Schizophrenia: from Minimal Self-disturbances to Disrupted Narrative Identity

By

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INTRODUCTION

"I feel disconnected from myself at times."

"I feel like I am living someone else's memories."

-Park Lab study participants, 2014

Weakened sense of self and anomalous bodily experiences were central to early theories of schizophrenia. When coining the word schizophrenia, Dr. Eugen Bleuler combined two Greek words that together mean "splitting of the mind." Dr. Bleuler's (1911) thorough clinical observations led him to believe that the fragmentation of the self and the disintegration of cognitive, emotional, and social functions are at the core of schizophrenia. Although these disturbances of the self are still recognized, contemporary researchers rarely consider them central to schizophrenia symptomatology, and clinicians seldom target self-disturbances for treatment (see Nasrallah, 2012). However, there has been a steady increase in awareness of the importance of self-disturbances in schizophrenia (see Park & Nasrallah, 2014), triggering a shift back to Bleuler's early conceptualization of the disorder (Parnas & Handest, 2003). These recent efforts have led to the inclusion of distortions of the self-experience as one of eight core symptoms of schizophrenia in the forthcoming revision of the International Classification of Diseases-11 (Gaebel, 2017).

But what is meant by distortions of self experiences? Before we can empirically investigate the disrupted sense of self in schizophrenia, it is necessary to clarify the conceptualization of the self and self disturbances. The concept of "self" is complex and multilayered. Over the course of human history, vast efforts have been extended by philosophers, scientists, theologians, historians, and social scientists to clarify the concept of the self (see Hunt, 2015 for the history). Given the difficulties inherent to studying the elusive concept of self, the studies presented here will be deliberately constrained to the domains that render non-tautological definitions and where there is a broad agreement. At present, it is accepted that there are at least two levels at which selfhood is experienced: the minimal self and the narrative self (Nelson et al., 2014). The minimal self, also referred to as the “basic” self or “ipseity,” is thought to be pre-reflexive. It is the level at which the implicit first-person experience occurs. Ipseity gives rise to the “Self” as an invariant subject through which the world is perceived and lived. The minimal self is the most primal and foundational level of selfhood from which higher levels stem (Parnas, 2003). Through repeated experience and embodiment, we reach the explicit self-awareness characteristic of higher levels of selfhood. One of these “higher” levels—the narrative self— binds together various aspects of personality, personal history, and social experiences to build a stable sense of self. The narrative self gives rise to a self-concept: an individual’s beliefs about themselves that influences their interactions with others and determines their self-identity (Baumeister, 1999). Figure 1 illustrate the multilayered construct of selfhood.

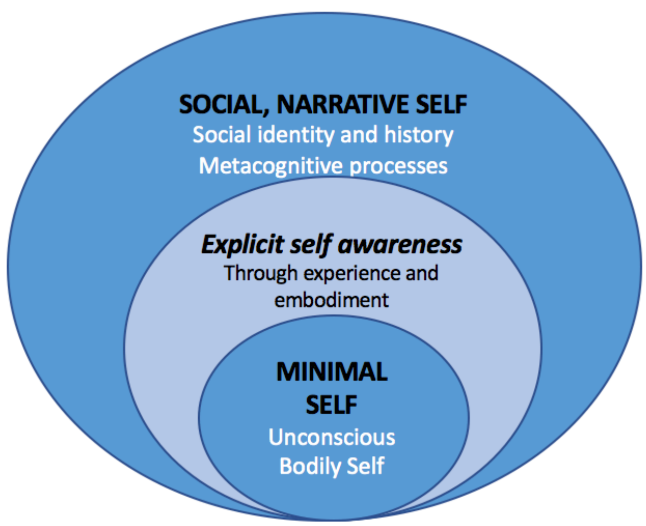


FIGURE 1. Levels of Selfhood

Both first-person accounts of schizophrenia (Kean, 2009) and empirical studies of the phenomenology of the disorder suggest that the self is a core feature of schizophrenia (Parnas et al., 2005; Nelson et al., 2012). Sass and Parnas (2003), proposed the "Ipseity-Disturbance Model of schizophrenia" (IDM). The IDM conceptualizes disturbances of the minimal self as both central to the phenomenology of schizophrenia and critical to its onset (Sass & Parnas, 2003). Disturbances of the minimal self in schizophrenia are well documented in mechanisms such as agency (Hauser et al., 2011), mismatch negativity (Randeniya et al., 2018), corollary discharge (Thakkar et al., 2015), and multisensory integration (Postmes et al., 2014). To understand the extent and variety of minimal self-disturbances in schizophrenia, Parnas and his colleagues (2005) developed the Examination of Anomalous Self-Experiences (EASE), a semi structured interview assessing IDM. Findings from the EASE repeatedly point at minimal self-disturbances as specifically characteristic of schizophrenia, already present in those at-risk for psychosis, and predicting overall outcome in individuals with schizophrenia (Nelson et al., 2014).

If the minimal, pre-reflexive self-disturbances highlight the importance of implicit bodily sense of self, disturbances at the narrative level represent disruption of the explicit, conscious, continuous sense of self (Mishara et al., 2014). In schizophrenia, the narrative self has been studied most extensively with respect to autobiographical memory impairments (McLeod et al., 2006). Robinson and Taylor (1998) argue that access to autobiographical memories is essential for individuals to create an identity, which is in turn key to a stable sense of self. Two studies directly investigated narrative identity in schizophrenia and found that patients had difficulty organizing memories and extracting meaning from them, which resulted in difficulty creating a coherent personal narrative and self-identity (Raffard et al., 2010; Berna et al., 2011).

Although individuals with schizophrenia routinely display both minimal and narrative self-disturbances, the etiology of such disturbances has not been extensively investigated. Nelson and colleagues (2012) found that basic self-disturbances predicted transition to psychosis in ultra high risk individuals, suggesting that disruptions in the minimal self might pre-date other symptoms of schizophrenia. However, less is known about the onset of narrative self-disturbances in the schizophrenia spectrum. Because the minimal self is the foundational level on which the narrative self is built, early disturbances of the minimal self in prodromal individuals may lead to disturbances of the narrative self in people with chronic schizophrenia. Roe and Davidson (2005) indeed argue that the self-disturbances associated with schizophrenia result in social and personal deficits making it difficult to create a coherent life narrative. In other words, the altered conscience of the bodily-self coupled with a fragmented identity observed in prodromal individuals may result in the disturbances of the narrative self and social deficits repeatedly endorsed by people with schizophrenia.

In healthy populations, emotional experiences and awareness of physiological sensations play a key role in the formation of autobiographical memories. The ability to create and recall accurate memories, in turn, is necessary to develop a sense of identity and acquire adequate social skills. Individuals with schizophrenia routinely demonstrate disturbances in all of the above: weakened sense of self, anomalous bodily experiences, and impaired autobiographical memory. We investigate this interplay and its resulting ramifications on social functioning for this population.

The junction of the minimal self and the narrative self, and the crucial role of bodily sensations of emotions in forming the “Self” motivated our research. We believe that the bodily sensation of emotions lies at the intersection of the minimal self and the narrative, social self.

Embodied emotions refer to a phenomenological experience where perception or recollection of emotional signals leads to perceptual, somatovisceral, and motor re-experiencing of the corresponding emotional state. Thinking about an emotion activates the autonomic nervous system in a similar fashion as actively experiencing that emotion (Levenson, 2003). This suggests that bodily self-awareness and autobiographical memory affect our ability to physically experience emotions. Furthermore, the somatomotor simulation and re-enacting of emotions may allow us to plan for action, facilitate adaptive behavior, and support interpersonal interactions (Decety & Jackson, 2004; Niedenthal 2007; Keysers et al. 2010). Additional functions of embodied emotions are linked to social cognition and functional outcome. In sum, embodied emotions rely on perception of bodily sensations and facilitates social functioning.

The process by which one perceives internal bodily sensations is known as interoception. The construct of interoception is divided into different dimensions including “interoceptive accuracy,” which refers to an individual’s objective performance on a interoception task, and “interoceptive awareness,” which characterizes one’s ability to consciously interpret the bodily signals that arises from their physiological states (Cameron, 2001; Garfinkel et al., 2015). Greater interoceptive awareness is associated with improved emotion reappraisal (Füstös et al., 2013) and higher strength of neural response to emotional stimuli (Pollatos et al., 2005).

