



Increased plasticity of bodily self-experience in individuals who may carry latent liability for schizophrenia

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ABSTRACT

Self-disturbances such as altered perception of one's own body boundary are central to the lived-in experience of schizophrenia. Bodily self-disturbances are also prevalent in healthy individuals who may carry latent liability for schizophrenia. Much of the research on self-disturbances rely on clinical interviews but these experiences are often difficult to verbalize, conceptualize and quantify. Furthermore, experimental evidence for plasticity of bodily self-experience in the schizophrenia-spectrum is scarce.

We sought to quantify body boundary experience in healthy young adults who might be at an increased risk for schizophrenia with a multisensory paradigm known as the Pinocchio Illusion (PI) task that engenders the feeling that one's nose is changing, and has previously been used to demonstrate increased plasticity of bodily self-boundary in schizophrenia.

62 college students participated in the PI task that assessed bodily self-disturbances, and a tactile discrimination task. We administered the Prodromal Questionnaire Brief (PQ-B) and the Schizotypal Personality Questionnaire (SPQ) to assess latent liability for schizophrenia. We found that PI was enhanced in individuals with elevated PQ-B scores but their tactile sensitivity was intact. PI was associated with the positive syndrome of schizotypy, but not with negative or disorganized factors. Increased PQ-B and SPQ scores were associated with loneliness. To conclude, these results highlight the importance of bodily self-disturbances in the broader context of the schizophrenia spectrum.

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"I sometimes feel my hands are huge, or my legs have gotten longer"
(Study participant, 2015)

1. Introduction

Anomalous bodily self-experiences are salient and prevalent in individuals with schizophrenia (Chapman et al., 1978; Lysaker and Lysaker, 2010; Nelson et al., 2012; Nasrallah, 2012; Brent et al., 2014), and those at risk for schizophrenia (Stanghellini et al., 2012; Raballo and Parnas, 2012; Nelson et al., 2014). Individuals with schizophrenia report experiencing subtle perceptual aberrations such as temporary changes in the shape, size, or location of one's own body parts (see Chapman et al., 1978), as well as disrupted agency, body ownership, and self-other boundary (Hur et al., 2014; Noel et al., 2017). Feelings of body image distortions are often accompanied by blurred self-other boundaries (Quinlan and Harrow, 1974), in which one has difficulty

distinguishing between themselves and those around them (Blatt and Ritzler, 1974). In her memoir about living with schizophrenia, Elyn Saks (2008) describes a feeling that she "was dissolving...like a sand castle with all the sand sliding away". Such experiences of loss of self-boundary is radically different from the solid sense of spatial self that anchors healthy individuals. It has been suggested that a weakened or more flexible representation of the shape, location and boundary of one's body and a loss of implicit self-other differentiation may arise from impaired multisensory integration (Postmes et al., 2014; Noel et al., 2017).

Self-other boundary can be disrupted in several ways. It can be breached such that one may have an out-of-body experience (OBE), a form of autoscopic phenomena (Blanke et al., 2004; Blanke et al., 2005). An OBE involves the perception of *leaving* one's own physical body and seeing one's physical body from an extrapersonal perspective (Brugger et al., 1997). In sum, an OBE consists of a feeling of disembodiment, an extrapersonal perspective, and the visualization of one's own physical body from this perspective but while there is a breach of the perceived self-boundary (i.e. sensation of leaving the physical body), the body boundary itself remains solid. There is no feeling of melting into the environment; one is either in or out of the physical body but there is no blurriness of the bodily self-boundary. On the

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other hand, perceptual aberrations captured by Chapman et al. (1978) involving subtle changes of shape, size and locations of one's own body parts suggest an increased plasticity of perception and experience of one's body boundary in the schizophrenia-spectrum.

Perceptual aberrations involving one's own body parts have been empirically studied in the schizophrenia-spectrum with multisensory illusion induction paradigms such as the Rubber Hand Illusion (Peled et al., 2003; Thakkar et al., 2011; Ferrè et al., 2013; Germine et al., 2013), and the Pinocchio Illusion (PI) (Michael and Park, 2016). Individuals with schizophrenia are more prone to the PI, a proprioceptive illusion that generates the feeling that one's nose is changing. To induce it, a vibrator is applied to the biceps brachii of the participant while the participant touches her nose with the index finger of the stimulated arm (Fig. 1). The vibrator stimulates muscle spindles in the biceps that would normally be activated by the stretching muscle, but since the arm position is fixed by requiring the subject to touch her nose and the finger touching the nose is still giving tactile information of being in contact with the nose, the participant feels that the nose is moving away from the face, as the brain works to reconcile conflicting proprioceptive and tactile data.

