ARTICLE IN PRESS
SCHRES-08676; No of Pages 8
Schizophrenia Research xxx (xxxx) xxx
Contents lists available at ScienceDirect
Schizophrenia Research
journal homepage: www.elsevier.com/locate/schres

Altered self-recognition in patients with schizophrenia

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ARTICLE INFO

Article history:
Received 14 August 2019
Received in revised form 12 January 2020
Accepted 19 January 2020
Available online xxxx

Keywords:
Schizophrenia
Enfacement illusion
Multisensory integration
Neurophenomenology
Body-illusions

ABSTRACT

Self-alienation is a common characterization of various disturbing experiences in patients with schizophrenia. A vivid example comes from patient reports of not recognizing themselves when inspecting their specular image in the mirror. By applying the multisensory paradigm of the Enfacement Illusion, this study empirically addresses the specular Self-Other discrimination in patients with schizophrenia. 35 patients diagnosed with schizophrenia and 35 healthy matched controls were enrolled in the study. Results found that the group of patients with schizophrenia had a significant skewed self-other discrimination towards the *other* at baseline. Furthermore, the effect of visuo-tactile stimulation on self-recognition in the schizophrenia patients was significantly altered after both synchronous and asynchronous stimulation compared to baseline. This contrasted with healthy controls which in line with earlier studies only had significantly different self-recognition after synchronous stimulation. The study thus suggests that patients with schizophrenia have deviations in their specular self-recognition compared to healthy controls. Moreover, that temporal factors in multisensory integration may contribute to alterations of self-related stimuli in patients with schizophrenia.

1. Introduction

Looking at oneself in the mirror is a peculiar situation where one is suddenly confronted with one's own subjectivity objectified in the specular image. Such experience may be fleetingly unsettling, perhaps motivating some thoughts about self-identity. The fact that the person I see in the mirror is *me*, is a more implicit and automatic identification. It is typically this identification, which makes it worthwhile spending time in front of the mirror.

Among the various features of schizophrenia the relatives of patients often described that the future patient could spend hours in front of the mirror inspecting herself ("mirror sign" or "signe du miroir" [(Abely, 1930)]). This behaviorally defined sign of schizophrenia may reflect various alarming subjective experiences such as not recognizing oneself, seeing oneself as being not alive or detecting morphological changes etc. (some patients have a tendency to avoid the mirrors altogether) (Parnas et al., 2005). Since the first report of the "mirror sign" by Abely, several empirical studies have been published on a variety of abnormalities in mirror-behavior and self-recognition in schizophrenia patients (Caputo et al., 2012; Rosenzweig and Shakow, 1937; Weckowicz and Sommer, 1960). The "mirror sign" is emblematic to the self-alienation that characterizes many symptoms and signs in schizophrenia patients. In a phenomenological perspective the self-alienation in schizophrenia can be described as an instability in the first personal perspective of experience i.e. the way experiences pre-reflectively and transparently articulate themselves as our own (there is an automatic self-ascription of experience) (Parnas and Henriksen, 2014).

For most patients, self-disorders will be elusive and difficult to verbalize, giving rise to characteristic though vague complaints such as a feeling of strangeness, or not truly existing or being present. The instability of the first-person perspective may manifest itself in multiple experiential domains such as temporal self-continuity, self-demarcation and a normally unproblematic sense of embodiment, i.e. existing as a unified psychophysical organism.

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https://doi.org/10.1016/j.schres.2020.01.022

Please cite this article as: K.E. Sandsten, J. Nordgaard, T.W. Kjaer, et al., Altered self-recognition in patients with schizophrenia, Schizophrenia Research, https://doi.org/10.1016/j.schres.2020.01.022

Since early foundational texts on schizophrenia, emphasis on pre-psychotic disturbances to the ego or self has been described as a specific and constitutive trait of the disorder (Bleuler, 1911; Parnas, 2011). Instead of viewing schizophrenia as a mixture of isolated symptoms and signs the demarcation of the disorder was to be found in a characteristic abnormal gestalt of the patient's subjectivity (Sass and Parnas, 2003).

These phenomenological observations motivate certain neurobiological approaches to the self. An important contribution to this area of research comes from studies in multisensory integration including the landmark study of the Rubber Hand Illusion (RHI) (Botvinick and Cohen, 1998). The experiment demonstrated how the felt sense of "ownership" of one's hand could be transferred to a rubber hand by use of visuo-tactile stimulation. In the standard procedure of the illusion a rubber hand is placed in front of the participant while the participant's real hand is hidden from view. The experimenter simultaneously stimulates the rubber hand and the participant's hidden hand with two brushes producing the illusory experience of ownership over the rubber hand. The RHI has been tested several times on patients with schizophrenia and indicate higher susceptibility and a stronger sense of the illusion compared to healthy controls (Peled et al., 2000; Peled et al., 2003; Thakkar et al., 2011) (for a review see (Klaver and Dijkerman, 2016)). These findings support the notion that patients with schizophrenia have alterations in the multisensory integration relating to bodily self-experience.