The “shared network” hypothesis suggests that brain regions recruited during the processing of one’s own emotional experiences are also involved in the processing of the emotional experiences of others (Singer, 2006). Thus, our ability to infer the emotional states of others stems from our capacity to internally simulate and re-create the bodily states of others. This suggests that decreased awareness of the bodily sensations of emotions in oneself might be associated with difficulty recognizing emotions in others. Previous studies have found disrupted interoceptive capacity in people with schizophrenia (Ardizzi et al., 2016). According to "shared network" hypothesis, this disrupted interoceptive ability in the context of emotions could contribute to the poor social functioning of individuals with schizophrenia. This hypothesis offers a framework for understanding how hypothesized anomalous physiological sensations of emotions may lead to disturbances of the narrative self and broad social impairments.

Together, these previous results suggest that basic self-disturbances, such as impaired interoception, may lead to altered bodily sensation of emotions in schizophrenia. The literature also emphasizes that autobiographical memory deficits are central to narrative self-disturbances in schizophrenia. Autobiographical memory requires the ability to mentally recreate the affective, somatovisceral, and motoric context of an episode. These memories thus require adequate interoceptive awareness and emotional embodiment during the event. However, both interoception and emotional experience are altered in schizophrenia, potentially resulting in lowered ability to create a stable narrative identity from autobiographical memories.

Bodily/self-disturbances and anomalous emotional functioning, both core features of schizophrenia, play a major role in social and functional outcome (Hooker & Park, 2002; Strauss & Herbener, 2011; Kring & Ellis, 2013). Much has been written about abnormal perception and expression of emotions in schizophrenia but less is known about the bodily experience of emotions in this population. Considering the prevalence of anomalous self and bodily experiences (Parnas & Handset, 2003) and interoception deficits (Ardizzi et al., 2016) in schizophrenia, it seems likely that the embodiment of emotions might be severely affected in this population. However, contemporary researchers have neglected the study of the bodily sensation of emotions in this population, thus ignoring this fundamental aspect of emotional experience. The first aim of this project was to directly study the bodily sensation of emotions in schizophrenia. Given findings of bodily/self-disturbances and impaired emotion functioning in schizophrenia, we hypothesized that people with schizophrenia would have anomalous bodily sensations of emotions.

We then investigated disturbances of varying levels of selfhood in high risk individuals to shed light on the onset of self-disturbances in the schizophrenia spectrum. Our second aim was to gain insight on the etiology of such symptoms in schizophrenia. Given findings of minimal self-disturbances in prodromal individuals (Nelson et al., 2014) and evidence that emotional embodiment relies on the minimal self to create the narrative self, we hypothesized that high risk individuals would show evidence of interoceptive deficits and anomalous bodily embodiment but largely intact narrative identity.

STUDY 1. THE STRANGER WITHIN: ABNORMAL BODILY SENSATION OF EMOTIONS IN SCHIZOPHRENIA

Bodily-self disturbances and emotional deficits are central to schizophrenia. Importantly, bodily states and emotional experiences are linked via embodied emotions. Emotional embodiment relies on our bodily awareness and allows us to understand the affective states of others, therefore essential to social functioning. Anomalous embodied emotions could contribute to the disrupted sense of self and poor functional outcome of individuals with schizophrenia. In this study, we directly examined emotional embodiment in schizophrenia. We hypothesized that people with schizophrenia would have anomalous bodily sensations of emotions.

Method

Overview

Participants completed a questionnaire for demographic information and a computerized task in which they colored bodily regions where they felt a change in activity in the context of different emotions. Subjects also completed standard metrics assessing cognitive ability and schizophrenia symptomatology. Protocols were approved by Vanderbilt University Institutional Review Board and participants gave written informed consent to participate in the study.

Participants

Participants' demographic and clinical characteristics are summarized in Table 1. Fifty-two participants completed the study, half who met the DSM-IV criteria for schizophrenia (SZ; mean age= 46.1± 8.5, 12 females), and half healthy controls (CO; mean age= 40.9 ± 11.9, 10 females) matched for age ($t(50) = -1.81$, $p = 0.08$) and gender ($\chi^2 = 0.08$, $p = 0.78$.) Diagnosis was established by the Structured Clinical Interview for DSM-IV (SCID; First et al., 2002). All patients were clinically stable at the time of assessment and taking antipsychotic medication administered in a standard dose. SZ symptoms were rated using the Brief Psychiatric Rating Scale (BPRS; Overall & Gorham, 1962), the Scale for Assessment of Positive Symptoms (SAPS; Andreasen, 1984), and the Scale for Assessment of Negative Symptoms (SANS; Andreasen, 1983). Schizotypy was assessed in CO using the Schizotypal Personality Questionnaire, Brief (SPQ-B, Raine & Benishay, 1995). All participants provided written informed consent after procedures had been fully explained and were compensated at a rate of $20 per participation hour and reimbursed for travel expenses.

TABLE 1. Demographic and clinical information for Study 1 participants

	SZ (N=26)		CO (N=26)	
Characteristic	Mean	SD	Mean	SD
Gender (M/F)	14/12	-	16/10	-
Age (years)	46.12	8.49	40.92	11.91
Education (years)*	13.31	2.11	15.27	2.07
Estimated IQ[a]	102.81	8.82	110.31	6.72
Medication (mg/day)[b]	287.67	217.91		
SAPS score	19.00	15.96		
SANS score	29.12	12.39		
BPRS score	17.31	7.58		
SPQ-B				
Total score			4.96	4.63
Perceptual/cognitive subscale			1.42	1.53
Interpersonal subscale			2.54	2.45
Disorganized subscale			1.00	1.47

[a] Based on the North American Adult Reading Test.

[b] All patients were medicated. Antipsychotic dosage was converted to chlorpromazine (CPZ) equivalent following guidelines provided by Andreasen et al. (2010).

* Participants in the CO group had significantly more years of educations than those in the SZ group, $t(50) = -3.38$, $p = 0.002$.

Procedure

After signing consent, participants provided background information (age, gender, race, handedness, education, relationship status, weight and height, and medication). Emotion embodiment data were then acquired using the EmBODY tool (Nummenmaa et al., 2014; http://www.psy.vanderbilt.edu/faculty/sohee/embody/v1/).In this task (see Figure 2), participants were shown two ventral views of human silhouettes and an emotion word. The silhouettes were abstract and two-dimensional to lower the cognitive load of the task. Participants were asked to read the emotion word and use the mouse to color the bodily regions whose activity they felt increasing (on the left body) or decreasing (on the right body) when experiencing each emotion. This process was repeated for thirteen emotion categories (anger, fear, disgust, happiness, sadness, surprise, anxiety, love, depression, contempt, pride, shame, and jealousy) and a neutral condition. Emotion words were used instead of emotional stimuli because Nummenmaa et al. (2014) previously found that both techniques resulted in concordant maps.

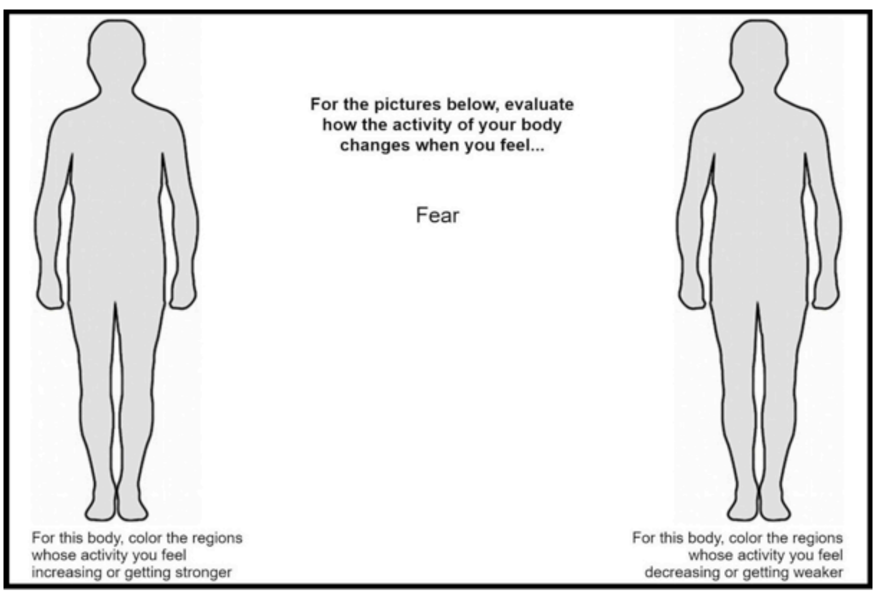


FIGURE 2. The EmBODY tool

Participants used a computer mouse to color bodily regions whose activity they feel becoming stronger (left body) or weaker (right body) in the context of a specific emotion (i.e. fear). There was no time limit for the task.

Results

Data Analysis

The analysis stream was similar to that of Hietanen et al. (2016) and was adjusted for small samples. Pre-processing consisted of manually screening individual maps for anomalous coloring (e.g., writing on the body or random scribbling) and masking responses outside the silhouettes.

