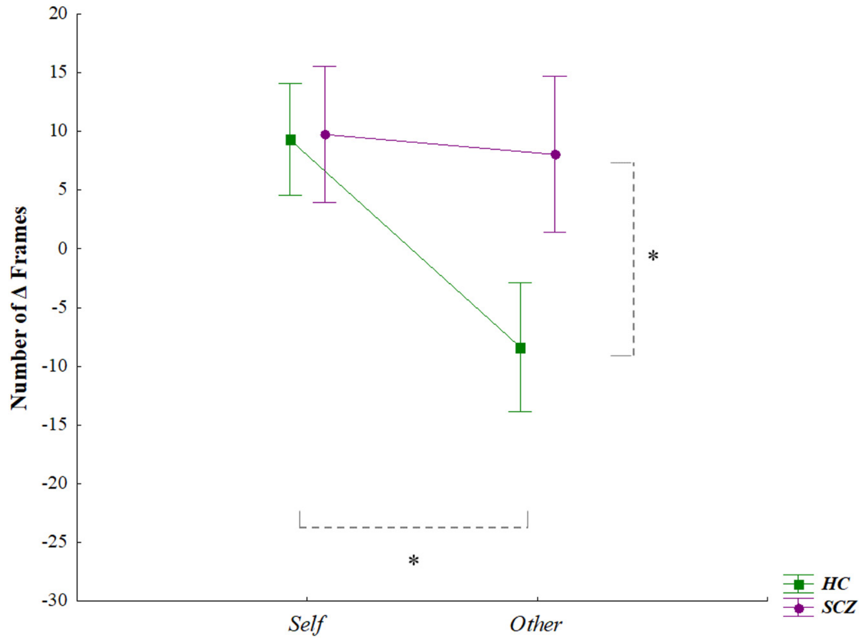

Fig. 5. Enfacement Illusion comparing Schizophrenia patients and controls. Number of Δ Self frames and Δ Other frames of Healthy Controls (green/square) and Schizophrenia patients (purple/circle). * = p < 0.05, error bars depicted SE. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

3.2.2. Illusion Questionnaire

Significant main effect of Statement ($F_{(3,123)} = 37.98$, $p < 0.01$, $\eta^2_p = 0.48$). Tukey post-hoc comparisons showed that the score of the Statement 1 differed from the other scores (Statement 1 = 60.92 SE 4.42; Statement 2 = 28.27 SE 4.82; Statement 3 = 26.66 SE 4.47; Statement 8 = 20.90 SE 3.31; all $p_s < 0.01$). All other interactions were non-significant (all $p_s > 0.26$).

Results of t-tests against 50 showed that the only Illusion Questionnaire statement that was rated significantly higher than 50 was statement 1 when referring to the experience of EI after Congruent stimulation (64.93 SE 5.35, $t_{(42)} = 2.79$ p = 0.008). Similarly to what happened among controls, this was also the only statement that discriminated between Congruent and Incongruent stimulations. Indeed, no significant difference from 50 was found for statement 1 referring to the experience of EI after Incongruent stimulation (56.93 SE 5.70, $t_{(42)} = 1.21$ p = 0.23). All the other comparisons were significantly lower than 50 (all $p_s < 0.001$).

4. Discussion

The present study investigated, for the first time, EI proneness in schizophrenia. To accomplish this goal, the classical EI protocol was adapted to test the potential plasticity of both Self-Other and Other-Other boundaries. The results obtained considering only healthy participants showed that controls manifested the expected Enfacement Illusion effect. Indeed, only after Congruent stimulation, the number of frames attributed to the Self increased significantly from zero and were significantly different from the number of frames attributed to the Self after the Incongruent stimulation. At an explicit level, the IQ questionnaire revealed an increment of the sensation of being touched at the same location where participants saw the Other being touched (i.e., Statement 1 of Illusion Questionnaire), especially after the Congruent stimulation. Overall, these results confirm that, at least among controls, the sharing of a synchronous and congruent multisensory experience modifies the usual Self-Other boundary, shifting it toward the Other's face.