Thus, the perceived shape, size and orientation of one's own body parts can be manipulated to generate false information about limb position. In contrast to the Rubber Hand Illusion, the PI does not include an "other" component, and therefore, is suited for studying flexible representation of bodily boundaries without influences of altered agency or body ownership. Individuals with schizophrenia experience the PI more readily and intensely compared to control participants, and this was not due to increased sensitivity to physical sensations but driven by perceptual aberrations about the body. Increased PI was positively correlated with severity of symptoms and negatively associated with tactile sensitivity (Michael and Park, 2016). Thus, such empirical demonstrations of increased plasticity of bodily self-boundary match the phenomenological descriptions of bodily self-aberrations in individuals with schizophrenia.

More specific evidence for altered experience of self-other boundary in schizophrenia comes from empirical studies that aim to measure peripersonal space (PPS) representation (Delevoeye-Turrell et al., 2011). Delevoeye-Turrell et al. (2011) estimated PPS in individuals with schizophrenia by asking participants to indicate when objects and individuals entered or exited their reaching space. They found that individuals with schizophrenia and control participants did not differ in their judgments of the extension of PPS, but the patients were much more variable in their judgments for PPS and this variability was associated with the severity of symptoms. Thus, the boundary between peri- and extra-personal spaces in schizophrenia seems more variable and plastic on a trial-by-trial basis, consistent with the hypothesis that the representation of bodily self-boundary may be more flexible.

Self-disturbances are also a prominent feature of the prodromal stage in individuals at risk for schizophrenia (Nelson et al., 2012), as

indicated by clinical interviews such as the Examination of Anomalous Self-Experience (EASE; Parnas et al., 2005). EASE and other currently available instruments that assess self-disturbances rely almost exclusively on the ability of the participants to recall and communicate their experiences. However, phenomenology of bodily self-aberration can be difficult to describe and measure, especially in at-risk population or in individuals with schizophrenia who may already have cognitive and social impairments. Therefore, it would be helpful to document the presence and extent of bodily self-disturbances using empirical methods that do not exclusively rely on verbal ability and memory in addition to clinical interviews.

In the present study, we sought to quantify the plasticity of bodily self-boundary in individuals who may carry latent liability for schizophrenia (i.e., those with elevated schizotypal traits or prodromal signs) with the Pinocchio Illusion paradigm. Our aim in this study was not to predict the conversion to psychosis but to survey the extent of bodily self-aberration in healthy participants who show elevated signs that are consistent with the schizophrenia-spectrum. Based on past results of increased Pinocchio Illusion and impaired tactile sensitivity in schizophrenia patients (Michael and Park, 2016), we hypothesized that increased susceptibility to anomalous bodily experiences and impaired exteroceptive awareness would be present in those who may share latent liability for schizophrenia. We further hypothesized that the increased proneness to PI in the schizophrenia-spectrum arises from greater perceptual aberration concerning the body rather than just an increased sensitivity to physical stimulation. With respect to the assessment of putative liability for schizophrenia, we used two validated and reliable self-report measures: Prodromal Questionnaire Brief (PQB; Loewy et al., 2011) and the Schizotypal personality questionnaire (SPQ; Raine, 1991).

2. Methods

2.1. Participants

62 college students enrolled in introductory psychology courses were recruited from the Vanderbilt Psychology Research Subject Pool. Given the rarity of individuals who show prodromal psychosis signs in the non-help-seeking college population, we used a two-step strategy. First, we screened students taking large introductory psychology classes with the Prodromal Questionnaire Brief (PQ-B; Loewy et al., 2011). PQ-B is a reliable self-report tool for ascertaining risk for psychosis in the general population, and is closely related to schizotypal traits at the subclinical level (Fonseca-Pedrero et al., 2016). We used the cut-off score of 6 distressing endorsements on the PQ-B, as prescribed (Loewy et al., 2011) and contacted them to ask if they would like to participate in a future study. We also selected randomly from the same pool to recruit low PQB participants. The PQ-B scores used for screening were deleted and were not used for the study. For those who participated, PQ-B was given again in the laboratory. Inclusion/exclusion criteria were as follows: no past or current diagnosis of DSM 5 Axis 1 disorder, no current use of psychotropic medication, no use of pain medication within the past 24 h of the experiment, no past nose surgery, and no recent injury to the nose or the arms.