We first generated mean emotion-wise body maps for SZ and CO. Because violations of normality were observed for the embodiment scores, nonparametric analyses were implemented. To obtain group maps, we took frequency counts for the number of participants choosing activation only, and the number of participants choosing deactivation only for each pixel, for each emotion. These counts were then divided by the total number of participants in the group, creating proportions. For a given pixel and emotion, these two proportions were partitioned across two matrices, each showing the 50,364 pixels by 14 emotions. The two matrices were then combined into one final matrix, accounting and correcting for directionality. This final matrix of values from -1 to 1, corresponding to the blue-red color continuum, was used to generate the group map. The maps were thresholded at $p < 0.05$, FDR corrected. This nonparametric method is illustrated in Appendix A. In these emotional bodily sensation maps, warm colors represent bodily activation while cold colors show bodily deactivation. We conceptualize "embodiment" as both activation and deactivation, representing a single continuum.

To test whether different emotions are associated with statistically different bodily sensations in each group, we implemented statistical pattern recognition with linear discriminant analysis (LDA). To estimate classification accuracy scores, we used stratified 126-fold cross-validation where we trained the classifier to recognize all emotions against all others (complete classification). The cross-validation scheme was run iteratively 100 times to yield standard deviations of the classification accuracy scores. To obtain significance thresholds for observed accuracy scores, we generated random data emulating the structure of observed data and analyzed it with the same LDA process. We then calculated the mean and variance of the resulting random empirical distribution, compared actual data to this random distribution, and obtained significance thresholds from these comparisons.

To obtain similarity scores for maps between groups, we first averaged each emotion condition map within-group, giving 14 mean maps per group. Our data followed an exponential distribution, Spearman rank correlations were therefore computed for each vector of embodiment scores. To correct for multiple testing, a FDR correction was applied. This process yielded a correlation coefficient per emotion, quantifying the similarity between the topographical map of an emotion between two groups. Hietanen et al. (2016) computed the normalized Euclidean distance (NED) between both groups to generate similarity scores for each emotion condition. Because emotion conditions are represented as vectors rather than matrices, we used correlations instead of NED. To ensure the validity of this method, we computed similarity scores using both NED and Spearman correlations and found a direct linear relationship between each set of scores. In the interest of parsimony, we report Spearman correlation coefficients as a measure of similarity scores.

Results

Figure 3 shows the bodily sensation maps associated with each emotion for the CO and SZ groups. In both groups, the emotions are associated with distinct distributions of body areas where activity was felt to change. In the CO group, the uniqueness of the emotion maps is more evident and in accordance with previous results (Nummenmaa et al., 2014), whereas the maps of the SZ group show more similarity across emotions including (e.g. activation in the head and chest across emotions).

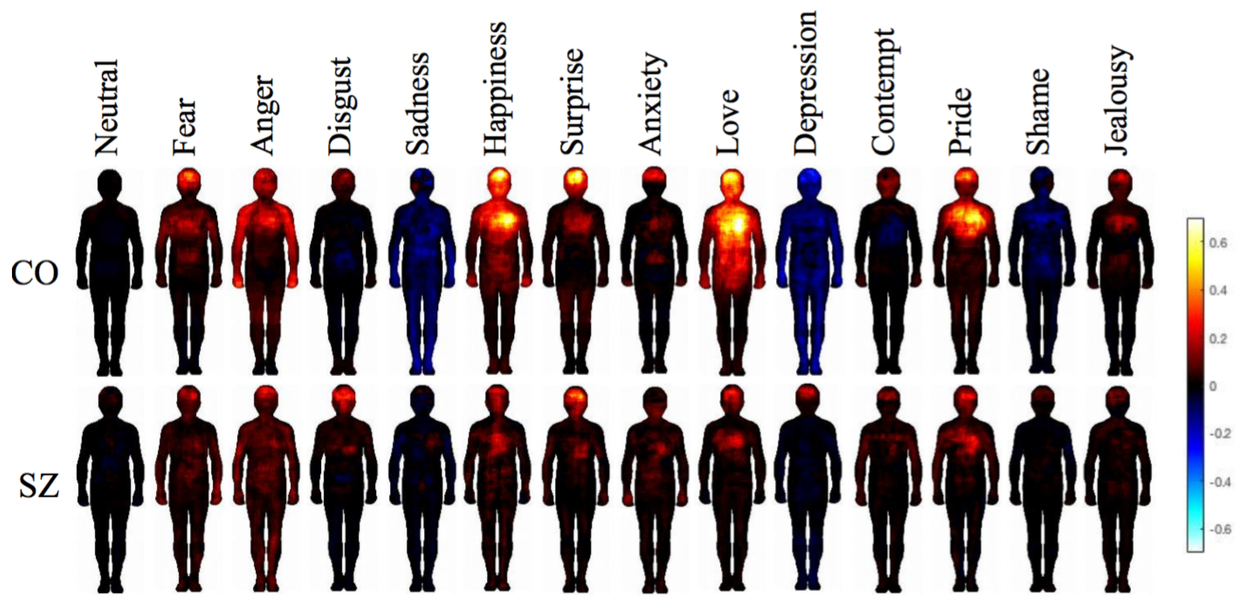
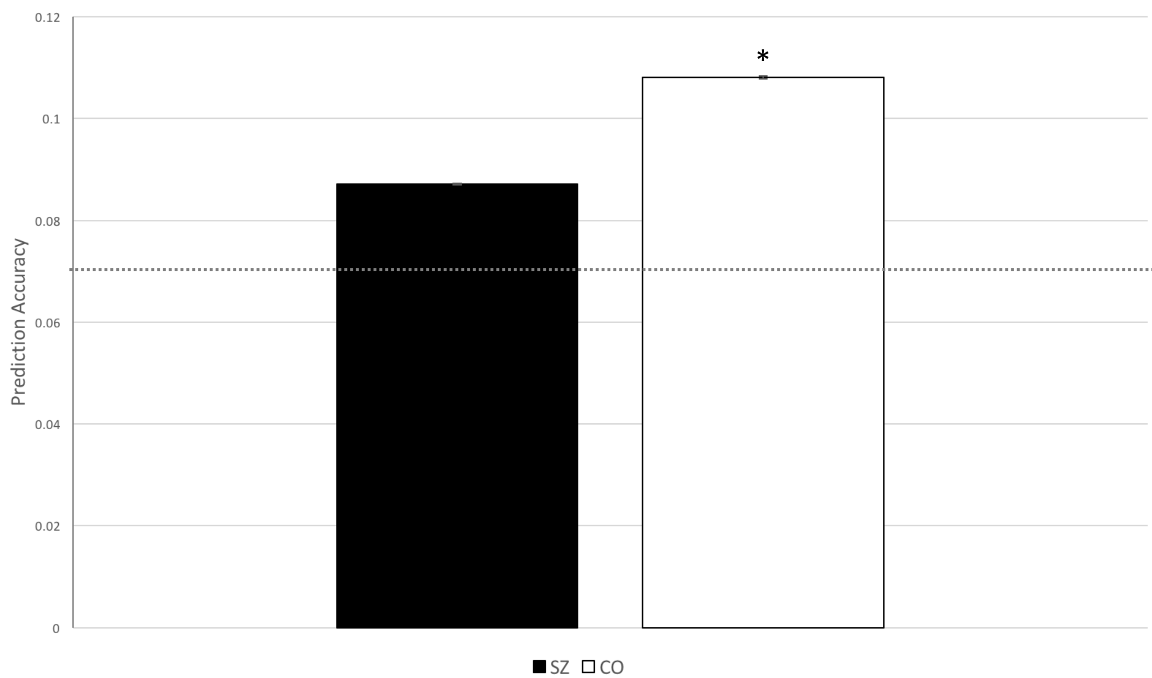


FIGURE 3: Bodily topography of emotions in CO and SZ

Topographical maps of bodily sensations associated with 13 emotions and a neutral state in for the CO sample (top) and SZ sample (bottom). The maps show bodily regions whose activation increased (warm colors) or decreased (cool colors) when experiencing each emotion. The color bar indicates the t-statistic range. The maps were FDR corrected at $p < 0.05$.

The classification, linear discriminant analysis (LDA) confirmed the independence of body maps across emotions in the CO group only. The overall prediction accuracy was higher for CO than SZ (see Figure 4). Average classification accuracy exceeded chance level (0.07) significantly in CO (0.11, $p<0.01$) whereas it was below chance level in SZ (0.09, $p>0.05$). To replicate Hietenan et al.'s (2016) original method, we included all 14 emotion conditions as separate categories, which explains de low prediction accuracy scores reported here.