Among the varieties of multisensory illusion tests, we also find the Enfacement Illusion (EI) introduced by Tsakiris (2008). This experiment has shown how multisensory stimulation can affect self-recognition (Tsakiris, 2008; Tajadura-Jimenez et al., 2012b). In the test, self-recognition is evaluated before and after a stimulation session by letting the participant look at a morphing-video between the participant's own face (self) and the face of a stranger (other). The participant has to judge when she starts recognizing herself in the morphing-video by pressing a button, in direction *other* to *self*, and vice versa in the *self* to *other* direction. During the stimulation session, the participant watches a video displaying the face of the *other* looking straight back (as if looking into the mirror but seeing the *other*), while receiving a tactile stimulation with a paintbrush at the cheek simultaneously applied to the *other* in the video. By comparing the self-recognition tests, i.e. the percentage of other-frames accepted as looking like *self*, before and after stimulation it has been possible to show how self-recognition can be altered. This suggests that facial self-recognition in mirrors to some degree is dependent upon an ongoing multisensory integration of visual and tactile stimuli.

Ferroni et al. (2018) recently published the first study of EI performed on patients with schizophrenia. The study compared the effects of EI between patients and controls but found no differences between groups with regard to their self-other distinctions. The study used a spatial incongruence condition during the visuo-tactile stimulation, i.e. stimulating on the opposite cheek. The temporal contribution to the multisensory integration in EI for schizophrenia patients thus remains unaddressed.

Based on some of these considerations, we decided to test self-recognition and multisensory integration in patients with schizophrenia by applying the EI. We hypothesize that the group of patients with schizophrenia will have a different self-other boundary in the enfacement illusion by being more susceptible to the illusion and accepting more of the *other* as *self*.

2. Methods

2.1. Participants

35 patients diagnosed with schizophrenia (SCZ) (mean age 22.11 years, SE 0.665, 14 males) and 35 matched healthy controls (HC) (mean age 24.06 years, SE 0.548, 14 males) were included in the study (see Table 1). The patients were recruited from three psychiatric outpatient clinics in Region Zealand in Denmark. The majority of patients were under medical treatment with atypical antipsychotics. Healthy controls were recruited from various educational institutions in Region Zealand by flyers and personal contact to students and staff. All participants were recruited between May 2017 and February 2019. The paradigm used in this study was part of a larger test-battery. The number of included subjects was determined based on a power calculations for estimated differences between groups from this comprehensive test-battery.

The inclusion criteria for the SCZ group were 1) age between 18 and 40 years 2) diagnosed with schizophrenia within the last year according to Diagnostic and Statistical Manual of Mental Disorders V (DSM V) (Association, 2013) 3) a stable phase of the illness (without need for hospitalization and capable of 3 h long interviews). Exclusion criteria were 1) active drug abuse 2) any organic pathological conditions likely to affect cognition or the somatosensory system (known injury or illness in the central nervous system and mental retardation).

Inclusion criteria for HC were an age between 18 and 40 years. Exclusion criteria where the same as in the SCZ group, moreover participants were excluded if they suffered from a current episode of any mental illness or had a history of a chronic mental illness (schizophrenia, schizotypy, bipolar illness and severe personality disorder).

All inclusion and exclusion criteria were assessed based on the psychopathological evaluation, a psychiatric and neurological clinical history and a focused neurological examination of vision (with Snellens eye-chart), hearing (fingers crackling) and sensation (facial sensation in the three branches of trigeminal nerve).

A written consent was obtained from all participants after having received a thorough oral and written description of the tests performed in the study. The study was approved by the regional data agency and ethics committee in Region Zealand, Denmark and in line with the ethical standards of the Declaration of Helsinki 2013.

2.2. Clinical evaluation

All participants went through a comprehensive psychopathological evaluation including Assessment of Positive and Negative Syndrome Scale (PANNS) (Kay et al., 1987), the Operational Criteria Checklist for Psychotic Illness and Affective Illness (OPCRIT) (McGuffin et al., 1991) and Examination of Anomalous Self Experience (EASE) (Parnas et al., 2005). Moreover, all participants were intelligence-tested (Liepmann et al., 2001).

The psychiatric evaluation was performed by KES, a senior resident in psychiatry, who was specifically trained and reliability tested by the founder of the EASE scale (JP) and another senior EASE expert (JN). The majority of the psychiatric interviews were video recorded. In cases of diagnostic or assessment problems the clinical material was discussed with a senior psychiatrist (JP) and a consensus resolution was achieved.

2.3. Experimental setup

2.3.1. Morphing movie

Each participant had a digital photograph of their face (Self) taken before starting the experiment. Furthermore, a digital library with photographs of different (age, sex and ethnicity) unfamiliar faces (Other) had been produced and was available for the purpose of this study. Each photograph was imported into Abrosoft Fantamorph 5 (Version 5.4.8) and converted to a greyscale. Photographs of participants where flipped horizontally (as in the mirror). Non-facial attributes (e.g. ears, hair, background) were removed by applying on oval frame around the face and photographs of the participants (Self) were then matched (sex, age and ethnicity) with a photo of an unfamiliar face (Other). Two morphing movies each lasting 15 s and consisting of 150 frames (10 frames/s) were created of the two faces. The morphing directions were *Self-Other*, starting with the Self photograph (100% Self; 0%

Table 1
Background demographic information presented with mean scores, percentage in group (%), standard deviation (SD) and estimated between-group differences with mean and *p*-values. SCZ = schizophrenia patient group. HC = healthy control group. Significant differences between groups are marked with *. Non applicable scores are marked as n.a.