Even if body-illusions have been considered self-specific, the inclusion in the present study of a new control condition to test the malleability of the Other-Other boundary demonstrated unexpected significant results. Among controls, besides the expected increment of the number of frames attributed to the Self after the Congruent stimulation, there was also a significant decrement of the number of frames attributed to the Other. This decrement was significantly less than zero only after the Congruent stimulation, and not after the Incongruent one. Besides the plethora of studies focused on Self-Other boundary, little is known about how the Other-Other boundary could be modified by body-illusions protocols. On the basis of the current state of the art, we can only speculate that the reduction of the number of frames attributed to the Other, visible among controls, may represent a functional adjustment, probably relevant in the context of social domains. According to this view, Zahavi (2014) claimed that "…as existing-in-the-world, we are constantly dependent upon others, and their coexistence is co-implied in our daily activities." The phenomenal experience we entertain when relating to others is possible by our bodily nature which shapes our perception and pre-reflective conception of others as other selves incarnated in a motorly capable physical body with capacities and experiences similar to ours (Gallese, 2014).

This intriguing new finding may suggest that congruent visual-tactile stimulation is one of the potential mechanisms influencing both Self-Other and Other-Other boundaries, soliciting also a better investigation of the mechanisms underlying the body-illusions (or at least the EI), which might be not purely self-related. However, considering that this is the first study addressing this topic, in order to generalize our results, additional research is needed.

Comparing the two groups, results showed common and distinct effects of EI on controls and schizophrenia patients. On the one side, both groups showed an equal malleability of the Self-Other boundary after EI. Indeed, both groups increased the number of frames attributed to the Self in the Post-Test. Furthermore, they both rated similarly the experience of the illusion at an explicit level. Specifically, only after Congruent visuo-tactile stimulation, participants reported a significant sensation of being touched by the cotton bud in the same location where they saw the Other's face being touched (i.e., scores significantly >50 in Statement 1 of Illusion Questionnaire). These results do not confirm schizophrenia patients' higher tendency to be affected by body-illusions (Ferri et al., 2014; Peled et al., 2003; Peled et al., 2000; Thakkar et al., 2011). It is possible that body-parts ownership (i.e., the hand tested by RHI) is more malleable than face ownership in schizophrenia, probably because of the particular distinctiveness of the face and the specific procedure followed by EI that anchors patients more explicitly to their self-identity than other body-illusions paradigms (i.e., RHI and full-body illusion). It is important to outline that, according to a recent meta-analysis (Shaqiri et al., 2018), the sense of ownership over body-parts or over the full body seems to be unaffected by the illness. Consequently, the present negative result could support and extend this conclusion to the sense of ownership of the face.

In spite of the above-mentioned similarity in the Self-Other boundary, the two groups differed in the malleability of the Other-Other boundary. After visuo-tactile stimulation, controls decreased the number of frames attributed to the Other when it was paired with the Stranger. Oppositely, schizophrenia patients increased the number of frames attributed to the Other in the same condition. In other words, after the visuo-tactile stimulation, controls increased the number of frames attributed to the Stranger and decreased the number of frames attributed to the Other. Conversely, schizophrenia patients increased the number of frames attributed to the Other and decreased the number of frames attributed to the Stranger. This opposite performance led to a significantly greater number of frames attributed to the Other after the multisensory procedure among schizophrenia patients than controls. Interestingly, in schizophrenia patients group the number of frames attributed to the Other and to the Self were not significantly different.

These results suggest that instead of a greater EI proneness, a qualitative difference is visible among patients in the malleability of the Other-Other boundary. Indeed, in controls, EI differentially affects the malleability of the Self-Other and Other-Other boundaries, as they increased the number of frames attributed to the Self and decreased the number of frames attributed to the Other. Differently, patients extended in the same way both the Self and the Other toward their respective different poles, as they showed an equal increment in the number of frames attributed both to the Self and to the Other after EI. Indeed, schizophrenia patients often reportedly showed a disordered sense of uniqueness, assigned not only to the Self but also to surrounding people (Cutting, 1991; Margariti and Kontaxakis, 2006). Coherently, at a psychopathological level delusional misidentification syndromes (i.e., Capgras and Frégoli syndromes), which represent this blurred sense of uniqueness, occur primarily in schizophrenia.

