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Rethinking Body Ownership in Schizophrenia: Experimental and Meta-analytical Approaches Show no Evidence for Deficits

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Schizophrenia is a severe psychiatric disorder, in which patients experience an abnormal sense of self. While deficits in sensorimotor self-representation (agency) are well documented in schizophrenia, less is known about other aspects of bodily self-representation (body ownership). Here, we tested a large cohort ($N = 59$) of chronic schizophrenia patients and matched controls ($N = 30$) on a well-established body illusion paradigm, the Full Body Illusion (FBI). In this paradigm, changes in body ownership are induced through prolonged multisensory stimulation, in which participants are stroked on their back while seeing the stroking on the back of a virtual body. When the felt and seen stroking are synchronous, participants typically feel higher identification with the seen body as well as a drift in self-location towards it. However, when the stroking is asynchronous, no such changes occur. Our results show no evidence for abnormal body ownership in schizophrenia patients. A meta-analysis of previous work corroborates this result. Thus, while schizophrenia patients may be impaired in the sense of agency, their multisensory bodily self-representation, as tested here, seems to be unaffected by the illness.

Key words: schizophrenia/body ownership/bodily illusions/multisensory integration/meta-analysis

Introduction

Schizophrenia has been conceptualized as a disorder of the self,[1–3] in which the typical segregation of the self from the environment and other conspecifics is altered or weakened. It has been argued that this may account for symptoms such as auditory verbal hallucinations, passivity symptoms (feeling of external control over one's actions) or thought insertion (feeling that one's thoughts are those of another person).[4–9] Two main aspects of the self have been highlighted in this context in the past[5]: First, the sense of agency, refers to the feeling that we are the authors of our actions. Agency is thought to be based on sensorimotor brain mechanisms allowing us to discriminate self-generated actions from those caused by external sources.[10–15] Second, the sense of ownership refers to the feeling that the body belongs to the self, and has been related to the integration of multisensory bodily signals.[16–23]

A large volume of research has linked deficits in the sense of agency with schizophrenia,[6,9,24–29] giving rise to the hypothesis that abnormal sensorimotor signal integration is fundamentally linked to agency deficits (ie, loss of agency for one's action) and may account for some of the symptoms found in psychotic states.[7,30,31] Comparatively, the study of the sense of ownership in schizophrenia has been relatively neglected. The sense of ownership is typically studied using bodily illusions, such as the rubber hand illusion (RHI)[32–34] or a full body version of this illusion, termed the Full body illusion (FBI).[18,19,35] Both illusions are based on visuo-tactile conflicts, in which the hand or the back of the participants are stroked while they view a spatially displaced hand or body being stroked. When the viewed and felt stroking are synchronous, the multisensory conflict during stimulation (stroking is felt on the back but seen on another person's back) gives rise to an altered state of bodily self-consciousness, including subjective changes in body ownership, a modulation of the sense of self location (which is judged to be closer to the seen body), as well as physiological changes, such as lower body temperature.[16,18,19,36]

Several studies have attempted to probe the sense of ownership for a limb in schizophrenia, employing the RHI paradigm,[22,37–39] and have yielded mixed results. Some of these studies have shown an increased illusion effect (ie, higher illusion scores and/or more rapid onset) in schizophrenia patients,[37,38,40] which has been interpreted as evidence for abnormal body ownership processing in schizophrenia (see table 1 for details on these studies). However, a closer look at the results of these studies shows that they did not include control conditions typically used in RHI[32–34,36,41,42] such as asynchronous visuo-tactile stroking, or control questions (CONQ) to test for response biases, thus, leaving the possibility that the results did not stem from the multisensory integration processes thought to underlie the RHI[32,34] but rather from a response bias in the schizophrenia patients (table 1). Two RHI studies, which employed both synchronous and asynchronous stroking conditions, as well as objective measures of proprioceptive drift, have

Table 1. Review of Studies Testing the Sense of Ownership in Schizophrenia or Schizotypy