Scales	SCZ	HC	Between-group difference
Participants (male/female)	35 (14/21)	35 (14/21)	0
Age (years)	22.11; SD 3.93	24.06; SD 3.24	1.95; $p = 0.027$*
Education (years)	11.06; SD 1.85	14.63; SD 1.59	3.57; $p < 0.001$*
Intelligence score	93.15; SD 10.96	96.32; SD 10.20	3.17; $p = 0.21$
PANSS general score	42.43; SD 7.07	n.a.	n.a.
PANSS positive score	17.74; SD 3.72	n.a.	n.a.
PANSS negative score	22.57 SD 4.98	n.a.	n.a.
Antipsychotic medication (%)	30 (86)	0 (0)	30; $p < 0.001$*
Antiepileptic (%)	2 (6)	0 (0)	2; $p = 0.156$
Antidepressant (%)	5 (14)	2 (6)	3; $p = 0.238$

Other) and gradually morphed into the Other photograph (0% Self; 100% Other). A similar procedure in opposite direction was used to create an *Other-Self* movie, thus starting with the Other (0% Self; 100% Other) and ending with Self (100% Self; 0% Other) (see Fig. 1).

For the control condition, two more movies (Other1-Other2 and Other2-Other1) were created in a similar fashion but with two new unfamiliar faces of similar sex, age and ethnicity. The first movie was thus going from Other1 (100% Other1; 0% Other2) to Other2 (0% Other1; 100% Other2) and the second movie starting from Other2 (0% Other1; 100% Other2) to Other1 (100% Other1; 0% Other2). All participants had to approve that they recognized their own face (Self) in the post processed photo used in the experiment furthermore not before having seen the faces referred to as Other, Other1 and Other2.

2.3.2. Stimulation movie

The stimulation-movies had all been produced prior to the experiments. They display a 120 s movie of the face of the “Other” looking straight into the camera while receiving a tactile stimulation with a cotton-bud at the right cheek, starting at the zygomatic bone and moving 2 cm inferior at the pace of 0.40 Hz (see Fig. 2). In each experiment the stimulation movie was of the same face as the one used as “Other” in the morphing movies (Self-Other and Other Self). The same movie was used twice for every participant in the so called synchronous and asynchronous stimulation (see below).

2.3.3. Experimental procedure

Experimental presentation including morphing- and stimulation movies were presented using PsychoPy (v1.84.2). Participants were seated approximately 50 cm from a screen in a well-lit room. The experiment started with a training session consisting of two morphing videos using the faces of famous people and a color-morphing of a blue ball gradually shifting its color into green. As in the subsequent experiment sessions morphing movies had a duration of 15 s and participants were asked to evaluate and react similarly. The training session was used to assure that participants understood all instructions.

All three sessions (Pre- and Post-stimulation sessions) would consist of the same four facial recognition tasks, namely Self-Other, Other-Self, Other1-Other2 and Other2-Other1, displayed in randomized order. In the Self-Other recognition task, participants would view the Self-Other morphing video and asked to press “spacebar” when they *stopped* seeing the face on the screen as being themselves. When viewing the Other-Self morphing video they were asked to press “spacebar” when they *started* seeing the face as being themselves. In the two control conditions (Other1-Other2 and Other2-Other1) participants were asked to press “spacebar” when they no longer recognized the face that was displayed from start.

The experimental setup would consist of one Pre-stimulation and two Post-stimulation recognition tasks (see Fig. 2). The two Post-stimulation sessions were preceded by two different stimulation phases (synchronous and asynchronous). The stimulation phases were performed before each of the two Post-stimulation sessions. For each participant, there would be a *synchronous* and an *asynchronous* stimulation phase leading up to the Post-stimulation session, the order being randomly assigned to each participant. During the synchronous stimulation phase the participant would watch the stimulation movie while receiving a temporally synchronous tactile stimulation

