



Psychosis-proneness and the rubber hand illusion of body ownership

Laura Germine^{a,*}, Taylor Leigh Benson^b, Francesca Cohen^a, Christine I'Lee Hooker^a

^a Department of Psychology, Harvard University, 33 Kirkland Street, Cambridge, MA 02138, USA

^b Department of Psychological Sciences, Vanderbilt University, 2301 Vanderbilt Place, Nashville, TN 37240, USA

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ABSTRACT

Psychosis and psychosis-proneness are associated with abnormalities in subjective experience of the self, including distortions in bodily experience that are difficult to study experimentally due to lack of structured methods. In 55 healthy adults, we assessed the relationship between self-reported psychosis-like characteristics and susceptibility to the rubber hand illusion of body ownership. In this illusion, a participant sees a rubber hand being stroked by a brush at the same time that they feel a brush stroking their own hand. In some individuals, this creates the bodily sense that the rubber hand is their own hand. Individual differences in positive (but not negative) psychosis-like characteristics predicted differences in susceptibility to experiencing the rubber hand illusion. This relationship was specific to the subjective experience of rubber hand ownership, and not other unusual experiences or sensations, and absent when a small delay was introduced between seeing and feeling the brush stroke. This indicates that individual differences in susceptibility are related to visual–tactile integration and cannot be explained by differences in the tendency to endorse unusual experiences. Our findings suggest that susceptibility to body representation distortion by sensory information may be related or contribute to the development of psychosis and positive psychosis-like characteristics.

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1. Introduction

Before the rise of symptom-based classifications of mental illness, schizophrenia was described as an abnormality in self representation by both Kraepelin (1913) (the “orchestra without a conductor”) and Bleuler (1916) (the loss of the “individual self”) (Parnas, 2011). Viewing schizophrenia from a phenomenological perspective, Sass and Parnas suggested that a key factor in the pathogenesis of psychosis is a deficit in “ipseity” or the basic sense of inhabiting the self (Sass and Parnas, 2003). This is consistent with findings in the cognitive neuroscience literature where schizophrenia is linked to basic deficits in self processing, such as source monitoring (Frith, 1992; Ditman and Kuperberg, 2005) and self-referential processing (Vinogradov et al., 2008). Deficits in self processing may underlie the deficits in social cognitive processing characteristic of schizophrenia (Fisher et al., 2008) and deficits in emotion perception in psychosis-prone individuals (Germine and Hooker, 2011).

Individuals with psychosis or high risk for developing psychosis report disruptions to the bodily self (Chapman et al., 1978; Lenzenweger, 2006, 2010), including abnormalities in the experience of inhabiting the body (Sass and Parnas, 2003; Nelson et al., 2008) or the perception that the body has undergone some morphological

change (Chapman et al., 1978; Nelson et al., 2008). These body image aberrations are thought to be part of a broader set of perceptual deficits in psychosis (Chapman et al., 1978; Lenzenweger, 2010).

The perception of one’s body is a basic dimension of subjective experience, and is unique in its stability and consistency relative to external percepts (James, 1890; Merleau-Ponty, 1962). Understanding how body representation stability differs in individuals with varying levels of psychosis-proneness (i.e. with varying levels of vulnerability to developing psychosis) may offer key insights into the disturbances of self processing that may contribute to psychosis development (Nelson et al., 2008).

Despite the stability of the body in our perceptual experience, illusions of body ownership are readily inducible in healthy individuals (Botvinick and Cohen, 1998; Tsakiris and Haggard, 2005). The rubber hand illusion, in particular, has been used to investigate the structure of body representations (Tsakiris, 2010) and the phenomenology of the bodily self (Longo et al., 2008). In this illusion, the participant feels the touch of a brush on their own hand, hidden from view, at the same time that they see a brush touching a rubber hand. After a brief period of simultaneous stimulation of the participant’s own hand and the rubber hand, approximately 40% of healthy participants will experience the bodily sense that the rubber hand is their own hand (Botvinick and Cohen, 1998). This distortion in bodily experience has been linked with biased judgments of the body’s location in space (proprioceptive drift; Botvinick and Cohen, 1998), illusory sensations on the rubber hand

* Corresponding author. Tel.: +1 617 953 3935.

E-mail address: lgermine@fas.harvard.edu (L. Germine).

(Durgin et al., 2007), and cooling of the participant's own hand (Moseley et al., 2008).

Susceptibility to the rubber hand illusion varies across individuals and experimental conditions (Botvinick and Cohen, 1998; Tsakiris and Haggard, 2005). The tendency to experience the illusion can be reduced or eliminated by disrupting perceptual cues that drive visual–tactile integration through asynchronous stimulation (i.e. by stroking the rubber hand and the participant's hand asynchronously, such that the brush is seen to touch the rubber hand at a different time than the touch is felt on the participant's own hand; Tsakiris and Haggard, 2005) or by violating constraints related to knowledge about the body (e.g. substituting a wooden block for the rubber hand; Tsakiris, 2010; Tsakiris et al., 2010).

The rubber hand illusion provides an experimentally tractable way of tapping into the subjective experience of the body and investigating how individual differences in psychiatric vulnerability relate to the bodily self. Psychosis and psychosis-proneness are associated with deficits in somatosensory processing (Chapman et al., 1978; Lenzenweger et al., 2003; Chang and Lenzenweger, 2005; Lenzenweger, 2010) and abnormalities in the experience of the body are evident in the prodromal stages of psychosis, representing a basic aspect of disturbed phenomenology (Sass and Parnas, 2003; Lenzenweger, 2006, 2010; Nelson et al., 2008). Given these previous findings, susceptibility to distortions of body representations may be related to individual differences in psychosis-like characteristics (psychosis-proneness) even in the absence of psychotic symptoms. If this is the case, body representation abnormalities may be part of the fundamental vulnerability to developing psychosis or psychosis-like experiences.