Illusion	Reference and Methods	Sample	Main Statistical Results	Summary of Results
RHI	Thakkar et al[22] RHI with both synch and asynch conditions. Measured PD and Questionnaires.	24 SCZ (mean age: 41.7, 9 Females) and 21 HTY (mean age, 40.1, 10 Females).	Main effect of Synch $P = .0002$ and Group: $P = .02$ No interaction found $P = .4$ No effect sizes reported.	Main effect of synchrony and of group, no interaction. SCZ showed larger PD in the synchronous condition.
RHI	Peled et al[40] RHI with only synch condition. Measured Questionnaires and illusion onset time.	26 SCZ (mean age: 36, 6 Females); 23 HTY (mean age: 40, 13 Females)	Questionnaire results indicate group effect with higher illusion ratings for SCZ group $P < .05$ Illusion onset time faster in SCZ group: $P < .001$	Only synchronous condition tested. Reported group differences on the time for illusion onset and the intensity of the illusion.
RHI	Peled et al[38] RHI with only synch condition. Measured Questionnaires and SEP.	19 SCZ (mean age: 32, 3 Females); 19 HTY (mean age 25, 2 Females)	No statistics reported for subjective illusion. Reported replication of Peled et al[40]	SEP differences between groups. Report only score on illusion intensity and time.
RHI	Kaplan et al[39] RHI with both synch and asynch conditions. Measured PD and Questionnaires	17 SCZ (mean age: 39, 13 Females); 17 HTY (mean age: 35, 13 Females); 17 Body dysmorphic disorder (BDD, mean age: 36, 13 Females)	Main effect of synch ($P < .001$, $\eta_p^2 = 0.53$). Main effect of group ($P = .049$, $\eta_p^2 = 0.12$)	SCZ had a main effect of higher illusion scores ($P = .04$) overall. No group by synch differences at alpha .01. Also, no group differences for the PD.
RHI (but without contact)	Ferri et al[51] RHI with no tactile contact. Employed synch, asynch and object control condition.	21 SCZ (mean age: 41.1, 0 Females); 17 HTY (mean age: 46.6, 0 Females)	Main effect of group and of condition (HTY had a higher mean rating (1.05) compared to SCZ (−0.21) for hand congruent condition ($P < .001$).	SCZ patients had lower illusion scores during hand-congruent condition compared to HTY.
RHI (HTY only)	Germine et al[52] Healthy participants tested on the RHI. Schizotypy based on high or low scores of psychosis-proneness. Used synch and asynch conditions. Measured Questionnaires	55 HTY (with high or low psychosis-proneness scores; mean age: 28, 35 Females).	Synch condition was associated with higher ownership, agency and drift (all P values $< .05$)	Healthy controls tested with the RHI based on high or low scores of psychosis-proneness. High schizotypy scores were correlated with high RHI effect in the synchronous condition.
RHI (HTY only)	Asai et al[86] Healthy controls tested on the RHI. Used only a synchronous condition. Measured Questionnaires	72 HTY (with high or low schizotypy scores; mean age 19.7, 36 Females)	RHI sensitivity score and drift were correlated $P < .01$ The RHI sensitivity was also correlated with positive schizotypy $P < .01$	Healthy controls tested on the RHI. Only synchronous condition. Correlated RHI sensitivity with schizotypy proneness and empathic personality traits.

Note: RHI, rubber hand illusion; PD, proprioceptive drift; synch, synchronous visuo-tactile condition; asynch, asynchronous visuo-tactile condition; SCZ, schizophrenic patients; HTY, healthy controls; SEP, somatosensory evoked potentials.

found no interaction between group and synchrony for the subjective aspects of the illusion (Note however that both of these studies found higher subjective ratings for both synchronous and asynchronous conditions suggesting that schizophrenia patient tend to respond with higher ratings to such questions, even in a condition that does not elicit the illusion in healthy participants, a finding which has been replicated in many studies, including the current one.).[22,39] For the proprioceptive drift measures, one study reported large synchrony dependent differences between the control and schizophrenia groups,[22] while the other found no differences for the schizophrenia patients (Note that in the study by Kaplan and colleagues[39], the schizophrenia group was a control group to compare with body dismorphic disorder patients.).[39] Furthermore, these previous studies have employed a low number of patients (M = 23.2, SD = 4.7) with limited statistical power. Thus, while claims for abnormal ownership in schizophrenia have been widely cited and discussed,[23,43–46] the empirical support for such claims is quite limited (see table 1 and meta-analysis below). The current study investigated body ownership in a large cohort of chronic schizophrenia patients (N = 59) and matched controls (N = 30) using the FBI, which has been used extensively in healthy participants[18,19,35,47–50] but not in patients with schizophrenia. Using both subjective measures and objective measures of body ownership, as well as Bayesian statistics, we found no evidence for abnormal body ownership in schizophrenia. Furthermore, a systematic review and meta-analysis of the previous experimental studies of body ownership in schizophrenia indicated no substantial evidence for differential body ownership in schizophrenia.