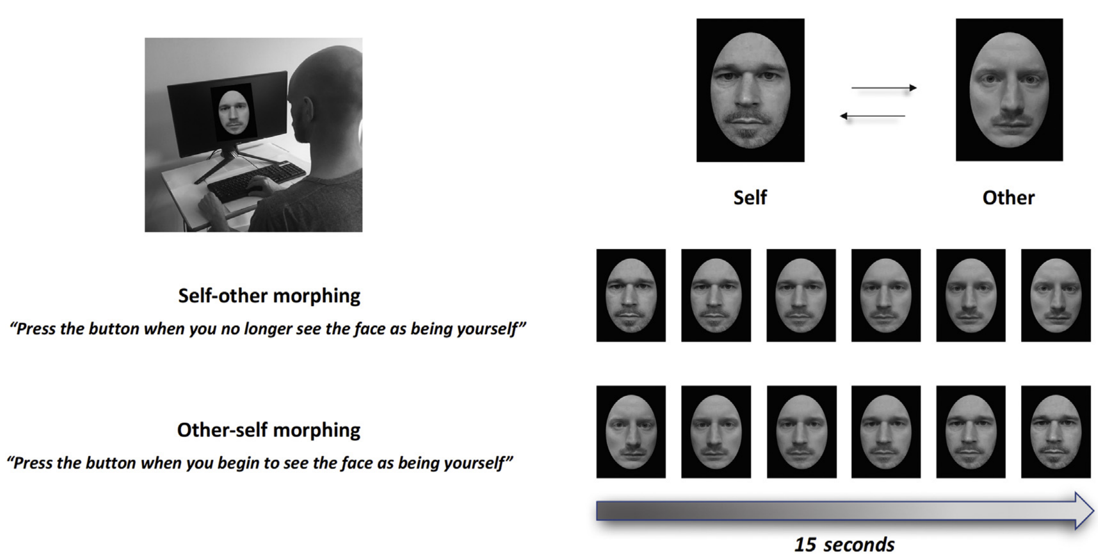

Fig. 1. Displaying the morphing-movies used in the self-recognition test and the respective instruction to participants. The morphing directions showed are the *self to other* and *other to self*, which gradually change in the movie in the given direction.

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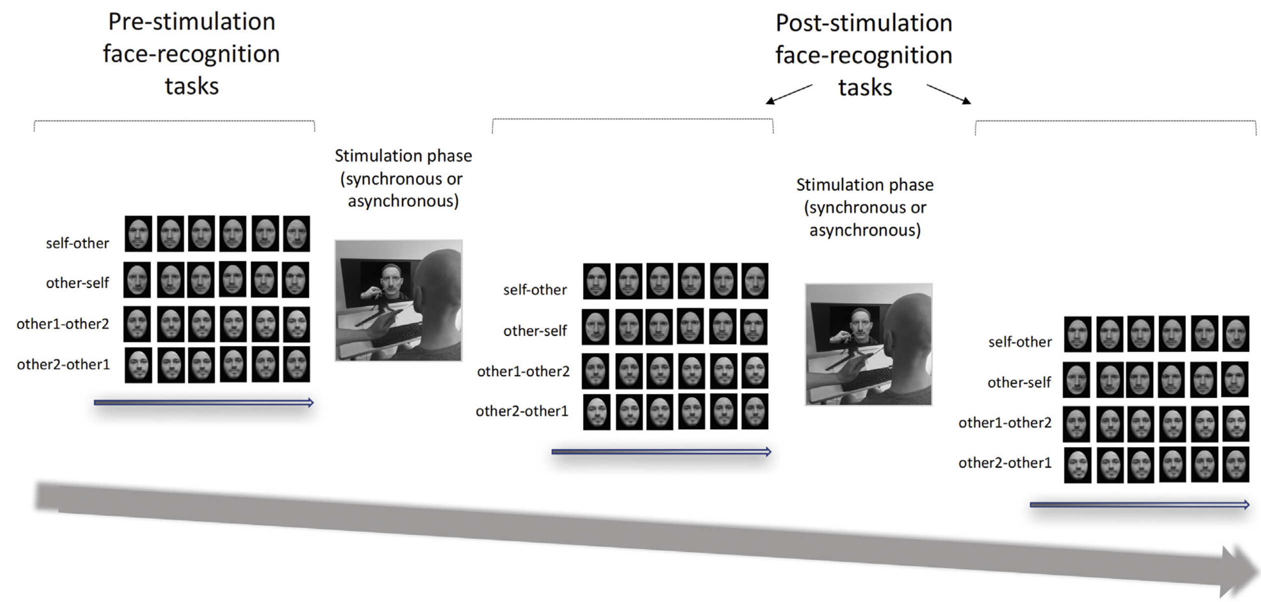

Fig. 2. The experimental setup consisting of three face-recognition tasks (one pre-stimulation and two post-stimulation) and two visuo-tactile stimulation phases. Face-recognition tasks would consist of 4 randomly displayed morphing videos lasting 15 s. In the Self-Other recognition task, participants were asked to press "spacebar" when they *stopped* seeing the face on the screen as being themselves. When viewing the Other-Self morphing video they were asked to press "spacebar" when they *started* seeing the face as being themselves. In the two control conditions (Other1-Other2 and Other2-Other1) participants were asked to press "spacebar" when they no longer recognized the face that was displayed from start.

with a cotton-bud on the specular cheek for the duration of the movie. For the asynchronous stimulation participant would watch the same stimulation movie as in the synchronous condition but the tactile stimulation would be applied temporally asynchronous in respect to the stimulation movie in a similar frequency and at the specular cheek. Participants were asked to sit still and look directly into the eyes of the person in the movie during all stimulation phases. There was a 1 min break between the two Post-stimulation sessions.