Once the students who met the inclusion criteria consented to participate, they were assigned participant identification numbers to protect their identity, and they were given the PQ-B again in the laboratory, as well as the SPQ (see Section 2.2. Procedure for details). The personnel conducting the experiments were blind to the PQ-B scores. After the conclusion of the data collection, the blind was broken. We then used the PQ-B scores from this stage to designate participants who scored >6 on the endorsement with distress items to the high PQB group ($n = 16$), and the rest to the low PQB group ($n = 46$).

There were no significant differences among demographic variables across the high- and low-PQB groups in sex, age, years of education, handedness, or race. All participants gave written informed consent

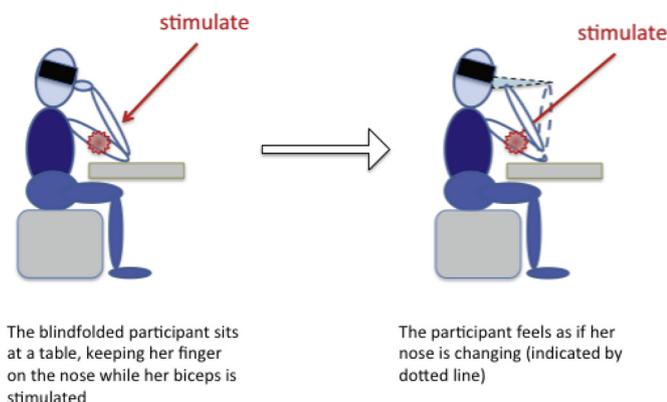


Fig. 1. Procedure for the Pinocchio Illusion Task.

approved by the Vanderbilt Institutional Review Board and received partial course credit for their participation. Demographic information is summarized in Table 1.

2.2. Procedure

After informed consent and instructions, participants completed self-report questionnaires, the Pinocchio Illusion task (PI; Burrack and Brugger, 2005; Michael and Park, 2016) and the 2-point tactile discrimination task (2PT; Chang and Lenzenweger, 2001, 2005). The order of the task presentation was counterbalanced across participants.

2.2.1. Self-report questionnaires

The 21-item Prodromal Questionnaire-Brief (PQ-B; Loewy et al., 2011) was administered to assess the risk for psychosis. We used the PQ-B Endorsements with Distress score >6 as a cut-off threshold for detecting psychosis-risk, as recommended (Loewy et al., 2011). Those who endorsed 6 or more as distressing were designated the high PQB group. 16 participants were designated to the high PQB group.

The 74-item Schizotypal Personality Questionnaire (SPQ; Raine, 1991) was used to assess schizotypy. The SPQ consists of the Positive (Cognitive-Perceptual), Negative (Interpersonal), and Disorganized factors. Raine (1991) reported that 55% of those scoring in the top 10 percentile of the total SPQ were diagnosed with Axis 2 schizotypal personality disorder. We used this guideline to divide participants into high and low SPQ groups. In our sample, the top decile score was 48. When a participant scored 48, we included this person in the high-SPQ group. There were 7 participants who scores 48 or more.

The 20-item UCLA Loneliness Scale (Russell, 1996) was included to estimate loneliness and perceived social isolation. PI and bodily self-aberrations are associated with loneliness in schizophrenia (Michael and Park, 2016; Michalska da Rocha et al., 2017) and there is an epidemic of loneliness among young adults (Cigna U.S. Loneliness Index, 2018).