Methods

Participants

Fifty-nine schizophrenia patients and 30 controls participated in the study. Groups are described in table 2. Schizophrenia patients were recruited from the Gotsiridze psycho-neurological dispensary and the Asatiani psychiatric hospital and rehabilitation center of Tbilisi, Georgia.[53,54] Healthy controls were recruited from the general population. We excluded all participants with neurological disorders, with traumatic brain injury or with a history of drug or alcohol abuse.

The study was approved by the ethics committee of the Georgian National Council on Bioethics and in accord with the principles of the Declaration of Helsinki. Participants signed informed consent and were informed that they could quit the experiment at any time.

Diagnosis and Psychopathology

Patients were diagnosed using the DSM-IV by means of an interview based on the SCID. Psychopathology was assessed by the Scale for the Assessment of Negative (SANS) and Positive (SAPS) Symptoms, carried out by an experienced senior psychiatrist (E.C.). All patients were under neuroleptic medication. Chlorpromazine equivalents are reported in table 2.

Table 2. Participants' Characteristics

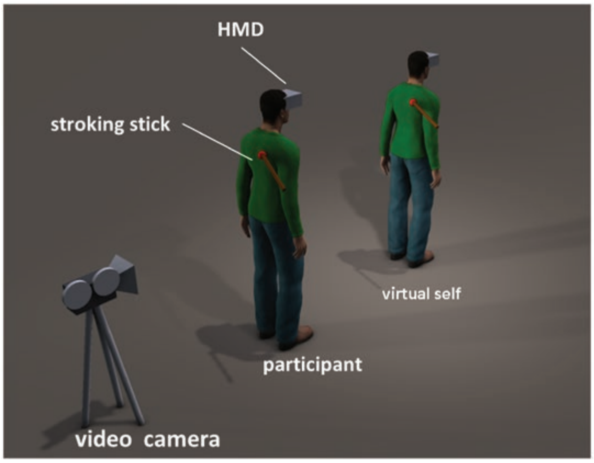
	Schizophrenia Patients (N = 59)		Controls (N = 30)	
	Mean	SD	Mean	SD
Female	15/59		14/30	
Age (y)	36.53	9.52	36.93	8.03
Age range (y)	17–55		22–54	
Education (y)	12.94	2.4	14.9	2.64
Illness duration (y)	11	9.54		
SANS	12.08	5.1		
SAPS	9.76	3.17		
CPZ	557.35	461.03		

Note: SANS, Scale for the Assessment of Negative Symptoms; SAPS, Scale for the Assessment of Positive Symptoms; CPZ, Chlorpromazine equivalents. The age, age range, education and illness duration are reported in years.

Procedure

The FBI setup with a body viewed from the back was employed.[18,35] Participants stood with their back towards a camera, positioned 2 meters behind them (figure 1). The video of their back was projected onto a head-mounted display (HMD) in real time (synchronous condition) or with a 800 ms delay (asynchronous condition). The camera was controlled by an in-house software ExpyVR (http://lnco.epfl.ch/expyvr). Participants were exposed to each condition once, in a randomized order. During each condition, the participants' back was stroked by the experimenter with a long wooden stick in an irregular fashion. Participants could see the stroking (but not the experimenter) in the HMD. Participants were instructed to keep their eyes open and fixate the middle of their back without moving their body. Each condition lasted for 1.5 minutes, after which the HMD went black, and participants were instructed to close their eyes. At this point, global self-localization (drift) was measured: participants were gently displaced 1.5 meters backwards by the experimenter, making very small shuffling steps (a procedure practiced beforehand). Participants had to then walk back with normal steps to the location where they felt they stood before (keeping their eyes closed). The experimenter measured the distance between their initial position during the experimental block and the position participants walked to. White noise was continuously played through headphones during the procedure. After these measurements were taken, participants were randomly displaced in the room to preclude any feedback about their accuracy when they opened their eyes. They could then open their eyes, sit down, and fill out a questionnaire on self-identification with the illusory body.