2.4. Statistical methods

Reaction times (rt.) from the self-recognition tasks (0–15 s.) were converted into percentage of Other frames seen as Self. For Self-Other direction (rt./15) ∗ 100 and Other-Self (15-rt./15) ∗ 100. For Other1-Other2 and Other2-Other1 recognition it was done by (rt./15) ∗ 100. In the case that participants would react after the morphing movie had finished (+15 s.) the rt. would be changed to 15 s.

The statistical procedure for comparing pre-stimulation tasks between the groups SCZ and HC was done by an unpaired *t*-test. Differences within each group between pre- and post-stimulations were done by mixed models including id as a random variable.

For all analyses, SAS Enterprise Guide 7.1 was used. *p*-values <5% was considered significant.

As shown in Table 1, there was a small numerical but statistically significant age difference between groups. We had no a priori expectation that IQ or age would influence the outcome on the tests. IQ had a non-significant correlation of $r = -0.036$ ($p = 0.77$) with the pre-stimulatory Self-Other and a correlation of $r = 0.14$ ($p = 0.25$) with the post-stimulatory target variable of asynchronous Other-Self. Age had similarly a non-significant correlation of $r = -0.14$ ($p = 0.26$) with pre-stimulatory Self-Other and $r = -0.003$ ($p = 0.98$) with the post-stimulatory asynchronous Other-Self. The results are non-significant for all other key variables as well. Based on these considerations we did not to correct for IQ or age.

3. Results

For an overview of all results shown in Fig. 3, see Supplementary material.

3.1. Pre-stimulation

In the pre-stimulus condition the SCZ group attributed 64.75% of frames to Self while the HC group attributed 52.36% (Fig. 4). This difference was seen in the Self-Other morphing direction and was significantly different [12.39%; $p = 0.001$; SE = 3.60] between the two groups. In Other-Self morphing direction SCZ group attributed 31.41% of the frames to Self and HC 30.55% being non-significant [0.85%; $p = 0.79$; SE = 3.17]. The difference between SCZ and HC were non-significant for all other-other conditions during pre-stimulation.

3.2. Post-stimulation

The effect of stimulation on self-recognition in the post-stimulation sessions for Other-Self morphing direction is displayed in Fig. 5. The effect of synchronous stimulation for Other-Self direction in the SCZ group was statistically significant [7.75%; $p = 0.018$; SE = 0.482]. Likewise, for the HC group there was a significant effect of synchronous stimulation in Other-Self direction [7.93%; $p = 0.006$; SE = 0.428]. Following asynchronous-stimulation a significant increase in frames attributed to self was found in the SCZ group [6.49%; $p = 0.046$; SE = 0.482]. In the HC group the increase was non-significant [4.53%; $p = 0.115$; SE = 0.428]. There was no significant effect in the self-recognition for self-other morphing condition between pre- and post-stimulus for any of the groups.

For all other-other conditions (Other1-Other2 and Other2-Other1) there were no significant differences found in any of the groups between all pre- and post-stimulation sessions (synchronous and asynchronous). In order to assess any effect of the order in which participants were exposed to synchronous and asynchronous stimulation, the difference between first and second post-stimulation session (regardless of it being synchronous or asynchronous) were addressed. For all participants, the percentage of other accepted as self between the first and second session were non-significant for other-self [3.47%; $p = 0.105$; SE = 0.319] and self-other [1.50%; $p = 0.567$; SE = 0.391].

We found no significant differences between target variables depending on the order of stimulation, i.e. between those subjects who were

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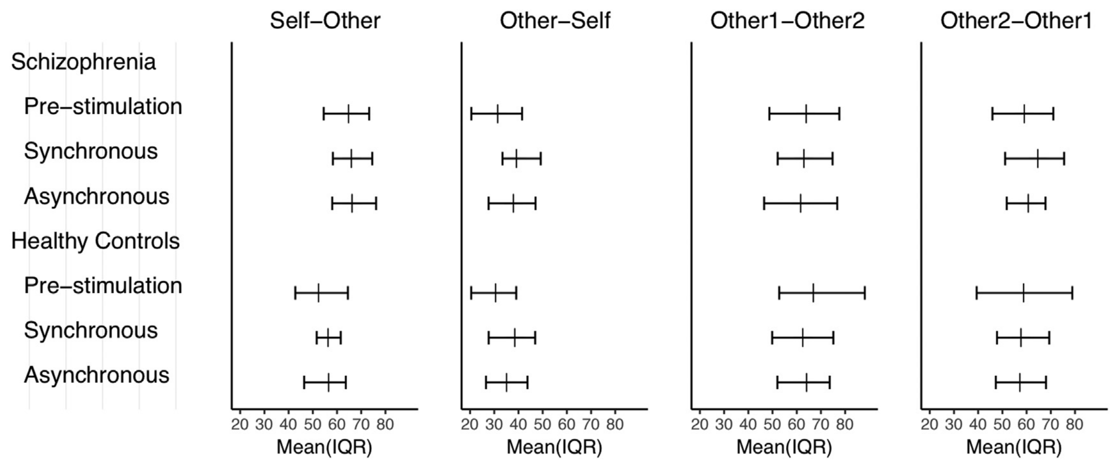

Fig. 3. A graphical presentation of the results from all participants. Mean score and 25th and 75th percentiles are marked for each group in the four judgement tasks defined by morphing directions in pre-stimulation, synchronous and asynchronous condition.

exposed to synchronous stimulation in the first stimulation phase vs. those beginning with asynchronous stimulation.