We demonstrated that in all participants, both Self-Other and Other-Other boundaries malleability was a specific effect of the Congruent stimulation (i.e., significant interaction Morphing by Stimulation). However, the absence of a three ways interaction between Group, Morphing and Stimulation prevents us to fully ascribe to the multisensory stimulation the specific effect found in the malleability of Other-Other boundary in patients. This was mainly due to the high sensitivity of the patients to the Incongruent stimulation, as revealed by the significant interaction Group by Stimulation. This greater sensitivity could be due to impaired self-processing in the tactile domain demonstrated in schizophrenia (Blakemore et al., 2000; Chang and Lenzenweger, 2005; Lenzenweger, 2000). Moreover, specific touch side remapping was found in the high schizotypes when compared to low and moderate schizotypes (Ferri et al., 2016). Accordingly, other studies performed on schizophrenia patients failed to find a significant difference even between synchronous and asynchronous stimulation (e.g., Kaplan et al., 2014), suggesting that patients may have an atypical spatiotemporal tactile experience. Besides the here described potential justifications, according to the present results it could be possible that even the mere exposure to the Other's face induced the patients' specific malleability of the Other-Other boundary. This consideration acquires a crucial importance to better delineate the psychopathological side of this effect, also considering the well-demonstrated familiarity alteration among schizophrenia patients (Ameller et al., 2015, 2017; Horn et al., 2015).

In conclusion, the present study confirms the plasticity of Self face representation to temporarily include another person's facial features following an multisensory procedure, as it has already been demonstrated by previous studies on the EI (Sforza et al., 2010; Tsakiris, 2008). Noteworthy, we also demonstrated, for the first time, that after the Enfacement Illusion protocols the Other-Other boundary of the controls is affected in a specific direction as showed by the decrement of the number of frames attributed to the Other only after a congruent and simultaneous visuotactile stimulation. This result suggests that Enfacement Illusion effect is not only related and confined to self sphere, but it extends to the way we distinguish others, representing a potential crucial aspect in the social domain. Secondly, the present study demonstrates that patients' Self-Other boundary is not more flexible than in controls. Instead, schizophrenia patients show an opposite malleability of the Other-Other boundary as revealed by an increment, and not a decrement, of the number of frames attributed to the Other after a visuotactile synchronous stimulation. In the light of these new findings, further studies should investigate the role of multisensory integration in the perception of the boundary between others as a potential crucial link between the phenomenology of self-experience and social cognition.

Some limitations of the present study should be highlighted. First of all, the authors are completely aware that even though the decision to exclude a control asynchronous condition was due to specific reasons (see introduction section), the lack of the asynchronous condition could represent a potential intrinsic limit of the present study. However, recent studies have shown how asynchrony, commonly used as control condition in multisensory integration paradigms, may not be an actual sensitive measure (Longo et al., 2008; Rohde et al., 2011). Moreover, differences between laboratory settings and daily life in self-face recognition should be considered. Specifically, it is unusual to observe our own face displayed in a neutral expression or without the characteristic facial features (such as hair or ears). Lastly, we involved in the protocol only patients in stable phase of recovery. This selection criterion may reduce the sensibility to EI illusion as well as the potential psychopathological interaction with the tested effects.

Conflict of interest

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

Contributors

Francesca Ferroni designed the experimental set-up, collected the data, undertook the statistical analyses, managed the literature searches and wrote the manuscript. Martina Ardizzi conceived and designed the study, undertook the statistical analyses and wrote the manuscript. Valeria Lucarini and Matteo Tonna conceived the study and selected the patients. Daniel Benjamin administered the EASE scale to patients. Vittorio Gallese, Carlo Marchesi and Mariateresa Sestito conceived and designed the study. All authors contributed to and have approved the final manuscript.

Role of the funding source

The funding source had no role in the design of this study and will not have any role during its execution, analyses, interpretation of the data, or decision to submit results.

Acknowledgments

This work was supported by Maria Paola Chiesi and by a PRIN grant on Perception, Performativity and the Cognitive Sciences to V.G.

We thank Barbara Palladini, who kindly assisted with the collection and the analysis of the data, and Brigitte Pietrangelo for her contribution in collecting the preliminary data. We really thank also Ana Tesanovic for her kind contribution in improving the present paper. Authors would like to acknowledge the patients involved in the study together with their relatives.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.schres.2018.11.018.

References

Ameller, A., Dereux, A., Dubertret, C., Vaiva, G., Thomas, P., Pins, D., 2015. What is more familiar than I? Self, other and familiarity in schizophrenia. Schizophr. Res. 161 (2–3), 501–505. https://doi.org/10.1016/j.schres.2014.12.007.

Ameller, A., Picard, A., D'Hondt, F., Vaiva, G., Thomas, P., Pins, D., 2017. Implicit recognition of familiar and unfamiliar faces in schizophrenia: a study of the skin conductance response in familiarity disorders. Front. Psych. 8 (SEP), 1–11. https://doi.org/10.3389/fpsyt.2017.00181.