A.



B.

1. **It seemed as if I were feeling the touch of the stick in the location where I saw the virtual body touched.**
2. **It seemed as though the touch I felt was caused by the stick touching the virtual body.**
3. **I felt as if the virtual body was my body.**
4. **It felt as if my (real) body was drifting towards the front (towards the virtual body).**
5. **It seemed as if I might have more than one body.**
6. **It seemed as if the touch I was feeling came from somewhere between my own body and the virtual body.**
7. **It appeared (visually) as if the virtual body was drifting backwards (towards my body).**
8. **It seemed as though I was in two places at the same time**

Fig. 1. (A) Setup for the Full Body Illusion. (B) The 8 questions of the body ownership questionnaire.

Body Ownership Questionnaire

We used a typical questionnaire employed in previous studies using the FBI[18,35,55] which were translated to Georgian by 2 of the authors (M.R. and E.C.). The questionnaire included 8 items of which 3 aimed at measuring body ownership (experimental questions [EXPQ]: questions 1 to 3) and the other 5 (CONQ) were used to control for suggestibility or other response biases (figure 1). The measurement of subjective changes in body ownership induced by illusions such as the RHI and FBI typically rely on comparing subjective responses on items known to be modified by the visuo-tactile illusion with those which are not.[18,19,32,55–57]

Responses were given on a Likert type visual scale with 7 levels describing the level of agreement with the question ranging from disagree strongly (−−−) to agree strongly (+++).

Data Analysis

Subjective Responses and Bayesian Analysis. Subjective responses on the questionnaire were transformed to numerical score (+3 to −3) and averaged for the questions probing the illusion (EXPQ: Q1–Q3) and the control questions (CONQ: Q4–Q8) for the synchronous (synch) and asynchronous (asynch) condition for each participant. The data where then analyzed using a 2 (EXPQ/CONQ) × 2 (synch/asynch) repeated measures ANOVA with group (healthy controls/schizophrenia patients [HTY/SCZ]) as a between subject factor.

We performed a Bayesian analysis using the method of Gallistel[58] in order to test the strength of the evidence relating to the null hypothesis (see also Cappe[59]). We ran a Bayesian repeated measures ANOVA on the questionnaire data, with group (HTY/SCZ) as a between subject factor and (synch/asynch) as a within subject factor using the JASP software (JASP team, 2016). This approach allows to measure if the null hypothesis is more likely or less likely, given the data. Further exploratory, post hoc, analyses taking into account the Scale for the Assessment of Negative (SANS) and Positive Symptoms (SAPS) were performed. Patients were divided into high and low SAPS and SANS groups based on a median split of the data. Two separate repeated measure ANOVAs with question type (EXPQ/CONQ) × synchrony (synch/asynch) as within subject factors and group (HTY/SCZ High SAPS/SCZ Low SAPS) as a between subject factor were conducted (one for SAPS and one for SANS). We further ran identical Bayesian repeated measures ANOVAs with subject as a random effect using BayesFactor[60] package in R software (Rteam).

Global self-localization was measured as the difference between the participant original location and the location to which they arrived when asked to return to the original location.[18] The distance in centimeters was analyzed using a repeated measures ANOVA with (synch/asynch) as a within subject factor and group (HTY/SCZ) as a between subject factor.

Ranking and Power Analyses. If the data from the subjective responses on the EXPQ of the questionnaire and from the drift were correlated, we would expect participants who show a high illusion score to also have a large score on the drift. In the extreme case, we would expect the participant with the highest score on the questions and drift to be ranked first, the second to be ranked second in all measures, and so on. On the other hand, if having high scores on questions is unrelated to performance in the drift test, then we would expect each participant's rank over the scores to average around the middle rank (ie, 25 for the schizophrenia patients and 15 for the controls). In this case, participants' score should also not be different from a rank that was assigned randomly during a simulation. This was assessed using a rank analysis (figure 3), in which we tested if the performance of our participants differs from a simulation where we assign a random rank to each participant.

Finally, to assure that our null results do not stem from a lack of statistical power, we computed a power analysis using GPower.[61] In addition, we did not adjust for multiple comparisons in order to have a conservative estimate for null effects.