4. Discussion

The purpose of this study was to identify changes in self-recognition among patients with schizophrenia with a hypothesis that they would be more susceptible to the Enfacement Illusion by accepting more of the *other* as *self*. The focus in this paper is on group differences and does not include measures of EASE or any other psychopathological scales as this is beyond the scope of this article.

The Enfacement Illusion is designed to test the role of ongoing multisensory integration on self-recognition by using the face of another in a simulated mirror-like situation using visuo-tactile stimulation. The use of a synchronous and asynchronous visuo-tactile stimulation draws on the need for a degree of temporal synchrony in order for the multisensory integration, and thus the illusion, to take place.

This study found no differences between groups with regard to the effect sizes of the illusion compared across the different morphing directions. However, within groups the SCZ group had significant effect of both synchronous and asynchronous stimulation on self-recognition in Other-Self morphing direction. Thus, they accepted significantly more of the *other* in post-stimulation self-recognition session compared to pre-stimulation regardless of whether the stimulation was synchronous or asynchronous. Similar to other studies (Tajadura-Jimenez et al., 2012a; Tsakiris, 2008), there was only significant effect of synchronous- but *not* asynchronous visuo-tactile stimulation on self-recognition in the HC group in Other-Self direction. Previous studies comparing schizophrenia patients with healthy controls in body-illusion paradigms report similar findings of illusion effects in the SCZ

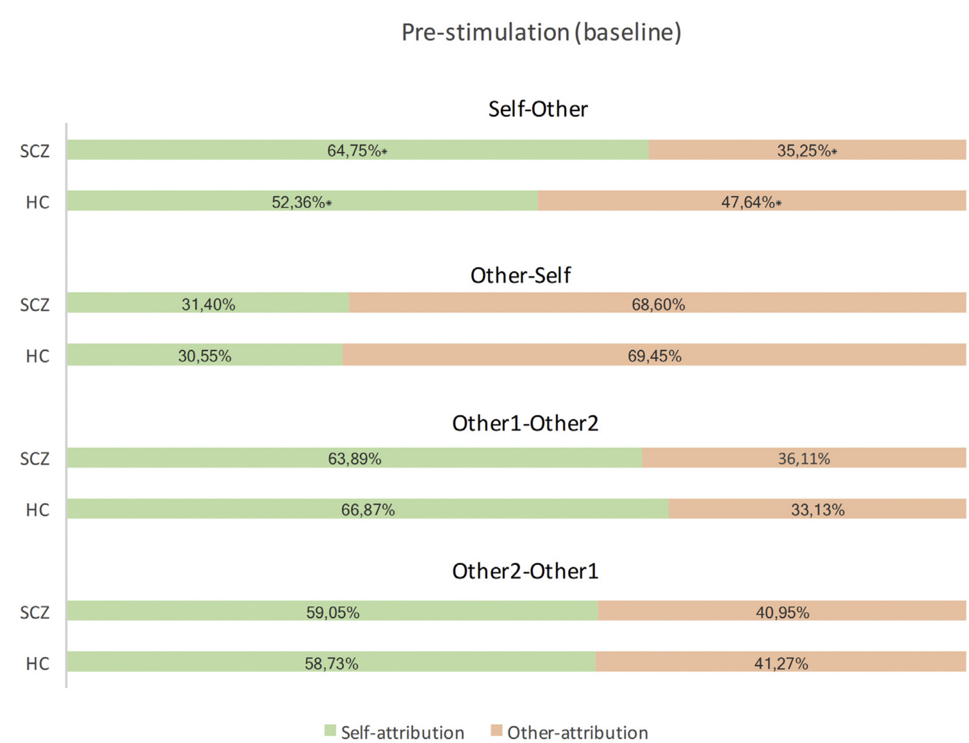

Fig. 4. A graphical presentation of the pre-stimulation phase for all conditions between SCZ and HC groups. Displaying mean % of frames perceived as self and other (for self-other and other-self) and for the control condition displaying a mean % of the second (other) face seen as belonging to first (other) face in the other-other conditions. Significant differences between groups are marked with *.