Two previous studies have attempted to link psychosis with susceptibility to the rubber hand illusion. Peled et al. (2000) and Thakkar et al. (2011) showed that participants with schizophrenia are more prone to experiencing the rubber hand illusion than healthy control participants, and that these relationships were related to positive symptoms. The results of Peled et al. (2000) are hard to interpret though, as they lacked a comparison condition and thus could not control for the general tendency to endorse unusual experiences or bodily sensations among schizophrenia patients. In contrast, the findings from a comprehensive study by Thakkar et al. (2011) are more interpretable, as the experimental design included a control condition to look at rubber hand illusion experiences and proprioceptive bias after asynchronous stimulation. Thakkar et al. (2011) found that schizophrenia was associated with greater proprioceptive drift after synchronous as compared with asynchronous stimulation, indicating greater proprioceptive sensitivity to synchronous visual–tactile information among individuals with schizophrenia. Furthermore, schizophrenia patients also had greater self-reported experiences of the rubber hand illusion when compared with healthy controls. The difference in self-reported experiences after synchronous and asynchronous stimulation was similar for both patients and controls, however (that is, the group \times condition interaction was not significant for self-report), leaving the possibility that differences in self-reported experiences among schizophrenia patients may be related to an overall elevated tendency to experience a feeling of ownership over a rubber hand regardless of the experimental manipulation. Thakkar et al.'s finding of a schizophrenia-related dissociation in proprioception between synchronous and asynchronous stimulation conditions argues against this possibility, but conclusions about the relationship between psychosis and the rubber hand illusion would be strengthened by a similar dissociation in self-reported experience of the illusion.

In the current manuscript, we approach the relationship between illusions of body ownership and psychosis from the perspective of psychosis vulnerability or variations in psychosis-like characteristics among healthy individuals. This approach allows

us to look at whether flexibility in body representations is a pre-existing or even predisposing characteristic in psychosis-prone individuals, as has been suggested by previous work (Chapman et al., 1978; Lenzenweger, 2010; Thakkar et al., 2011). The goal of the current study was to identify whether there is a specific relationship between experimentally-induced illusions of body ownership and psychosis-proneness. We hypothesized that greater psychosis-proneness, as measured by self-reported psychosis-like characteristics, would be related to a greater tendency to experience the rubber hand illusion after synchronous stimulation (stroking the rubber hand and the participant's own hand at the same time). We predicted that this relationship would be reduced or absent after asynchronous stimulation (stroking the rubber hand and the participant's own hand with a small temporal offset), as temporal synchrony is needed for multisensory integration (Tsakiris and Haggard, 2005). In other words, we predicted that the relationship between psychosis-proneness and the rubber hand illusion would be driven by differences in the tendency to alter the body representation in response to visual–tactile cues that lead to illusion formation in healthy adults. We further predicted that the experience of the rubber hand illusion would be more closely associated with positive psychosis-like characteristics (e.g. cognitive and perceptual distortions) than negative psychosis-like characteristics (e.g. anhedonia), as positive symptoms often include abnormalities in bodily experience. Finally, we predicted that psychosis-proneness would be specifically related to subjective feelings of body ownership/agency and not a general tendency to have or endorse unusual experiences. For example, the experimental procedure can induce feelings of diminished or abnormal sensory perception in the participant's own hand (which we refer to as “reduced afference”, e.g. feelings of tingling or numbness; Longo et al., 2008). We expected that variations in psychosis-proneness would not predict variations in feelings of reduced afference. Confirmation of a link between individual differences in psychosis-like characteristics and susceptibility to illusions of body ownership would provide an avenue for further exploration into how the phenomenology of self, body, and psychosis are related.

2. Methods

2.1. Participants

Participants were 55 healthy volunteers (20/55 males) with a mean age of 28 (S.D.=11) recruited through the community-wide Harvard University study pool. All participants spoke English as a native language, were neurologically healthy, and had no DSM-IV Axis I psychiatric disorders based on administration of the MINI clinical interview (Sheehan et al., 1998). All participants gave informed consent before participating and the protocol was approved by the Committee for the Use of Human Subjects at Harvard University.

2.2. Psychosis-proneness measures

We assessed psychosis-proneness with several widely used self-report questionnaires that measure positive and negative psychosis-like characteristics. Our measure of positive psychosis-like characteristics (positive psychosis-proneness) included 132 items taken from the cognitive-perceptual subscale of the Schizotypal Personality Questionnaire (33 items; Raine, 1991), the Chapman Magical Ideation Scale (30 items; Eckblad and Chapman, 1983), the Chapman Perceptual Aberration Scale (35 items; Chapman et al., 1978), and the Referential Thinking Scale (34 items; Lenzenweger et al., 1997). Our measure of negative psychosis-like characteristics (negative psychosis-proneness) included 73 items taken from the interpersonal subscale of the Schizotypal Personality Questionnaire (33 items; Raine, 1991) and the Chapman Revised Social Anhedonia Scale (40 items; Eckblad et al., 1982; Mishlove and Chapman, 1985). We omit disorganized psychosis-like characteristics from our analysis due to a relative dearth of evidence that disorganized characteristics are predictive of psychosis development and the relatively few items included in the above scales (16 in total from the Schizotypal Personality Questionnaire) for measuring disorganized features.

These scales all have established associations with vulnerability to schizophrenia spectrum disorders (Chapman et al., 1994; Gooding et al., 2005; Kwapił, 1998; Lenzenweger et al., 1997; Raine, 1991; Raine et al., 1994; Startup et al., 2010).

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