Blakemore, S.J., Smith, J., Steel, R., J., Ohnstone, E.C., Frith, C.D., 2000. The perception of self-produced sensory stimuli in patients with auditory hallucinations and passivity experiences: evidence for a breakdown in self-monitoring. Psychol. Med. 30 (5), 1131–1139.

Blanchard, J.J., Mueser, K.T., Bellack, A.S., 1998. Anhedonia, positive and negative affect, and social functioning in schizophrenia. Schizophr. Bull. 24 (3), 413–424.

Blanchard, J.L., Horan, W.P., Brown, S.A., 2001. Diagnostic differences in social anhedonia: a longitudinal study of schizophrenia and major depressive disorder. J. Abnorm. Psychol. 110 (3), 363.

Bleuler, E., 1958. Dementia Praecox or the Group of Schizophrenias. International Universities Press, New York.

Bortolon, C., Capdevielle, D., Raffard, S., 2015. Face recognition in schizophrenia disorder: a comprehensive review of behavioral, neuroimaging and neurophysiological studies. Neurosci. Biobehav. Rev. 53, 79–107.

Bortolon, C., Capdevielle, D., Altman, R., Macgregor, A., Attal, J., Raffard, S., 2017. Mirror self-face perception in individuals with schizophrenia: feelings of strangeness associated with one's own image. Psychiatry Res. 253 (September 2016), 205–210. https://doi.org/10.1016/j.psychres.2017.03.055.

Botvinick, M., Cohen, J., 1998. Rubber hands feel touch that eyes see. Nature 391 (6669), 756. https://doi.org/10.1038/35784.

Bufalari, I., Lenggenhager, B., Porciello, G., Serra Holmes, B., Aglioti, S.M., 2014. Enfacing others but only if they are nice to you. Front. Behav. Neurosci. 8 (March), 1–12. https://doi.org/10.3389/fnbeh.2014.00102.

Cannon, M., Jones, P., Gilvarry, C., Rifkin, L., McKenzie, K., Foerster, A., Murray, R.M., 1997. Premorbid social functioning in schizophrenia and bipolar disorder: similarities and differences. Am. J. Psychiatr. 154 (11), 1544–1550.

Caputo, G.B., Ferrucci, R., Bortolomasi, M., Giacopuzzi, M., Priori, A., Zago, S., 2012. Visual perception during mirror gazing at one's own face in schizophrenia. Schizophr. Res. 140 (1–3), 46–50. https://doi.org/10.1016/j.schres.2012.06.029.

Catalano, L., Heerey, E., Gold, J., 2018. The valuation of social rewards in schizophrenia. BioRxiv 319095.

Chan, R.C., Li, H., Cheung, E.F., Gong, Q.Y., 2010. Impaired facial emotion perception in schizophrenia: a meta-analysis. Psychiatry Res. 178 (2), 381–390.

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.

Cornblatt, B.A., Carrión, R.E., Addington, J., Seidman, L., Walker, E.F., Cannon, T.D., Woods, S.W., 2011. Risk factors for psychosis: impaired social and role functioning. Schizophr. Bull. 38 (6), 1247–1257.

Costantini, M., Robinson, J., Migliorati, D., Donno, B., Ferri, F., Northoff, G., 2016. Temporal limits on rubber hand illusion reflect individuals' temporal resolution in multisensory perception. Cognition 157, 39–48. https://doi.org/10.1016/j.cognition.2016.08.010.

Cutting, J., 1991. Delusional misidentification and the role of the right hemisphere in the appreciation of identity. Br. J. Psychiatry 159 (S14), 70–75.

Ferri, F., Costantini, M., Salone, A., Di Iorio, G., Martinotti, G., Chiarelli, A., ... Gallese, V., 2014. Upcoming tactile events and body ownership in schizophrenia. Schizophr. Res. 152 (1), 51–57. https://doi.org/10.1016/j.schres.2013.06.026.

Ferri, F., Ambrosini, E., Costantini, M., 2016. Spatiotemporal processing of somatosensory stimuli in schizotypy. Sci. Rep. 6 (November), 1–8. https://doi.org/10.1038/srep38735.