* $p< 0.01$

FIGURE 4: Overall classification accuracy in SZ and CO

Mean (+/- SD) overall classification accuracy per group. The dashed horizontal line denotes chance level (0.07).

The maps showed in Figure 3 also suggest as specific deficit in bodily deactivation in the context of emotions in the SZ group, evidenced by the lack of cold colors. This observation was quantitatively confirmed by computing Spearman correlations for the map of each emotion for the SZ and CO group. We found the highest correlations between the maps of SZ and CO among high arousal emotions (love r_s=0.51, p<0.001; pride r_s =0.49, p<0.001; fear r_s =0.43, p<0.001) while the maps for some low-arousal emotions had correlations close to zero (sadness r_s = -0.01, p=0.11; depression r_s = -0.08, p<0.001). We note that although the correlations between the maps of SZ and CO are strongly significant for high arousal emotions (p<0.001), their effect sizes are in the moderate range ($0.43 < r_s < 0.51$). This discrepancy between significance and size of the observed effect can be explained by the large number of observations (N=50,364 pixels) used to compute each correlation coefficient. We are therefore careful in interpreting the magnitude of the relationship between the maps of SZ and CO and rather focus our subsequent discussion of similarity scores on the general trend observed. Figure 5 shows the similarity between emotion-wise bodily sensation of SZ and CO.

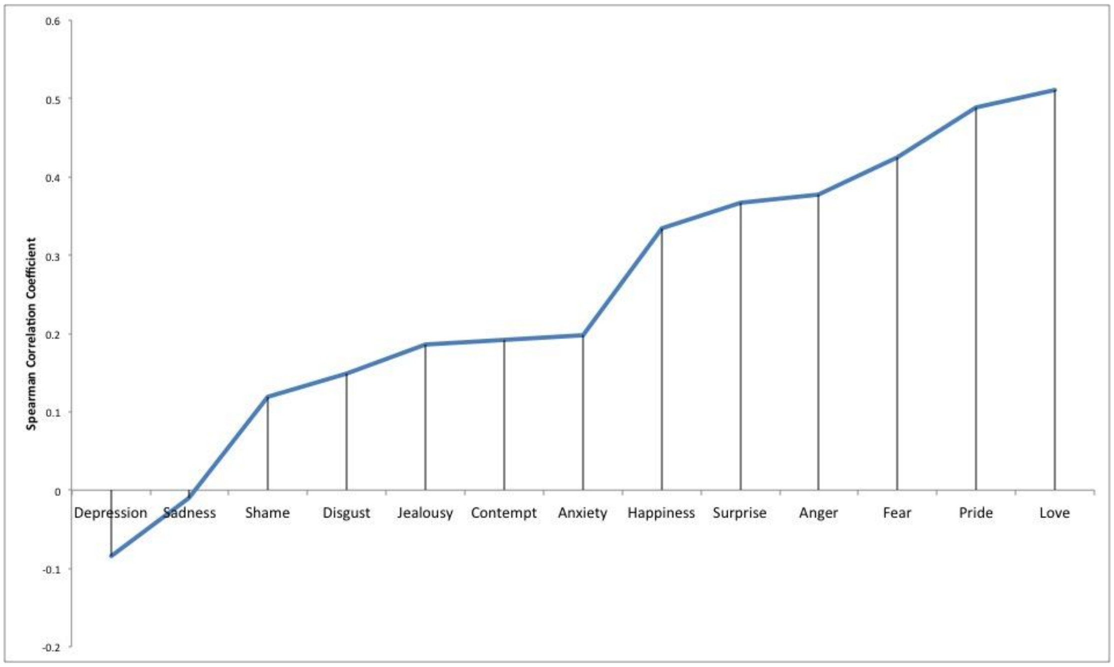


FIGURE 5: Similarity between the emotion-wise bodily sensation of SZ and CO

Discussion

Using a novel body mapping tool, we showed that people with schizophrenia experience abnormal physiological sensation of emotions. The anomalous topographical pattern of emotions was evidenced by qualitatively different maps as well as less discrete and less specific bodily sensations across emotions in individuals with schizophrenia as compared to healthy controls. The bodily maps of our patient group revealed strong physiological similarities across emotions, including increased activity in the head. Although our data cannot resolve the specific mechanism linking schizophrenia symptomatology and bodily sensation, it is possible that the activation of the head consistently reported in our patient sample illustrates physiological sensations associated with auditory hallucinations or disrupted cognition (i.e. delusions) rather than emotion-specific bodily sensation.

The low similarity score between the control and schizophrenia maps of low-arousal emotions suggests a specific deficit in embodiment of low-arousal emotions in our schizophrenia patients. Low-arousal emotions are primarily embodied as bodily deactivation in our healthy sample and prior cross-cultural studies (Nummenmaa et al., 2014), we therefore interpret this result as a specific deficit is bodily deactivation in emotional embodiment in schizophrenia. In understanding this finding, we turn to accounts of increased self-reported arousal in response to neutral stimuli in individuals with schizophrenia which might reflect a higher state of arousal at rest in individuals with schizophrenia (Llerena et al., 2012). Such a heightened baseline arousal could explain the difficulty in embodying low-arousal emotions in this population.

Because the EmBODY task inherently relies on the ability of an individual to recall emotional experiences, our finding of anomalous bodily sensation of emotions in patients is intrinsically tied to the autobiographical memory deficits experienced by this population. However, the link between autobiographic memories and embodied emotions remains unclear. The anomalous topographical sensation of emotions could result from disturbances of the minimal self previously described, and lead to difficulty recalling personal events. Indeed, the inability to properly embody emotional experiences could result in difficulty with mental somatomotor simulation and re-enacting of emotions, thus impacting an individual's ability to access personal memories. However, our data does not allow to draw such causal conclusions. In Study 2, we will examine basic self-mechanisms and autobiographical memory in individuals at risk for psychosis to understand the emergence of self-disturbances in the schizophrenia spectrum.

To understand the clinical implication of our results, we again turn to the "shared-network" hypothesis (Singer, 2006). If awareness of embodied emotions facilitates accurate perception of other people's emotional states, our finding of deficits in emotional embodiment in schizophrenia could have important clinical applications. Clinicians may be able to improve the social functioning of patients by training their ability to detect and identify their own physiological emotional experiences. Meditation and mindfulness-based therapies already show promise for improving interoception and bodily awareness (Khalsa et al., 2008), as well as changing the functioning of the neural network associated with interoceptive awareness (Farb et al., 2012; Hölzel et al., 2007; Lazar et al., 2005).

To our knowledge, the present study serves as the first self-report account of dysfunctional embodied emotions in schizophrenia. Previous studies have shown a disconnect of internal state and awareness in this population (Peterman et al., 2015). When asked to self-report their arousal in response to emotional stimuli, patients and controls did not significantly differ in their ratings although decreased galvanic skin response and heart beat were observed in schizophrenia (Peterman et al., 2015). Through the bodily mapping of their emotions, people with schizophrenia could non-verbally communicate the decreased physiological arousal in response to emotional stimuli previously measured. This finding reveals EmBODY as a useful tool to study emotional experience in clinical populations for which verbal self-report measures have proven inconclusive. Body mapping helped resolve the mismatch between measured and reported bodily sensation of emotions in schizophrenia (Peterman et al., 2015). However, the results reported here cannot disentangle whether the self-reported embodiment deficits (specifically for low-arousal emotions) match the physiological deficits measured in people with schizophrenia. Future work should aim at mapping the actual physiological changes during experimentally induced emotions. These physiological data could then be used to correlate the self-reported bodily sensations and the underlying physiological activity during emotions experiences in schizophrenia.

There are a few limitations to our study. First our schizophrenia patients were chronically medicated. Known side effects of antipsychotic medications include emotional numbness and social withdrawal (Moritz et al., 2013). In other words, medications effects could underlie some of the reported deficits in embodied emotions. The current study does not allow to disentangle medication effects from schizophrenia phenomenology in anomalous embodied emotions. Secondly, we did not control for previous exposure to computer technology. Although to our knowledge there are no comprehensive reviews of technology usage in schizophrenia, the high prevalence of unemployment and poverty in this population raises the possibility that our schizophrenia patients had less experience with computer technology than our control subjects. If our schizophrenia patients had no or limited previous exposure to technology, some of the embodiment deficits observed here could be due to difficulty properly using technology during the EmBODY task. Finally, the EmBODY tool did not include trial or control items to ensure that participants understood the task. We introduce such validity items in Study 2.