2.2.2. Pinocchio illusion task

The participant wore a blindfold and rested her elbow on a table with the forearm slightly angled towards the body so that the index finger could touch the nose (see Fig. 1). The experimenter then stimulated the bicep brachii tendon of the upper arm at 120 Hz with a physiotherapy vibrator (Novafon SK 1/1). The participant was instructed to report the onset of any sensations she might feel, apart from the vibrations. The vibration lasted for a total of 2 min and was applied to each arm. After each vibration administration, participants were asked to complete an 11-item questionnaire to quantify the experience of PI (see Appendix 1). The participant was asked to respond to each of the 11 statements on a scale from 0 to 100 in 25 point increments. A rating of 0 means that the participant did not have that experience during the stimulation, while a rate of 100 points means the participant fully endorsed having the experience described in the statement during the stimulation. The PI questionnaire consisted of two subscales: 1) Physical Sensation Subscale (Items # 5, 6, 7, 8, 10), and 2) Perceptual Aberration Subscale (Items #1, 2, 3, 4, 9, 11) (see Appendix 1). The Physical Sensation

subscale was concerned with the actual physical effects of the vibration procedure, or *physical sensations* associated with the PI procedure. The Perceptual Aberration Subscale tapped into the feeling that parts of one's body were changing, or *perceptual aberrations* associated with the PI. We set the vibrator at the highest amplitude setting, which reaches a depth of 1.6 mm. Both the right and left arms were stimulated. The order of stimulation of the arm was counterbalanced across participants.

2.2.3. Two-Point Discrimination task (2-PT)

Two-Point Discrimination task (2-PT) measures tactile sensitivity (Chang and Lenzenweger, 2001, 2005). The participant was blindfolded and asked to lay her hand flat on the table, palm up. An anesthesiometer was used to deliver precise tactile stimulation on the palm. Participants indicated whether they felt one point or two points on the palm by saying "one" or "two." There were three tactile stimulus conditions: one point, 6 mm between the two points (easy) and 10 mm between the two points (hard). There were 50 trials per hand, consisting of 30 one-point trials, 10 hard two-point trials, and 10 easy two-point trials. The order of these trials was randomized for each hand, and the order of the stimulation of the hand was counterbalanced across participants. We averaged across the easy and hard conditions and the left and right hand to yield a mean score of accuracy.

3. Results

About half of the participants reported experiencing the PI when asked outright at the end of the procedure. Endorsement of the PI was unrelated to age, sex, handedness, or years of education (all $p > 0.05$). As predicted, participants in the High PQB group scored significantly higher on the PI Total score compared to the Low PQB group ($F(1,61) = 9.2, p = 0.0036$). The High PQB group also scored higher on the PI Perceptual Aberration items ($F(1,61) = 13.1, p = 0.0006$) than the Low PQB group, but the two groups did not differ on the PI Physical score ($F(1,61) = 2.1, p = 0.14$). There was no group difference in the overall 2-Pt tactile accuracy score ($F(1,61) = 0.1, p > 0.71$). High PQB group showed elevated loneliness than the low PQB group ($F(1,61) = 10.1, p < 0.0024$) and increased schizotypy ($F(1,61) = 28.1, p < 0.0001$), as expected. In sum, the high PQB group appears to show proneness to PI without a reduction in tactile sensitivity, suggesting that their strange bodily self-experiences are not due to impairments in detecting physical, tactile sensations. See Table 2 for a summary of results.

We also examined PI with respect to high and low schizotypy. Analysis of high versus low SPQ shows that there was no group difference in the PI total score ($F(1,61) = 1.66, p = 0.23$) or the PI Physical score ($F(1,61) = 0.09, p = 0.76$), but there was a trend towards a group difference in the PI Perceptual Aberration score ($F(1,61) = 3.43, p = 0.069$). There was no group difference in the 2-PT tactile discrimination ($F(1,61) = 1.61, p = 0.21$). The high SPQ group reported increased loneliness than did the low SPQ group ($F(1,61) = 15.06, p < 0.0003$). See Table 2 for a summary of results.

3.1. Correlations

Spearman's rank correlations were conducted to test the predicted relationships among measures.

3.1.1. Schizotypy and PI

PI total score did not correlate with SPQ total score ($r = 0.12, p = 0.33$) or the negative syndrome of SPQ (interpersonal factor) ($r = 0.008, p = 0.95$), but there was a trend towards an association between the positive syndrome of SPQ (cognitive-perceptual factor) and PI total ($r = 0.23, p = 0.07$). When we examined the perceptual aberration aspect of the PI separately from the physical sensation from stimulation, we found that the positive syndrome of SPQ correlated significantly with the PI Perceptual Aberration score ($r = 0.26, p = 0.04$). Negative

Table 1
Demographic information.