Fioravanti, M., Bianchi, V., Cinti, M.E., 2012. Cognitive deficits in schizophrenia: an updated metanalysis of the scientific evidence. BMC Psychiatry 12. https://doi.org/10.1186/1471-244X-12-64.

First, M.B., Spitzer, R.L., Gibbon, M., Williams, J.B., 2002. Structured Clinical Interview for DSM-IV-TR Axis I Disorder-Patient Edition (SCID-I/P, Version 2.0). Biometrics Research Department, New York State Psychiatric Institute.

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), 118–127.

Fourneret, P., Franck, N., Slachevsky, A., Jeannerod, M., 2001. Self-monitoring in schizophrenia revisited. Neuroreport 12 (6), 1203–1208.

Fuchs, T., Schlimme, J.E., 2009. Embodiment and psychopathology: a phenomenological perspective. Curr. Opin. Psychiatry 22 (6), 570–575. https://doi.org/10.1097/YCO.0b013e3283318e5c.

Fuller, R.L., Luck, S.J., Braun, E.L., Robinson, B.M., McMahon, R.P., Gold, J.M., 2006. Impaired control of visual attention in schizophrenia. J. Abnorm. Psychol. 115 (2), 266.

Gallagher, S., 2000. Philosophical concepts of the self: implications for cognitive sciences. Trends Cogn. Sci. 4 (1), 14–21.

Gallese, V., 2014. Bodily selves in relation: embodied simulation as second-person perspective on intersubjectivity. Philos. Trans. R. Soc. B 369 (1644), 20130177.

Gallese, V., Ferri, F., 2014. Psychopathology of the bodily self and the brain: the case of schizophrenia. Psychopathology 47 (6), 357–364.

Gur, R.C., Gur, R.E., 2015. Social cognition as an RDoC domain. Am. J. Med. Genet. B Neuropsychiatr. Genet. 171 (1), 132–141.

Heinisch, C., Dinse, H.R., Tegenthoff, M., Juckel, G., Brüne, M., 2011. An rTMS study into self-face recognition using video-morphing technique. Soc. Cogn. Affect. Neurosci. 6 (4), 442–449. https://doi.org/10.1093/scan/nsq062.

Horan, W.P., Blanchard, J.J., Clark, L.A., Green, M.F., 2008. Affective traits in schizophrenia and schizotypy. Schizophr. Bull. 34 (5), 856–874.

Horn, M., D'Hondt, F., Vaiva, G., Thomas, P., Pins, D., 2015. Categorical perception of familiarity: evidence for a hyper-familiarity in schizophrenia. J. Psychiatr. Res. 71, 63–69. https://doi.org/10.1016/j.jpsychires.2015.09.015.

Kalin, M., Kaplan, S., Gould, F., Pinkham, A.E., Penn, D.L., Harvey, P.D., 2015. Social cognition, social competence, negative symptoms and social outcomes: inter-relationships in people with schizophrenia. J. Psychiatr. Res. 68, 254–260.

Kaplan, R.A., Enticott, P.G., Hohwy, J., Castle, D.J., Rossell, S.L., 2014. Is body dysmorphic disorder associated with abnormal bodily self-awareness? A study using the rubber hand illusion. PLoS One 9 (6), e99981. https://doi.org/10.1371/journal.pone.0099981.

Kay, S.R., Fiszbein, A., Opfer, L.A., 1987. The positive and negative syndrome scale (PANSS) for schizophrenia. Schizophr. Bull. 13 (2), 261.

Kraepelin, E., 1919. Dementia Praecox and Paraphrenia. 8th ed. ES Livingston, Edinburgh.

Lee, J., Kwon, J.S., Shin, Y.W., Lee, K.J., Park, S., 2007. Visual self-recognition in patients with schizophrenia. Schizophr. Res. 94 (1–3), 215–220. https://doi.org/10.1016/j.schres.2007.03.032.

Lenzenweger, M.F., 2000. Two-point discrimination thresholds and schizotypy: illuminating a somatosensory dysfunction. Schizophr. Res. 42 (2), 111–124.

Longo, M.R., Schüür, F., Kammers, M.P., Tsakiris, M., Haggard, P., 2008. What is embodiment? A psychometric approach. Cognition 107 (3), 978–998.

Maher, S., Mashhoon, Y., Ekstrom, T., Lukas, S., Chen, Y., 2016. Deficient cortical face-sensitive N170 responses and basic visual processing in schizophrenia. Schizophr. Res. 170 (1), 87–94. https://doi.org/10.1016/j.schres.2015.12.005.