Meta-analysis. We searched in Google Scholar and PubMed for all published studies using the keywords or the association of keywords: out of body experience/RHI and schizophrenia or out of body experience/RHI and psychosis. The search revealed $k = 7$ studies that corresponded to those criteria. Out of those 7 studies, we removed studies which did not include both synchronous and asynchronous visuo-tactile conditions (as they do not allow to control for documented response biases in schizophrenia cohorts). We also removed studies that did not have 2 groups (patients and controls), as this does not allow for group comparison. We performed a meta-analysis on the remaining 3 studies and also in a second step, we included the results of the current study (supplementary figure 1). For each study, we calculated the Cohen's d for the interaction between the synchrony condition (synch/asynch) and the group factor (HTY/SCZ). Standardized effect sizes (Hedges' g) were calculated using Cohen's d multiplied by the coefficient J, which is a correction for small samples.[62] Hedges' g were introduced as a generic effect size in the OpenMeta Analyst software (http://www.cebm.brown.edu/openmeta/) with the corresponding variance (SE). We used the continuous random-effect analysis with the DerSimonian-Laird (DL) method. The meta-analysis software computed 95% CI and the pooled effect size g^*. We note that our meta-analysis, while including all relevant studies, is based on a small number of published papers (for similar examples see[63–66]) and has low statistical power and therefore should be viewed as a statistical aggregate of current evidence on this topic. Furthermore, meta-analyses are known to suffer from publication bias in which typically only studies with significant effects are included. Given the low number of studies on this topic, it is not possible yet to formally test for a publication bias.[67] However, it has been suggested that publication bias is present in ~40% of meta-analysis such that meta-analytic effects are often larger than the true effect. Thus it is possible that the result of the meta-analysis is in fact higher than the true effect.[68–70]

Results

Subjective Responses

As expected, an ANOVA indicated a significant main effect of question type ($F(1,87) = 187.1$, $P < .001$, $\eta^2 = 0.68$) with higher responses on the EXPQ ($M = 1.75$, SD = 1.6) than on the CONQ ($M = -1.48$, SD = 1.75). The effect of synchrony was also significant ($F(1,87) = 6.48$, $P = .013$, $\eta^2 = 0.068$), with higher responses for questions in the synch condition ($M = 0.23$, SD = 2.33) than in the asynch condition ($M = 0.04$, SD = 2.33). The effect of group was significant as well ($F(1,87) = 42.2$, $P = .002$, $\eta^2 = 0.1$), with higher responses given by the SCZ group ($M = 0.38$, SD = 2.29) than in the HTY group ($M = -0.35$, SD = 2.33). Critically, the interaction between question type and synchrony was also significant ($F(1,87) = 4.6$, $P = .034$, $\eta^2 = 0.05$). This was driven by a significant modulation of the EXPQ by synchrony ($P = .01$) while the CONQ was not ($P = .65$, see figure 2). Importantly, the 3-way interaction between question type, synchrony and group was not significant and had a very small effect size ($F(1,87) = 0.26$, $P = .6$, $\eta^2 = 0.003$). Bayesian analysis of the null results indicated a $BF_{10} = 0.014$, suggesting a very strong evidence for the null hypothesis. While not of direct interest to our hypothesis, we nevertheless ran an exploratory post hoc analysis on the questions by group ($P = .73$, $BF_{10} = 0.37$) and the synchrony by group interactions ($P = .16$, $BF_{10} = 0.12$), which were not significant (for details, see supplementary table 1).

A post hoc analysis based on the SANS and SAPS scores indicated that even when the patient groups were median-split based upon their symptom clusters, there was no difference (ie, no 3-way interaction between synchrony by question type by group). This was the case for both the SAPS or the SANS based division of the data ($F(2, 86) = 1.57$, $P = .21$ and $F(2, 86) = 1.67$, $P = .19$, respectively). Further, Bayesian ANOVAs indicated that for both the SAPS and the SANS division of the data, there was higher evidence for the model of the 2-way synchrony by question type interaction than the model including the 3-way synchrony by question type by group interaction (BF_{10}SAPS = 4.31, BF_{10}SANS = 2.74).