To conclude, we believe that the altered bodily sensation of emotions experienced by people with schizophrenia reported here may lay at the intersection of the disturbances of the minimal self and the altered sense of narrative identity experienced by this population. We now turn to individuals at risk for psychosis to investigate the etiology of self-disturbances in schizophrenia

STUDY 2. BASIC AND NARRATIVE SELF-DISTURBANCES IN THE SCHIZOPHRENIA SPECTRUM

Past studies have almost exclusively relied on phenomenological self-report or interview measures to document bodily self-disturbances in schizophrenia. Study 1 provides new empirical evidence for the existence of bodily self-disturbances in schizophrenia that goes beyond phenomenology. However, we cannot rule out the potential impact of medication or illness duration in chronic patients with schizophrenia. One way to address these limitations is to examine healthy individuals who may share latent liabilities for schizophrenia. These people may be at risk for developing the disorder but are not medicated and are not ill. Therefore, in Study 2, we recruited individuals who may be at elevated risk for schizophrenia and matched control participants to examine embodiment of emotion and extend the study to another level of selfhood experiences. Emotional embodiment, which we found to be altered in schizophrenia, lies at the intersection of the two levels at which selfhood is experienced (the minimal self and the narrative self).

In Study 2, we examined high risk individuals to gain insight on the chronology and etiology of these self-disturbances in the schizophrenia spectrum. To test our hypothesis that minimal self-disturbances are followed by disturbances in emotional embodiment which later lead to a disturbances of the narrative identity, we examined interoceptive ability, emotional embodiment, and autobiographical memory in two samples of young adults at varying degree of risk for schizophrenia. We hypothesized that high risk individuals would show evidence of interoceptive deficits and anomalous bodily embodiment but largely intact narrative identity.

Method

Participants

Fifty-nine participants were recruited from Vanderbilt University. Exclusion criteria included prior history of neurological disorder or prolonged drug use. All participants provided written informed consent after receiving full explanation of the procedures, and received compensation through credits towards fulfillment of a psychology course requirement. Vanderbilt University Institutional Review Board approved the protocols.

The Prodromal Questionnaire, Brief Version (PQ-B; Loewy & Cannon, 2010) was used to create two sub-groups reflecting level of risk for psychosis. Detailed information on the PQ-B is provided in the following section. According to the guidelines provided by Loewy and colleagues (2011), the distress score of six was used as the cutoff for participants placed in the high risk for psychosis (HR) group. Participants with a distress score of zero or one were included in the low risk for psychosis (LR) group, which yielded equivalent sample sizes in both groups: 16 in the HR group and 17 in the LR group. Subjects in the HR and LR groups were demographically matched for age ($t(31) = -0.62$, $p = 0.54$), and gender ($\chi^2 = 0.31$, $p = 0.58$). Table 2 summarizes the participants' demographic and sub-clinical characteristics.

TABLE 2. Demographic and sub-clinical information for Study 2 participants

	HR (N= 16)		LR (N= 17)		All (N= 59)	
Characteristic	Mean	SD	Mean	SD	Mean	SD
Age (years)	19.88	1.50	19.59	1.12	19.69	1.27
Gender (M/F)	3/13	–	2/15	–	10/40	–
PQ-B endorsed*	8.63	4.43	1.77	1.64	4.93	4.36
PQ-B distress*	17.81	9.85	0.88	0.86	8.23	10.10
SPQ-B						
Total score*	9.81	5.05	5.29	3.08	7.44	4.49

Perceptual/cognitive subscale*	3.25	2.12	1.35	1.22	2.41	1.95
Interpersonal subscale*	3.93	2.24	2.24	1.44	2.88	2.16
Disorganized subscale	2.63	1.93	1.70	1.61	2.15	1.69

*Significant group difference between HR and LR

Procedure

Participants first gave written informed consent. They then completed all experimental measures described below in one session lasting about two hours. The order of task administration was counterbalanced across participants.

Tasks

Body mapping of emotions. The general data acquisition procedure for emotional embodiment is the same as previously laid out for Study 1 (see p.10). However, we made two changes to the EmBODY tool. To investigate the topographical mapping of stress and loneliness (social emotions that may be specifically relevant to college students), we adjusted the original version of the EmBODY tool by replacing surprise and contempt with loneliness and stress, respectively. To ensure that participants understood the task, we also asked them to color in the maps of two common and localized bodily sensations serving as "control" items: migraine and nausea (http://www.psy.vanderbilt.edu/faculty/sohee/embody/v3/).

Autobiographical memory. Singer and Moffitt's (1991) Self-Defining Memory (SDM) questionnaire was used. The SDM questionnaire prompts participants to write about three autobiographical memories that define them. A self-defining memory was characterized as: (1) being at least one-year old, (2) being clearly remembered and feeling important, (3) dealing with an enduring theme, issue, or conflict in the individual's life, (4) being linked to other similar memories, (5) leading to strong feelings, and (6) being thought about many times (Singer & Moffitt, 1991). For each memory, the participant wrote a caption to identify the event, described the memory including "details that could help an imaginary friend see and feel what [the subject] lived (i.e. where the event took place, who was present, what happened, and how did [the subject] and others react to the event)", and indicated the level of positive and negative emotions felt while recalling the memory on a 7-point Likert scale. Participants' memories were scored on two criteria: specificity, and meaning-making. The scoring criteria for specificity and meaning-making was taken from Singer & Blagov's (2001) Classification System and Scoring Manual for Self-Defining Autobiographical Memories. Specificity was defined as a unique occurrence that lasted less than one day, each memory received a specificity score of 0 or 1. If a participant did not explicitly attach meaning to a memory in this way, meaning-making was scored as not present. This created a binary measure of meaning-making such that each memory received a score of 0 or 1. Memories were used as the unit of analysis for specificity and meaning-making. The word counts of each memory were also recorded.

Working Memory and Verbal Ability. Working memory and verbal ability were measured to assess possible between-group differences in factors that could affect performance on the autobiographical memory task. Working memory was measured using the Letter-Number Sequencing (LNS) test (Keefe et al., 2006). In this task, participants are orally presented with sequences of numbers and letters and asked to repeat them starting with the numbers from smallest to biggest, followed by the letters in alphabetical order. The total number of sequences correctly recalled was recorded and used as an index of participant's working memory capacity. Verbal ability was assessed with the North American Adult Reading Test Revised (NART-R; Blair & Spreen, 1989) in which participants are asked to read 61 English words aloud. Each word was scored 0 or 1 based on the participant's pronunciation. The number of words correctly pronounced was converted into a standardized score representing the participant's verbal ability, following Blair and Spreen's (1989) scoring guidelines.

Heart Beat Counting Task. Interoceptive accuracy and awareness were measured using Schandry's Heart Beat Counting Task (HBCT; 1981). Before beginning the task, the participant was asked to sit with their hands on their lap and their palms up to prevent facilitation of heart beat detection. During the HBCT, the participant was instructed to count the number of times their heart beat during a certain interval of time. After a practice trial, the task was repeated four times for time intervals of 33, 25, 41, and 17 seconds. While the subject counted their heart beat, their actual number of heart beats was recorded using a Bluetooth Polar H10 heartrate monitor and chest strap (Polar Electro Öy, Kempele, Finland). After each trial, the participant was instructed to rate the confidence of their heart beat count on a 1-10 Likert scale. Interceptive accuracy was computed at the trial level using the following transformation:

(1-|recorded heartbeats – counted heartbeats|)/recorded heartbeats) (Schandry et al., 1981)

Interoceptive accuracy scores ranged from 0 to 1, with higher scores indicating less discrepancy between counted and recorded heartbeats, which therefore indicated higher interoceptive accuracy. Interoceptive awareness was computed by calculating the Pearson correlation coefficient between the interoceptive accuracy and the self-reported confidence rating at each trial (Garfinkel et al., 2015). Interoceptive awareness scores therefore also varied between 0 and 1, with higher score indicating greater correspondence between interoceptive accuracy and confidence ratings, therefore indicating higher interoceptive awareness.

Self-report questionnaires. The Schizotypal Personality Questionnaire, Brief (SPQ-B; Raine & Benishay, 1995) was administered to assess psychosis proneness. The SPQ-B is a 22-item, true/false questionnaire consisting of cognitive-perceptual, interpersonal, and disorganized schizotypy factors. The Prodromal Questionnaire, Brief Version (PQ-B; Loewy & Cannon, 2010) was administered to screen for psychosis risk. The PQ-B is a 21-item self-report questionnaire comprised of positive symptom items and follow up questions regarding distress and impairment caused by the endorsed items. The distress score cutoff of six was shown to have the greatest sensitivity in identifying individuals at risk for psychosis (Loewy et al., 2011). This cutoff score was therefore used to create groups as previously mentioned. Participants also provided completed a demographic questionnaire providing background information (age, gender, race, handedness, education, relationship status, weight and height, and medication).