Margariti, M.M., Kontaxakis, V.P., 2006. Approaching delusional misidentification syndromes as a disorder of the sense of uniqueness. Psychopathology 39 (6), 261–268. https://doi.org/10.1159/000095730.

Merleau-Ponty, M., 1964. Les relations avec autrui chez l'enfant. Bulletin de psychologie.

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. 38 (6), 1277–1287. https://doi.org/10.1093/schbul/sbs007.

Paladino, M.P., Mazzurega, M., Pavani, F., Schubert, T.W., 2010. Synchronous multisensory stimulation blurs self-other boundaries. Psychol. Sci. 21 (9), 1202–1207. https://doi.org/10.1177/0956797610379234.

Panagiotopoulou, E., Filippetti, M.L., Tsakiris, M., Fotopoulou, A., 2017. Affective touch enhances self-face recognition during multisensory integration. Sci. Rep. 7 (1), 1–10. https://doi.org/10.1038/s41598-017-13345-9.

Parnas, J., 2000. The Self and Intentionality in the Pre-Psychotic Stages of Schizophrenia.

Parnas, J., Handest, P., 2003. Phenomenology of anomalous self-experience in early schizophrenia. Compr. Psychiatry 44 (2), 121–134. https://doi.org/10.1053/comp.2003.50017.

Parnas, J., Møller, P., Kircher, T., Thalbitzer, J., Jansson, L., Handest, P., Zahavi, D., 2005. EASE: examination of anomalous self-experience. Psychopathology 38 (5), 236–258. https://doi.org/10.1159/000088441.

Parnas, J., Raballo, A., Handest, P., Jansson, L., Vollmer-Larsen, A., Saebye, D., 2011. Self-experience in the early phases of schizophrenia: 5-year follow-up of the Copenhagen Prodromal Study. World Psychiatry 10 (3), 200–204.

Payne, S., Tsakiris, M., 2017. Anodal transcranial direct current stimulation of right temporoparietal area inhibits self-recognition. Cogn. Affect. Behav. Neurosci. 17 (1), 1–8. https://doi.org/10.3758/s13415-016-0461-0.

Peled, A., Ritsner, M., Hirschmann, S., Geva, A.B., Modai, I., 2000. Touch feel illusion in schizophrenic patients. Biol. Psychiatry 48 (11), 1105–1108. https://doi.org/10.1016/S0006-3223(00)00947-1.

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. https://doi.org/10.1016/S0920-9964(03)00057-4.

Porciello, G., Bufalari, I., Minio-Paluello, I., Di Pace, E., Aglioti, S.M., 2018. The ‘Enfacement’ illusion: a window on the plasticity of the self. Cortex, 1–15 https://doi.org/10.1016/j.cortex.2018.01.007.

Postmes, L., Sno, H.N., Goedhart, S., Van Der Stel, J., Heering, H.D., De Haan, L., 2014. Schizophrenia as a self-disorder due to perceptual incoherence. Schizophr. Res. 152 (1), 41–50. https://doi.org/10.1016/j.schres.2013.07.027.

Raine, A., 1991. The SPQ: a scale for the assessment of schizotypal personality based on DSM-III-R criteria. Schizophr. Bull. 17 (4), 555–564. https://doi.org/10.1093/schbul/17.4.555.

Raven, J., Raven, J.C., Court, J., 1998. Manual for Raven's Progressive Matrices and Vocabulary Scales. p. 71.

Robertson, B.R., Prestia, D., Twamley, E.W., Patterson, T.L., Bowie, C.R., Harvey, P.D., 2014. Social competence versus negative symptoms as predictors of real world social functioning in schizophrenia. Schizophr. Res. 160 (1–3), 136–141.

Rohde, M., Di Luca, M., Ernst, M.O., 2011. The rubber hand illusion: feeling of ownership and proprioceptive drift do not go hand in hand. PLoS One 6 (6), e21659. https://doi.org/10.1371/journal.pone.0021659.

Sass, L.A., Parnas, J., 2003. Schizophrenia, consciousness, and the self. Schizophr. Bull. 29 (3), 427–444. https://doi.org/10.1093/oxfordjournals.schbul.a007017.

Schultze-Lutter, F., Ruhrmann, S., Klosterko, J., 2010. Basic symptoms and ultrahigh risk criteria: symptom development in the initial prodromal state. Schizophr. Bull. 36 (1), 182–191. https://doi.org/10.1093/schbul/sbn072.