Self-localization

The ANOVA on global self-localization drift measures indicated no difference between the groups (MSCZ = 3.09, SEM = 3.48; MHTY = 4.96, SEM = 4.89, $P = .79$), nor an effect of synchrony (Msynch = 5.11, SEM = 4.16; Masynch = 2.33, SEM = 3.85, $P = .51$), or an interaction between the 2 factors (MSCZ-synch = 4.15, SEM = 4.85, MSCZ-asynch = 2.04, SEM = 5.02, MHTY-synch = 7.01, SEM = 7.95, MHTY-asynch = 2.91, SEM = 5.82, $P = .83$).

Ranking and Power Analyses

We ranked the scores of the schizophrenia patients and controls in the EXPQ of the FBI questionnaire and the drift (after *z* transforming the scores). We then sorted the scores and plotted them from smallest to the largest. We then ran a simulation, in which we simulated more than 10 000 sets of observers, in which the ranked score of one observer was independent from the ranked score of another observer (using a permutation of the real data). We plotted those random-simulated data next to the data of our participants (figure 3). A Chi-squared test did not reveal a significant difference between the simulation and the scores of our schizophrenia or control participants for the EXPQ and the drift ($X^2(2, N = 58) = 6.32$, $P = 1$ and $X^2(2, N = 29) = 3.90$, $P = 1$, respectively).

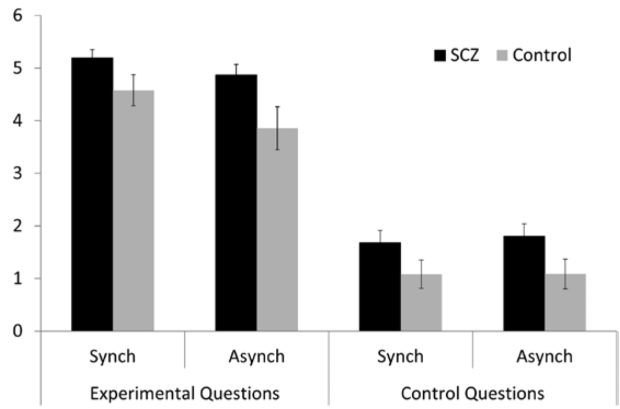


Fig. 2. Schizophrenia patients and controls answers for the subjective experience. We found a main effect of the questions type (experimental vs control questions), for the synchronous compared to asynchronous conditions (higher responses for the synchronous condition), as well as a group effect, with higher scores for schizophrenia patients compared to controls.

Finally, we performed a power analysis. With 89 participants in total (59 patients and 30 controls), we had the power to detect an effect size of 0.68, which is a medium effect size according to Cohen.[71]

Meta-analysis

Effect sizes in studies that examined the interaction between condition and group were not significant ($N = 134$, $k = 3$, $g = 0.005$, CI −0.964 to 0.974, $P = .992$). The meta-analysis shows therefore, that across studies, there is no difference for illusion scores between groups (HTY/SCZ) based on the visuo-tactile condition (synch/asynch). Figure 4 shows the Forest plot of the studies examining the interaction between condition and group. Those results were confirmed by the addition of our current study in the meta-analysis (supplementary figure 1). We note that the restricted number of studies in this field allows limited statistical power on their meta-analytical effect and should be regarded as such.

Discussion

Schizophrenia is a heterogeneous disease and abnormal functions are constantly found, including cognitive[72] and perceptual deficits,[54] abnormal brain morphology[73] connectivity,[74] and even an abnormal immune system[75] (for reviews see[76,77]). Recently, the bias towards publication of significant positive results (publication bias) and low powered studies[78] have been suggested as possible causes of overestimation of effects and low reproducibility rates in science. In clinical research,[79] including schizophrenia research, intact functions are reported to a lesser degree, causing a publication bias towards highlighting deficiencies in schizophrenia.[80,81] For example, a recent study found no differences between schizophrenia patients and controls in 7 different perceptual illusions (Grzeczkowski