	Low PQ-B mean (SD)	High PQ-B mean (SD)	Statistical test
% Women	67%	63%	$\chi^2 = 0.13, p = 0.72$
Age	19.1 (1.19)	18.9 (0.89)	$F(1,61) = 0.62, p = 0.43$
Years of education	13.5 (1.32)	13.1 (0.96)	$F(1,61) = 0.33, p = 0.33$
Edinburgh handedness ^a	+68.2 (36.6)	+58.1 (50.7)	$F(1,61) = 0.73, p = 0.39$
Race	56% Caucasian	44% Caucasian	$\chi^2 = 0.66, p = 0.42$

^a Oldfield, RC.1971. The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia*. 9 (1): 97–113.

Table 2
Summary of results.

	Low PQB mean (SD)	High PQB mean (SD)	Statistical test
PQB total	6.26 (4.5)	12.31 (2.7)	$F(1,61) = 25.9, p = 0.0001$
PQB distress	1.6 (1.9)	8.7 (1.7)	$F(1,61) = 172.1, p = 0.0001$
SPQ total	20.0 (12.1)	38.7 (12.4)	$F(1,61) = 28.1, p = 0.0001$
SPQ positive	6.9 (5.7)	15.4 (6.4)	$F(1,61) = 24.7, p = 0.0001$
SPQ negative	9.1 (6.7)	17.8 (6.3)	$F(1,61) = 20.2, p = 0.0001$
SPQ disorganized	5.5 (3.9)	9.8 (5.0)	$F(1,61) = 10.7, p = 0.0018$
UCLA loneliness	38.9 (10.8)	49.1 (10.6)	$F(1,61) = 10.1, p = 0.0024$
2-Pt accuracy	76.1% (8.7)	75.1% (10.9)	$F(1,61) = 0.13, p = 0.71$
PI total	657.3 (277.9)	917.1 (343.1)	$F(1,61) = 9.2, p = 0.0036$
PI physical	514.1 (190.6)	590.6 (144.0)	$F(1,61) = 2.1, p = 0.14$
PI perceptual aberration	143.13 (149.6)	326.5 (234.6)	$F(1,61) = 13.1, p = 0.0006$

	Low SPQ mean (SD)	High SPQ mean (SD)	Statistical test
PQB total	7.0 (4.5)	14.1 (1.3)	$F(1,61) = 16.8, p = 0.0001$
PQB distress	2.8 (3.1)	8.4 (2.5)	$F(1,61) = 19.6, p = 0.0001$
SPQ total	21.5 (11.9)	50.9 (3.6)	$F(1,61) = 41.8, p = 0.0001$
SPQ positive	7.7 (6.0)	20.0 (3.9)	$F(1,61) = 27.8, p = 0.0001$
SPQ negative	8.8 (6.6)	23.4 (2.9)	$F(1,61) = 28.6, p = 0.0001$
SPQ disorganized	6.1 (4.1)	13.0 (2.0)	$F(1,61) = 19.0, p = 0.0001$
UCLA loneliness	39.7 (1.4)	57.0 (4.2)	$F(1,61) = 15.1, p = 0.0003$
2-Pt accuracy	75.3% (9.1)	80.0% (10.1)	$F(1,61) = 1.61, p = 0.21$
PI total	706.1 (307.9)	867.7 (356.1)	$F(1,61) = 1.66, p = 0.23$
PI physical	531.4 (188.4)	553.6 (126.2)	$F(1,61) = 0.09, p = 0.764$
PI perceptual aberration	174.7 (176.9)	314.1 (265.2)	$F(1,61) = 3.43, p = 0.069$

syndrome (interpersonal) or disorganized factor did not correlate with the PI Perceptual Aberration score. PI Physical score did not correlate with schizotypy at all. To summarize, increased tendency to experience PI was associated with schizotypy, driven by the positive syndrome. In contrast, detecting physical sensations (e.g., vibration in the biceps when stimulated) was not associated with schizotypy.

3.1.2. PQ-B and PI

We examined the PQ-B scores across the whole sample in relation to PI scores. PQ-B distress score was significantly associated with the PI Perceptual Aberration score ($r = 0.26, p = 0.04$). PQ-B endorsements with distress were also significantly associated with PI Perceptual Aberration score ($r = 0.28, p = 0.02$).