Sforza, A., Bufalari, I., Haggard, P., Aglioti, S.M., 2010. My face in yours: Visuo-tactile facial stimulation influences sense of identity. Soc. Neurosci. 5 (2), 148–162. https://doi.org/10.1080/17470910903205503.

Shaqiri, A., Roinishvili, M., Kaliuzhna, M., Favrod, O., Chkonia, E., 2018. Rethinking body ownership in schizophrenia: experimental and meta-analytical approaches show no evidence for deficits. Schizophr. Bull. 44 (3), 643–652. https://doi.org/10.1093/schbul/sbx098.

Stevenson, R.A., Zemtsov, R.K., Wallace, M.T., 2012. Individual differences in the multisensory temporal binding window predict susceptibility to audiovisual illusions. J. Exp. Psychol. Hum. Percept. Perform. 38 (6), 1517–1529. https://doi.org/10.1037/a0027339.

Tajadura-Jiménez, A., Tsakiris, M., 2013. Balancing the ‘inner’ and the ‘outer’ self: interoceptive sensitivity modulates self-other boundaries. J. Exp. Psychol. Gen. 143 (2), 736–744. https://doi.org/10.1037/a0033171.

Please cite this article as: F. Ferroni, M. Ardizzi, M. Sestito, et al., Shared multisensory experience affects *Others'* boundary: The enfacement illusion in schizophrenia, Schizophrenia Research, https://doi.org/10.1016/j.schres.2018.11.018

Tajadura-Jiménez, A., Grehl, S., Tsakiris, M., 2012. The other in me: interpersonal multisensory stimulation changes the mental representation of the self. PLoS One 7 (7). https://doi.org/10.1371/journal.pone.0040682.

Tarbox, S.I., Pogue-Geile, M.F., 2008. Development of social functioning in preschizophrenia children and adolescents: a systematic review. Psychol. Bull. 134 (4), 561.

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). https://doi.org/10.1371/journal.pone.0027089.

Tsakiris, M., 2008. Looking for myself: current multisensory input alters self-face recognition. PLoS One 3 (12), 2–7. https://doi.org/10.1371/journal.pone.0004040.

Tsakiris, M., Hesse, M.D., Boy, C., Haggard, P., Fink, G.R., 2007. Neural signatures of body ownership: a sensory network for bodily self-consciousness. Cereb. Cortex 17 (10), 2235–2244. https://doi.org/10.1093/cercor/bhl131.

Tseng, H.H., Bossong, M.G., Modinos, G., Chen, K.M., McGuire, P., Allen, P., 2015. A systematic review of multisensory cognitive-affective integration in schizophrenia. Neurosci. Biobehav. Rev. 55, 444–452.

Waters, F.A., Badcock, J.C., 2008. First-rank symptoms in schizophrenia: reexamining mechanisms of self-recognition. Schizophr. Bull. 36 (3), 510–517.

Wechsler, D., 1997. Wechsler Memory Scale (WMS-III). vol. 14.

Young, J.W., Bismark, A.W., Sun, Y., Zhang, W., McIlwain, M., Grootendorst, I., Light, G.A., 2017. Neurophysiological characterization of attentional performance dysfunction in schizophrenia patients in a reverse-translated task. Neuropsychopharmacology 42 (6), 1338–1348. https://doi.org/10.1038/npp.2016.268.

Yun, J.Y., Hur, J.W., Jung, W.H., Jang, J.H., Youn, T., Kang, D.H., ... Kwon, J.S., 2014. Dysfunctional role of parietal lobe during self-face recognition in schizophrenia. Schizophr. Res. 152 (1), 81–88. https://doi.org/10.1016/j.schres.2013.07.010.

Zahavi, D., 2014. Self and Other: Exploring Subjectivity, Empathy, and Shame. OUP, Oxford.

Zahavi, D., Roepstorff, A., 2011. Faces and ascriptions: mapping measures of the self. Conscious. Cogn. 20 (1), 141–148. https://doi.org/10.1016/j.concog.2010.10.011.

Please cite this article as: F. Ferroni, M. Ardizzi, M. Sestito, et al., Shared multisensory experience affects *Others'* boundary: The enfacement illusion in schizophrenia, Schizophrenia Research, https://doi.org/10.1016/j.schres.2018.11.018