Results

Data Analysis

HR and LR participants were used in the group-level analyses. All 59 participants recruited for this study were included in sample-wide analyses investigating the link between different measures of self-experience and the continuum of schizotypy.

Bodily sensation of emotions. We employed the same method as the one used in Study 1 to pre-process the data, generate emotion-wise body maps for each group, test the independence of the bodily sensation of each emotion, and obtain similarity scores between the groups (see pp. 11-12).

Interoceptive Accuracy and Awareness. Because no violation of normality or homogeneity of variance were observed, group differences in interoceptive accuracy and awareness were assessed using independent samples *t*-tests. Effect sizes were calculated using Cohen's *d*. Individual trials were used as the unit of analysis for interoceptive accuracy and subject was used as the unit of analysis for interoceptive awareness. Pearson' correlations were conducted to evaluate the relation between interoception and schizotypy, and Holm corrections were applied to account for multiple testing.

Autobiographical Memory. Violations of normality were observed for both specificity and meaning-making scores. Therefore, group differences for these two measures were assessed using Mann-Whitney *U* tests. An independent samples *t*-test was used to compare the word count of memories in each group. For each memory, we subtracted the subject's rating of negative feeling from their rating of positive feeling to yield a total feeling score per memory. We then labelled each memory as "positive" (positive total feeling score), "negative" (negative total feeling score) or "neutral" (total feeling score of 0) and analyzed these data using a chi –square test to assess group differences in emotions experienced when recalling self-defining memories. Finally, Spearman rank correlations were computed to evaluate the relationship between measures of self-defining memories and schizotypy in the whole sample and Holm corrections were applied.

Working Memory & Verbal Ability. To test for between-groups differences in participant's working memory capacity and verbal ability—factors possibly influencing autobiographical memory—we performed two independent-samples *t*-tests comparing HR and LR.

Results

Body mapping of emotions. Figure 6 shows the bodily maps of emotions across the whole sample. These maps reveal that emotions are associated with distinct distributions of changing activity across bodily areas in our sample of young adults. These maps are also highly concordant with those obtained from the CO group in Study 1, as well as previous cross-cultural results (Nummenmaa et al., 2014). Our two substitute emotions, stress and loneliness, were also associated with specific patterns of bodily sensations. Stress is experienced as an increase in activity in the upper body, particularly the face and chest. Loneliness is felt as overall deactivation across the body, with some people reporting activation in the head. Finally, the embodiment of our two added “control” sensations (migraine and nausea) are precise, localized and reached a high level of agreement amongst participants, confirming the subjects' understanding of the EmBODY task.

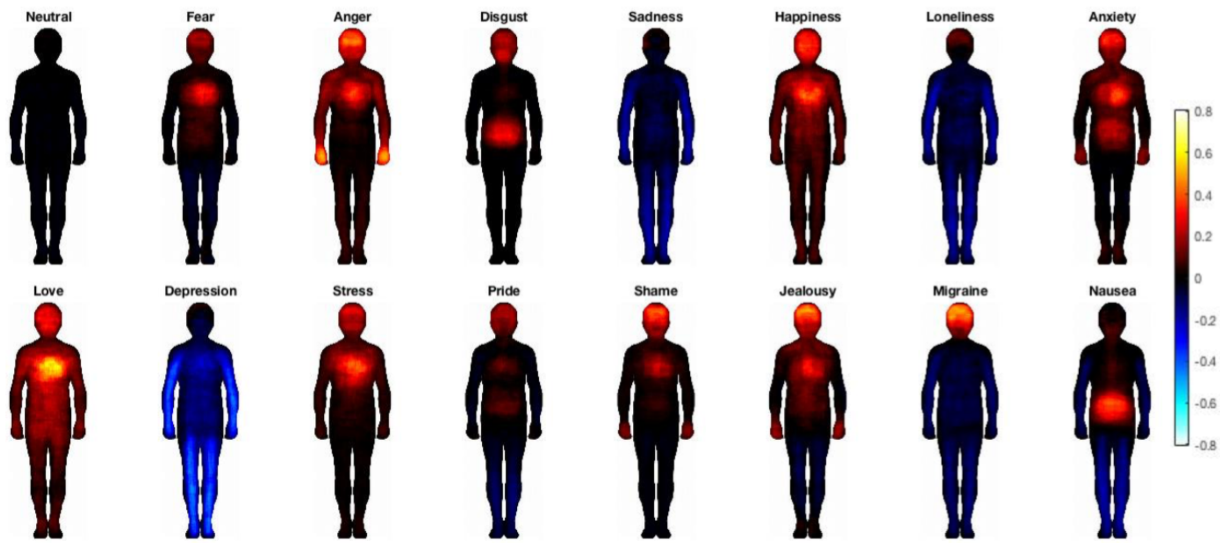


FIGURE 6: Bodily topography of emotions in young adults

Figure 7 shows the bodily sensation maps associated with each emotion for the LR and HR groups separately. The overall pattern on bodily sensation is similar between the HR and LR groups across emotions. However, the maps of the HR group show brighter and more localized sensations across different emotions (e.g. activation in the head and chest). HR also seem to report less deactivation in the context of low arousal emotions as compared to LR (e.g. sadness, loneliness). We observe good concordance in the HR and LR maps for the two control conditions (migraine and nausea), suggesting that participants in both groups understood the task.

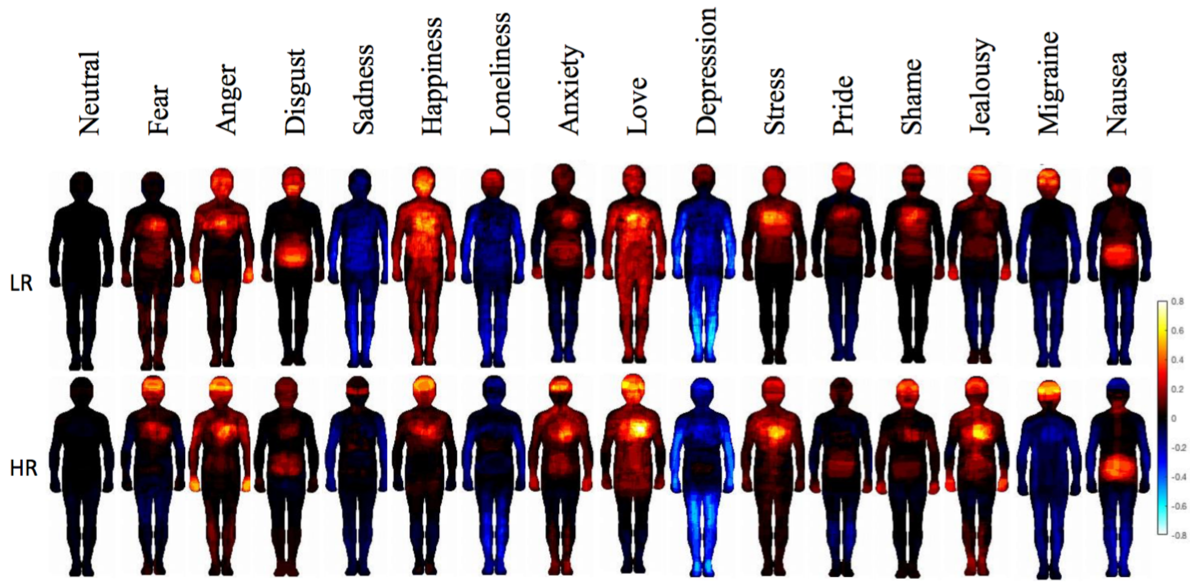
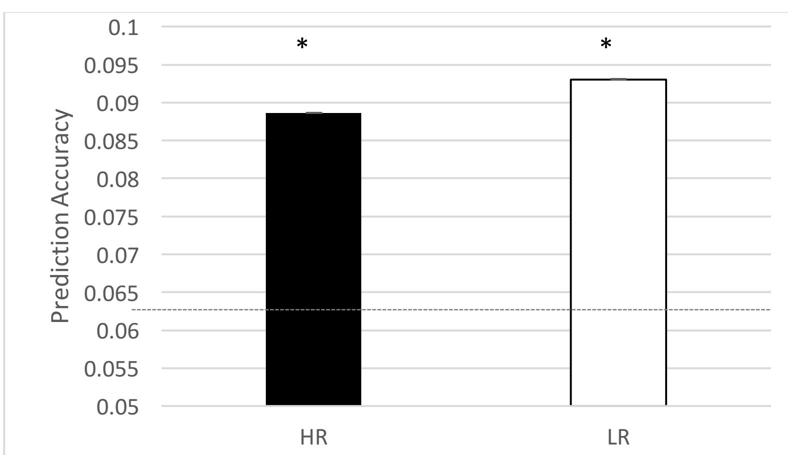


FIGURE 7: Bodily topography of emotions in LR and HR

The classification, linear discriminant analysis (LDA) confirmed the independence of body maps across emotions in both the HR and the LR groups. The overall prediction accuracy was higher for LR than HR (Figure 8). Average classification accuracy exceeded chance level (0.0625) significantly in both LR (0.093 $p<0.01$) and HR (0.089 $p<0.01$) although it was higher in LR.