3.1.3. Loneliness

Significant correlations were observed between loneliness and PQ-B endorsement ($r = 0.48, p = 0.0001$), PQ-B distress ($r = 0.49, p = 0.0001$), and PQ-B endorsements with distress ($r = 0.59, p = 0.0001$). Loneliness was also significantly associated with SPQ total ($r = 0.6055, p = 0.0001$), SPQ-interpersonal ($r = 0.7254, p = 0.0001$), SPQ-cognitive perceptual ($r = 0.4072, p = 0.0011$) and SPQ disorganized ($r = 0.4308, p = 0.0005$). No correlation was observed between loneliness and the PI scores or the 2-Pt scores.

For a table reporting all correlations among measures, please see Supplement 2.

4. Discussion

The main goal of the current study was to examine anomalous multi-sensory experience in non-help-seeking individuals who may carry latent liability for schizophrenia. As expected, participants in the high PQB group experienced the Pinocchio Illusion more strongly than the low PQB group. The High PQB group scored higher on the PI Perceptual Aberration items compared with the Low PQB group, but the two groups were not significantly different on the PI Physical scores. This finding suggests that increased proneness to experience bodily self-aberrations

is unlikely to be due to enhanced tactile perception. High PQB group reported greater loneliness than did the low PQB group. Given the association of loneliness and psychosis (Michalska da Rocha et al., 2017) and the epidemic of loneliness among young people (see Cigna U.S. Loneliness Index, 2018), our results suggest that loneliness in individuals at risk for schizophrenia ought to be monitored.

When we divided the participants into high and low SPQ groups and examined potential group differences, we did not observe any significant group differences in the PI scores except for a trend towards increased PI Perceptual Aberration scores in the high SPQ group. We observed significantly increased feelings of loneliness in the high SPQ group. The very small sample size of the high SPQ group cautions against drawing any firm conclusions from this high versus low SPQ group comparison. However, when we examined correlations among SPQ scales and the PI scores in the whole sample, we did observe significant associations. Total PI scores were correlated with SPQ total score that was driven by positive schizotypy. In contrast, negative or disorganized schizotypal traits were not associated with PI.

Overall, the emerging pattern is that those with elevated PQ-B scores are more prone to PI but there was no alteration in tactile sensitivity. This pattern of results suggests that enhanced PI in high PQB group is unlikely to be due to anomalous tactile perception. It is important to note that the high PQB participants in the present study were healthy, non-help-seeking students, and we do not know if these participants will ever convert to psychosis. It is, however, interesting that despite intact tactile sensitivity, high PQB participants were still more prone to experiencing the PI.

While loneliness was associated with both SPQ and PQ-B in the present study, which was expected given the role of social and interpersonal difficulties in both measures, loneliness was not correlated with the PI itself. Thus, in healthy young adults, anomalous bodily self-experiences and perceived social isolation may represent two different potential risk factors for poor mental health. One note of caution is that the student population in our study was embedded in a highly structured, social community because they all lived in college dormitories. Hence, perceived loneliness in this population may not scale in the same way as in the general population. Nevertheless, because loneliness is correlated with both PQ-B and SPQ, it seems important to examine social disconnection in young adults in relation to psychosis risk in future studies.

There are caveats. The sample size of the high-PQB group in this study was small ($n = 16$) and these participants were non-help-seeking. Therefore, it is difficult to draw firm conclusions about the role of bodily self-disturbances in prodromal psychosis. However, it is still worthy of note that those individuals who may carry latent liability for schizophrenia seem more susceptible to multisensory illusions about the body boundary. Another caveat is that although the Pinocchio illusion is very compelling, the scoring still depends on phenomenology and hence, our scoring system retains an element of subjectivity. In the future, inclusion of multiple tasks that probe plasticity of bodily experiences from different angles and the development of more objective quantification of phenomenological experience would help clarify some of the remaining questions.

To conclude, the results of this study highlight the potential importance of understanding and detecting the plasticity of bodily self-representations in relation to psychosis-proneness in healthy, young population in order to better characterize behavioral signs that may indicate latent liability for schizophrenia that could contribute to the prodromal period.

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Contributors

Taylor Benson and Sohee Park designed the study and wrote the protocol. Taylor Benson managed the experimental procedures, data collection. Taylor Benson and Sohee Park analyzed the data and wrote the manuscript. Both authors contributed to and have approved the final manuscript.

Conflict of interest statement

Authors have no conflicts of interest to report.

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