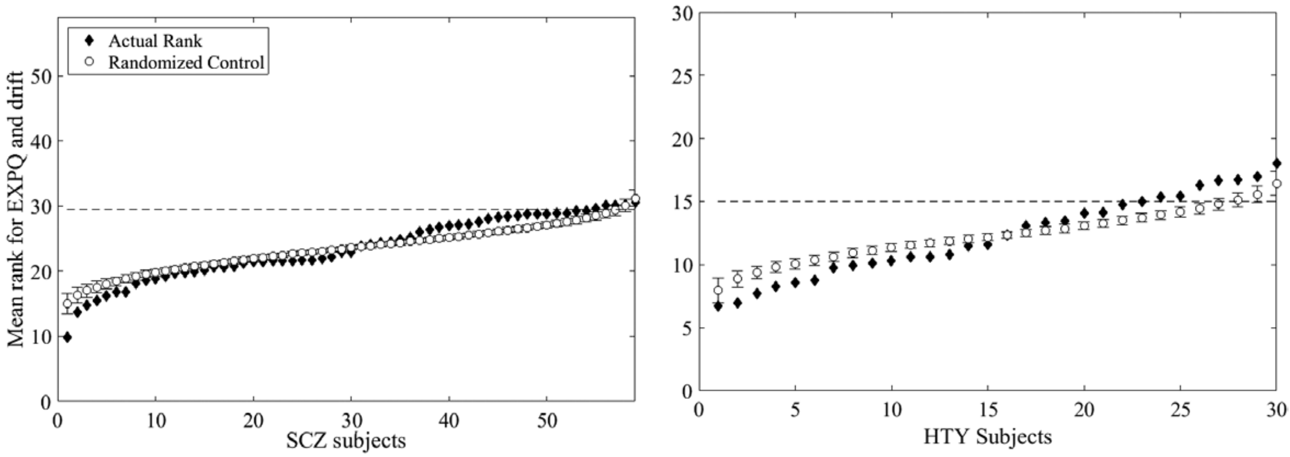


Fig. 3. Ranking analysis for schizophrenia patients and controls. We calculated the mean rank across all participants for the experimental questions (EXPQ) and the drift. We then ran 10 000 simulations for a random set of participants, where the scores for the questions would be independent of the score for another question or from the drift. The simulation matched the data. Error bars are the SDs of the ranks.

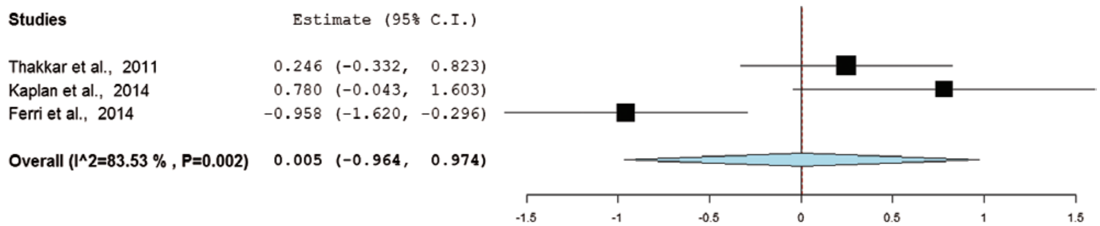


Fig. 4. Forest plot of 3 studies considering the interaction between the condition (synch/asynch) and the group (schizophrenic patients/healthy controls [SCZ/HTY]) ($N = 134$, $k = 3$, $g = 0.005$, $P = .992$).

L, Shaqiri A, Roinishvili M, et al., in preparation, 2016), suggesting intact perceptual processing capabilities which have not previously been reported. This is particularly important for a heterogeneous disease such as schizophrenia, in which variability in functioning and symptoms is considerable.[82,83]

Here, we report that body ownership, as determined by the FBI, shows no evidence for differential processing between healthy controls and schizophrenia patients. Our results contrast with previous reports that used the RHI, which have found higher subjective ratings for illusory body ownership in schizophrenia.[22,40] However, 2 of these studies did not use asynchronous control conditions,[38,40] making it difficult to establish if the results are due to a response bias in the schizophrenia patient group (who tend to give higher responses to ownership questions and often control questions irrespectively of visuotactile synchrony), as we found in the current study, as well as reported by other studies.[22,39] We note that such a response tendency, irrespective of the synchrony of the multisensory signals and often extending to control questions may be explained in several ways. First, it is possible that schizophrenia patients have a tendency to agree more strongly with questionnaire items in general (ie, response bias). Second, it is possible that the mere viewing of a fake hand or body induces anomalous body sensations in these patients which extend beyond the findings in healthy subjects thus including questionnaire items not typically experienced by healthy subjects (ie, visually induced ownership). Finally, it is possible that irrespective of any of the experimental manipulations, the schizophrenia patients have an atypical bodily experience. These possibilities, while clinically interesting, all suggest that this response tendency is unrelated to the multisensory mechanisms underlying body ownership in the RHI and FBI[16,17,21,84] for which the patients and participants showed no difference in the current study.