* $p< 0.01$

FIGURE 8: Overall classification accuracy in LR and HR

Mean (+/- SD) overall classification accuracy per group. The dashed horizontal line denotes chance level (0.0625).

Spearman correlations of the map of each emotion for the HR and LR groups revealed significant positive correlations across all emotions. We found the strongest correlations between the maps of HR and LR among high arousal emotions (disgust r_s=0.82, p<0.001; stress r_s =0.78, p<0.001; anger r_s =0.75, p<0.001) while the maps of low-arousal emotions (depression r_s = 0.20, p<0.001; sadness r_s=0.23, p<0.001; loneliness r_s=0.25, p<0.001) and the neutral condition (r_s=0.20, p<0.001) were only weakly correlated. Due to the small effect sizes of these relationships, our discussion of similarity scores will again focus on general trends emerging rather than strength of the relationship between HR and LR maps for a given emotion condition. See Figure 9 for the similarity score between all emotion-wise bodily sensations of HR and LR.

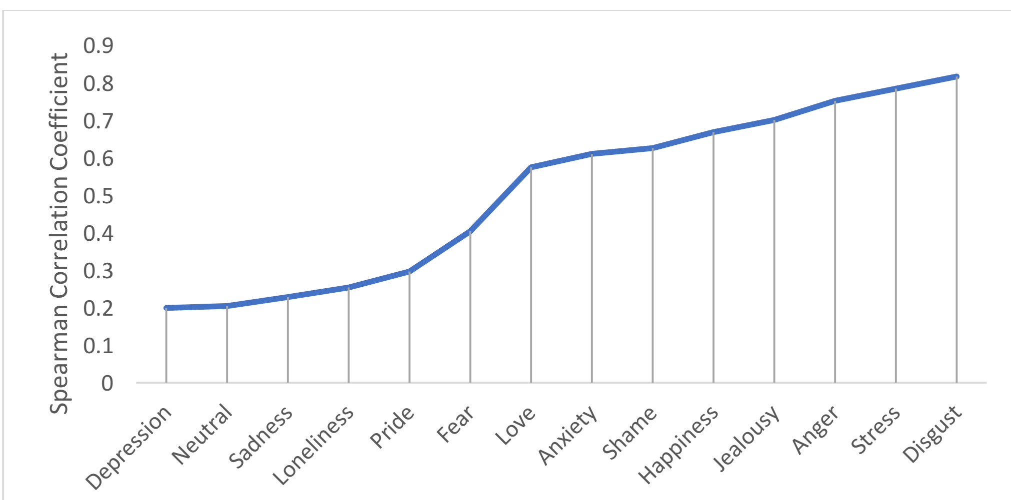
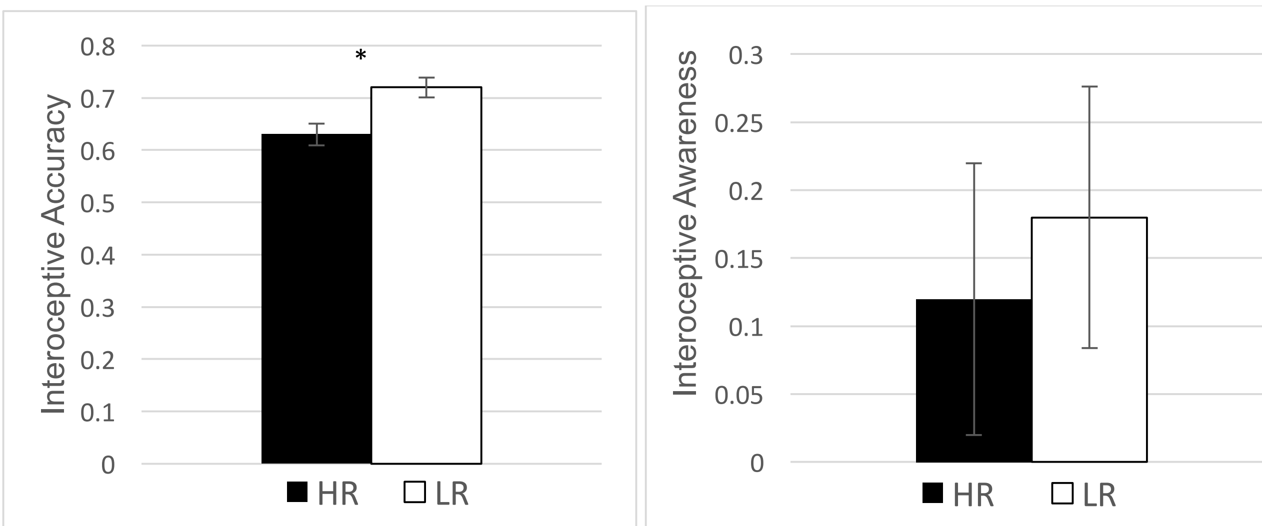


FIGURE 9: Similarity between the emotion-wise bodily sensation of LR and HR

Interoception. A significant group difference was observed in interoceptive accuracy $t(130)$= -3.02, p = 0.003, d = 0.55, with LR (M= 0.72, SD = 0.16) showing higher interoceptive accuracy than HR (*M*= 0.63, *SD* = 0.17). No significant difference was found in interoceptive awareness between HR (*M*= 0.12, *SD* = 0.58) and LR (*M*= 0.18, *SD* = 0.55), $t(31) = -0.30$, $p = 0.77$. These results are illustrated in Figure 10 below.



**p< 0.05*

FIGURE 10: Difference in interoceptive accuracy and awareness between LR and HR

Table 3 summarizes the results of correlations between measures of interoception and the three subscales of schizotypy, computed on the whole sample. Interoceptive accuracy and interoceptive awareness were not found to correlate with psychosis-proneness.

TABLE 3: Correlations between schizotypy subscales and measures of interoception

	SPQ-B Interpersonal	SPQ-B Disorganized	SPQ-B Cognitive
Interoceptive Accuracy	-0.31^{+}	-0.10	-0.13
Interoceptive Awareness	-0.10	-0.00	-0.07

$^{+}p<0.1$, $*p<0.05$

Autobiographical memory. There was no group difference in verbal ability or working memory capacity. HR (*M*=17.57*, SD*=2.75) and LR (*M*=18.5*, SD*=2.55) were closely matched in working memory ($t(31)= -1.33$, $p = 0.19$). Similarly, HR (*M*=113.18*, SD*=5.68) and LR (*M*=110.74*, SD*=6.30) did not differ in their verbal ability, $t(31)= 0.90$, $p = 0.38$. Because no working memory or verbal ability differences were observed between HR and LR, these measures were not included as covariates in the following analyses.

No group differences were found on measures of autobiographical memories between HR and LR. HR (*M*=2.13*, SD*=0.89) and LR (*M*=2.25*, SD*=0.93) did not differ in the number of specific memories they reported ($U= 141$, $p = 0.6$). Similarly, HR (*M*=1.25*, SD*=1.29) and LR (*M*=1.19*, SD*=1.22) did not differ in the number of meaning-making memories they recalled ($U= 124.5$, $p = 0.90$). No difference was observed in the type of emotion experienced when recalling self-defining memories between HR (positive: 69%, neutral= 2%, negative= 29%) and LR (positive: 60%, neutral: 7%, negative: 33%), $\chi^2(2, N=32) = 1.42$, $p = 0.49$. No difference was observed in the word count of memories produced by HR (*M*= 162.98, *SD* = 86.72) and LR (*M*= 185.17, *SD* = 112.38), $t(31) = -1.08$, $p = 0.28$.

Whole-sample analyses revealed a medium-effect size, negative relationship between the cognitive/perceptual subscale of schizotypy and specificity and length of autobiographical memories. In particular, increased cognitive/perceptual schizotypy was significantly correlated with decreased specificity of self-defining ($r = -0.32$, $p < 0.05$) memories and decreased number of words used to report memories ($r = -0.31$, $p < 0.05$) . Schizotypy was not related to the meaning-making quality of a memory or to the feelings experienced when recalling self-defining memories. See Table 4.