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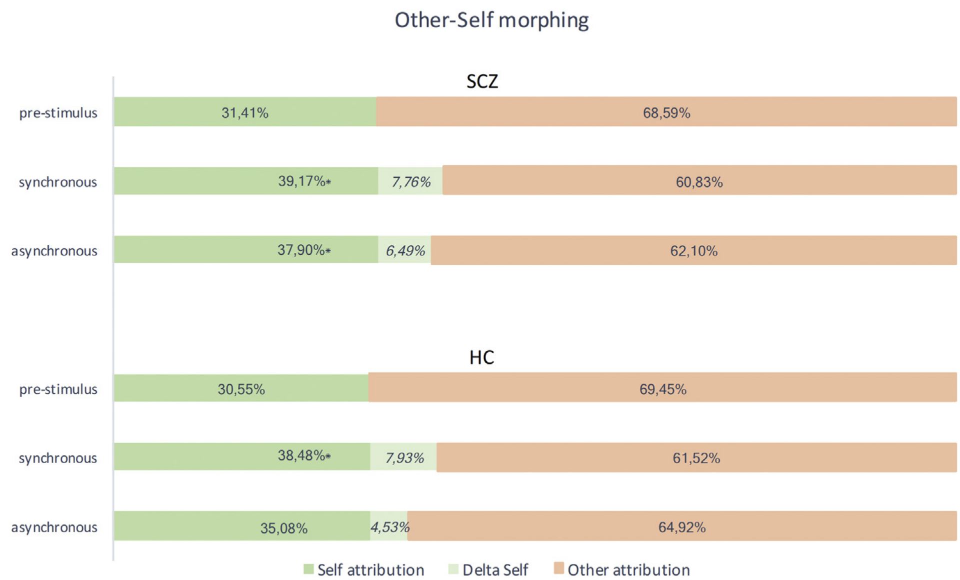

Fig. 5. Graphical presentation of the mean percentage of frames attributed to Self and Other in schizophrenia group (SCZ) and healthy control group (HC) for Other-Self morphing videos. Mean values of the difference between pre-stimulus and post-stimulus (synchronous and asynchronous) in frames attributed to Self are displayed as Delta Self. Significant differences within groups between pre-stimulus and post-stimulus are marked in the Delta Self with *.

in both synchronous and asynchronous stimulation conditions (Kaplan et al., 2014; Shaqiri et al., 2018; Prikken et al., 2019). For both groups SCZ and HC, there was no significant effect between the self-recognition tests in pre-stimulation and post-stimulation for Self-Other direction.

The findings of effect of both synchronous and asynchronous stimulation in SCZ group could be interpreted as a greater temporal tolerance in multisensory integration and thus seen as a higher susceptibility to the illusion. This temporal dimension of multisensory integration is sometimes tested using "temporal binding window" being the time within which paired stimuli from two different sensory modalities are perceptually bound. Some studies have shown that patients with schizophrenia have larger temporal binding windows and suggest this as a component of altered multisensory integration in schizophrenia (Klaver and Dijkerman, 2016; Costantini et al., 2016). The importance of spatial congruent/incongruent visuo-tactile stimulation on self-face recognition has been previously addressed in an Enfacement Illusion study on patients with schizophrenia (Ferroni et al., 2019). The study, which was the first to test the Enfacement Illusion paradigm on patients with schizophrenia, used a spatial incongruent condition (opposite cheek) instead of temporal asynchronous condition. The study reported no significant differences in self-other boundaries in the schizophrenia group compared to the healthy controls. The study did however report a difference in other-other boundaries in the schizophrenia group compared to healthy controls. Another notable difference between the current study and previous studies of EI which may have an impact on the results, is the duration of the morphing video. Previous studies of EI have had morphing videos spanning from 100 s. (Tsakiris, 2008) to 10 s. (Ferroni et al., 2019) where the current study had 15 s morphing movies.

The other-other conditions in this study were primarily used as control condition to address any test-retest variability between pre- and post-recognition tests, i.e. any general tendency among participants to respond in a certain way as a consequence to repeated testing. All comparisons within and between SCZ or HC group showed non-significant differences between pre- and post-other-other conditions. For an overview, see Appendix 1.

Disturbances in the processing of faces, body parts and perceptual gestalts in general are well documented in patients with schizophrenia (Uhlhaas and Mishara, 2007; Chan et al., 2010; Ferri et al., 2012). For this reason, we decided to look at differences in self-recognition prior to multisensory stimulation (baseline) between SCZ and HC groups. We did not have any a priori hypothesis as to whether the direction of morphing would influence the different scores between SCZ and HC. As shown in the results we only found significant differences between groups in the Self-Other direction where the SCZ group accepted 12.39% more of Other as Self compared to the HC group, results being highly significant ($p = 0.001$). This finding shows that the baseline Self-Other boundary in the SCZ group is notably displaced towards the Other. One could speculate as to the reason for this group difference only being present in the morphing direction Self-Other and not in Other-Self or Other-Other. From a clinical perspective, the mentioned mirror-sign in schizophrenia is related to various anomalous experiences relating to the situation of looking at one's specular image. This is on a crude level resembled in the Self-Other morphing video starting with a picture of Self, simulating the mirror-situation, unlike the Other-Self morphing video which begin with the face of the Other. We could speculate that SCZ patients when confronted with their own face (Self), adopt a more reflexive and observing attitude to the task, i.e. looking for facial features resembling their visual recollection of themselves. This would contrast with HC which would rely on a spontaneous and automatic self-recognition. However, in the Other-Self condition and especially in the other-other conditions, starting with Other, both groups would perhaps initiate the task similarly with the observational strategy of comparing facial features. Thus, the results would primarily differ in the Self-Other between groups.