Thus, while there has been much discussion in the scientific literature regarding abnormal body ownership in schizophrenia, there have been very few studies published, and even these few studies have yielded mixed results.[22,38,40,85] Two possibilities may explain the difference between our current results, showing no differential body ownership modulation between synchronous and asynchronous conditions between healthy controls and chronic schizophrenia patients, and the previous reports of abnormal body ownership in patients. First, it may be that there is no difference in body ownership related to multisensory conflicts (ie, synchrony dependent) between healthy and schizophrenia patients, but rather a response bias for higher illusion ratings in schizophrenia. This interpretation of our null results is well corroborated by Bayesian, power and rank analyses. We note that, our study included a large sample size (to date, the largest used in a study of body ownership in schizophrenia with more than twice the sample size of the second largest study). Taken together with the sparse and conflicting results of previous studies on this topic as well as our meta-analysis showing no effect of group based on the synchrony by group interaction, we believe that there is little evidence for a disturbance of body ownership in schizophrenia. Alternatively, one must consider the possibility that the difference between studies stems from the paradigms employed here (FBI) vs the one used in previous experiments (RHI). It may be that multisensory processes underlying body ownership illusions for body parts (ie, RHI) differ from those responsible for Full body ownership (ie, FBI). It has been argued that multisensory signals, as employed during the FBI, relate to global aspects of bodily self-consciousness (self-location and first person perspective[16,86,87]) due to interference with trunk-related multisensory signals in the FBI, but not the RHI. Previous reports of enhanced subjective RHI,[40] larger proprioceptive drift without altered subjective experience[22] or decreased[51] RHI in schizophrenia patients would thus point to a deficit in *limb ownership* (ie, the hand) rather than deficits in *body ownership* (the full body) as investigated here. Further research is necessary, directly comparing RHI and FBI, although the FBI and its interference with global aspects of bodily self-consciousness is arguably more relevant to the disturbed global representation of self, which has been argued to be a key deficit in schizophrenia.[2,3,8,63] The scarcity of results supporting abnormal body ownership in schizophrenia is strongly contrasted with the abundance of results for abnormal sense of agency in schizophrenia.[9,24–28] This suggests the possibility of a publication bias for body ownership deficits in schizophrenia. However, the low number of published papers does not allow to the necessary power for a *P*-curve analysis, to test this possibility.

Limitations

One drawback of our study is that while a significant effect for the illusion was found for the questionnaire, no significant effects were found for the drift measure. While the drift in the synchronous conditions was numerically higher than in the asynchronous conditions, we found a high variability in the drift measure. It is possible that the wide range of participants' ages (range 17–55) may have increased the variability of the drift measure as it has been shown to differ between age groups.[88] Moreover, several previous studies using the RHI[22,42] and FBI[19,87,89] have shown that proprioceptive drift and subjective experience measures do not always correspond and may reflect different aspects of body ownership.[42,89,90] Finally, as noted above, our meta-analysis while fully inclusive, is based on the limited number of studies available on the topic and therefore has limited statistical power.

Taken together, the current work suggests that the notion of abnormal body ownership in schizophrenia is not well supported by empirical evidence. Further well-controlled experiments using several delays, object control conditions and higher powered studies are required before any such claims can be made. Furthermore, of the 2 aspects of the self defined by Gallagher,[5] it seems that not all functions related to the self are disturbed in schizophrenia. Deficits relating to the sense of agency and sensorimotor predictions have been replicated across several paradigms and modalities[25–31] while the current results and meta-analysis suggest that there is no deficit in body ownership aspect of schizophrenia. This is an important distinction, allowing a realistic picture of the deficits of the self in this disease while recognizing that other aspects of the self remain intact.

Supplementary Material

Supplementary material is available at *Schizophrenia Bulletin* online.

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