The mirror-sign can from a phenomenological perspective be seen as a distortion of the psycho-physical self-coincidence giving rise to instability in the pre-reflective automatic self-ascription of the specular image. Multiple neurocognitive mechanisms have been proposed for self-disorders (Mishara et al., 2016; Nelson and Sass, 2017; Northoff and Stanghellini, 2016), and we would like to draw the attention to a recent empirical study. Nelson et al. used a composite score of source monitoring deficit to explain 38% of the variance in self-disorders (EASE-score) being substantially higher than for other clinical scores (Nelson et al., 2019). Source monitoring deficits in schizophrenia have been reported previously in the literature (Keefe et al., 1999) and are typically referred to as deficits in the implicit discrimination between different sources or origins of experience. They can be divided into the discrimination between internal (self) and external (other/world) as well as between two internal or two external sources (Nelson and Sass, 2017). A suggested mechanism involved in source monitoring

Please cite this article as: K.E. Sandsten, J. Nordgaard, T.W. Kjaer, et al., Altered self-recognition in patients with schizophrenia, Schizophrenia Research, https://doi.org/10.1016/j.schres.2020.01.022

deficit is that self-generated stimuli are accompanied by an efference copy (neural signal) which create a neural representation of sensory inputs influenced by efference copies, also known as "corollary discharge"(Poulet and Hedwig, 2007). By this mechanism self-generated stimuli can be discriminated from external signals and thus enable a basis for the various differences in prediction and intensity of the signals, i.e. self-generated signals are more predictive than non-self-generated signals and self-generated signals are thus attenuated. Other complementary approaches have addressed the issue at the level of functional brain networks involving default-mode network (including regions such as medial prefrontal cortex, the posterior cingulate cortex and precuneus) active during self-related (internal) processes and a task-positive networks positive network (including the regions: lateral prefrontal cortex and posterior parietal cortex) active during externally oriented tasks. The dynamic relation of activity between these networks is temporally structured within different frequency ranges and interacts by various mechanisms to ensure its communication. Deviations in the mechanisms regulating these functional networks and a general imbalance in the activity within different frequency bands are described in schizophrenia (Uhlhaas and Singer, 2010; Uhlhaas and Singer, 2015; Sun et al., 2013; Li et al., 2015) along with its possible implications for abnormal self-experience (Northoff and Duncan, 2016). This has also been conceptualized as "spatiotemporal psychopathology" (Northoff, 2018), linking spatiotemporal aspects of experience with the time and space of neural dynamics (Northoff and Stanghellini, 2016).

As described earlier, all patients were diagnosed with schizophrenia within the last year making it a unique sample with minimum influence of chronic aspects of the illness among patients. Some limitations in the present study can be highlighted. The lack of a spatially incongruent condition makes comparison with the previous study (Ferroni et al., 2019) difficult and limits the possibility of differentiation between temporal and spatial factors. We failed to show significant difference between synchronous and asynchronous in the other-self morphing direction among healthy controls, which has been reported in previous EI studies. There where however significant difference between pre- and post-stimulation conditions for both groups. Another limitation of the current study is the limited sample size. Obviously, larger studies are required to replicate the results of this study.

In conclusion, this study found significant difference in self-recognition in a pre- and stimulatory condition between patients with schizophrenia and healthy matched controls. The study provides quantifiable support of the notion that patients with schizophrenia exhibit alterations in self-face recognition and are more susceptible to multisensory illusions challenging self-other boundaries. The study supports the notion that temporal factors may contribute to an altered multisensory integration of self-related stimuli in patients with schizophrenia.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.schres.2020.01.022.

Contributors

All contributors have approved the final draft of the article. Furthermore:

Karl Erik Sandsten: The main author of the article as well as responsible for all inclusion and execution of the paradigm on all participants in the study. Partaking in the design of study and analysing the results.

Julie Nordgaard: Active in the design of the study, supervising the execution of the empirical study, drafting and critically revising the content of the article.

Janne Petersen: In charge of the statistical analysis of the results of the study, as well as partaking in drafting and revising the content of the article.

Troels Wesenberg Kjær: Partaking in the design and setup of the study. Took active part in critically analysing the results as well as the content of the article.

Francesca Ferroni: Contributing with interpretation of the data. Critically revising the content of the article.

Martina Ardizzi: Contributing to the practical setup of the study and interpretion of the data. Critically revising the content of the article.

Vittorio Gallese: Designed the study as well as analysing and interpreting the data. Critically revising the content of the article.

Josef Parnas: Designed the study and the drafting of the article as well as revising the results and other contents of the study.

Role of the funding source

Funding sources have had no role in the design, execution, analysis, interpretation or submission of this study.

Declaration of competing interest

None of the authors have any conflict of interest to declare.

Acknowledgements

We thank Maria Joy Normann Haverberg and Ulrik Nykjær Jeppesen for kindly assisting in the data collection. Moreover, we are thankful to Region Zealand (Denmark) for financial support of this study.

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Please cite this article as: K.E. Sandsten, J. Nordgaard, T.W. Kjaer, et al., Altered self-recognition in patients with schizophrenia, Schizophrenia Research, https://doi.org/10.1016/j.schres.2020.01.022