TABLE 4: Correlations between schizotypy subscales and measures of autobiographical memory across subjects

	SPQ-B Interpersonal	SPQ-B Disorganized	SPQ-B Cognitive
Feelings	-0.28^{+}	-0.093	-0.074
Specificity	0.017	-0.12	-0.32*
Meaning-Making	-0.072	-0.10	-0.038
Word Count	-0.18	-0.013	-0.31*

$^{+}p<0.1$, $*p<0.05$

Discussion

Using a variety of methods, we found evidence for the presence of minimal self-disturbances in individuals at risk for schizophrenia, but there was no clear evidence for impairments of narrative self-disturbances in this population. Specifically, we observed diminished interoceptive accuracy, mildly anomalous bodily sensation of emotions, but intact narrative identity in young adults who may be at increased risk for psychosis.

Using the EmBODY tool, we showed that individuals at risk for psychosis experience abnormal physiological sensation of emotions that mirror, to a lesser extent, those observed in our schizophrenia population in Study 1. Although the bodily maps of HR and LR individuals appeared qualitatively similar, the low similarity score between the maps of HR and LR for low-arousal emotions suggests a specific deficit in embodiment of low-arousal emotions in our HR individuals, again similar to that found in people with schizophrenia in Study 1. The anomalous topographical pattern of emotions was also evidenced by the prediction accuracy analysis which revealed less discrete and less specific bodily sensations across emotions in HR as compared to

LR. Previous research revealed a linear developmental trajectory of emotional bodily sensations in healthy individuals, from more to less specific patterns as a function of age (Hietanen et al. 2016). In the context of this previous finding, we interpret the present result as a failure to develop unique bodily sensations of specific emotions in individuals at risk for schizophrenia, which may stem from pre-existing disturbances of the minimal self (Nelson et al., 2014), and could result in a disrupted narrative identity as well as social deficits later in life.

The EmBODY tool is a self- report measure of emotional embodiment. Bodily maps obtained from this task therefore inherently rely both on the actual physical experience of emotions as well as awareness of these bodily sensations. In other words, the differences found between the bodily maps of HR and LR could illustrate diverging bodily sensations associated with emotions between the two groups, differences in interoception accuracy, or both. According to the "shared network" hypothesis, an individual physically experiencing emotions differently than others would have difficulty perceiving and understanding the affective states of others, which could lead to social impairments. Additionally, not being able to discern one's own internal affective states may result in a fragmented sense of self.

To understand possible mechanisms underlying the anomalous bodily sensation of emotions in HR, we examined a basic experience of the self: interoception. As predicted, we found that interoceptive *accuracy*, a measure of sensitivity to physiological signals originating inside the body, was lower in people at high risk for psychosis compared to those at low risk. This finding mirrors that of studies investigating interoceptive accuracy in people with schizophrenia (Ardizzi et al., 2013). The present results therefore suggest that an impaired awareness of bodily signals, a basic and pre-reflexive self mechanism, may appear prior to the onset of psychosis and/or may be an endophenotypic marker for the schizophrenia spectrum.

These interoceptive impairments underlie the anomalous bodily sensations of emotions previously described.

Interestingly, interoceptive *awareness* did not differ between people at high risk for psychosis and those at low risk, revealing that pre-reflexive self-disturbances may be central to psychosis risk but not conscious awareness of interoception. To our knowledge, no study has investigated interoceptive awareness in individuals with schizophrenia. However, the metacognitive deficits well established in the schizophrenia literature (Gulmey et al. 2011; Lysaker et al., 2014) suggest that interoceptive awareness might be impaired in this population. We also found that interoceptive accuracy and awareness did not correlate with domains of schizotypy, suggesting that minimal self-disturbances are specific to individuals at risk for psychosis rather than linked to broadly conceptualized psychosis-proneness.

No differences were found between the self-defining memories generated by individuals at high and low risk for developing psychosis, revealing intact narrative identity in prodromal individuals. Specifically, the memories reported in both group did not differ in specificity, meaning-making quality, or length. These results are in contrast with the well documented autobiographical memory deficits and disrupted narrative identity of individuals with schizophrenia. Using the SDM, Raffard and colleagues (2010) found deficits in specificity and meaning-making for the memories reported by people with schizophrenia as compared to those of matched controls. We interpret our finding of adequate narrative identity in HR individuals as evidence for the later onset of disturbances of the narrative self in people who do transition to psychosis. In other words, the disrupted sense of the social and narrative identity that characterizes the phenomenology of schizophrenia is not present in prodromal individuals. We therefore suggest that psychotic experiences may contribute to disturbances of the narrative self in this population.

An alternative hypothesis proposes that an anomalous chronological distribution of self-defining memories in individuals with schizophrenia might underlie disturbances of their narrative identity. Previous studies have found evidence for the presence of an earlier "reminiscence bump" in individuals with schizophrenia (peaking at 15-19 years) compared to healthy individuals (peaking at 20-24 years) (Raffard et al., 2009). The literature reveals well-established evidence that the reminiscence bump is essential to the development of a stable sense of narrative identity and that the timing of this reminiscence bump is critical to the nature of self-defining events (Conway, 2005; Rathbones, Moulin, & Conway, 2008). Because the age range of our sample was 18-22 years, we were not able to examine the reminiscence bump of our HR and LR groups. Our study therefore cannot attest for possible evidence of an early reminiscence bump in prodromal individuals.

In the whole-sample analyses we found a significant negative relationship between the cognitive subscale of schizotypy and the specificity and length of memories such that people who scored higher on the cognitive/perceptual subscale of schizotypy reported less specific and shorter self-defining memories. This finding aligns with that of non-specific self-defining memories in individuals with schizophrenia (Raffard et al., 2010), suggesting a tendency to report less specific autobiographic memories across the schizophrenia spectrum although not specific to individuals at risk for psychosis.

Our findings are in line with those of Postmes and colleagues (2014) who described schizophrenia as a self-disorder due to perceptual incoherence, and argued that impairments of multisensory integration lead to incoherent conscious experiences of the self. Here, we found that basic self-disturbances precede more complex ones. Our results suggest a similar sequential chain of self-disturbances in schizophrenia. Together, our findings suggest that basic bodily self mechanisms (e.g. interoception) are critical to our awareness of emotional bodily signals that help us understand others and create a sense of our own identity. Prodromal individuals already exhibit disturbances in some of the foundational levels of the sense of self.

There are several limitations to this study. First, the sample size is small. Second, risk for psychosis was measured using a self-report questionnaire (PQB), the external validity of our HR group would increase if we used a collection of methodology to assess risk for psychosis. Furthermore, our cross-sectional study design does not allow us to draw any causal conclusion regarding the chronological order of onset of self-disturbances in the schizophrenia spectrum. A longitudinal design following people at risk for psychosis until they transition to psychosis (or do not) would be useful in confirming the developmental trajectory of disturbances of the self in schizophrenia.

Overall, we found evidence for the presence of basic self-disturbances in individuals at risk for schizophrenia. We also found that these individuals experience mildly anomalous bodily sensation of emotions that mirror those observed in people with schizophrenia. However, we found no differences between the self-defining memories reported by individuals at high risk for schizophrenia compared to the memories recalled by those at low risk. Emotional embodiment relies on pre-reflexive bodily mechanisms (i.e. interoception) and is essential to create a stable self-concept, as well as to understand the emotional states of others. In other words, we argue that the embodiment of emotions relies on mechanisms of the foundational basic self, and gives rise to the narrative, social self.

CONCLUSION

Building on the well-established phenomenological literature on the minimal self and narrative self-disturbances in schizophrenia, in Study 1 we found that individuals with schizophrenia also experience anomalous bodily sensation of emotions. This finding not only adds to the collection of bodily/self-disturbances experienced by this population but also bridges the gap between disrupted pre-reflective and conscious self. We believe that embodied emotions lie at the intersection of the minimal self and the narrative self. Emotional embodiment allows us to pre-reflexively reach a first-person emotional experience, which in turn helps us understand the emotional states of others.

In Study 2, we investigated minimal self-disturbances (interoception), emotional embodiment, and disturbances of the narrative self (autobiographical memory) in healthy individuals who may carry latent liability for schizophrenia and matched controls. We found that interoceptive accuracy was impaired in individuals at risk for psychosis. We also found evidence for anomalies in emotional embodiment in the high risk group. However, the autobiographical memory of at-risk individuals was intact. The results of Study 2 suggest that the core minimal self-disturbances are present during the prodromal stage but there was no evidence of impairments of the narrative self in high risk individuals. Current study does not allow us to make inferences about the chronology of self disturbances across the schizophrenia spectrum but future longitudinal studies will be able to extend these findings.

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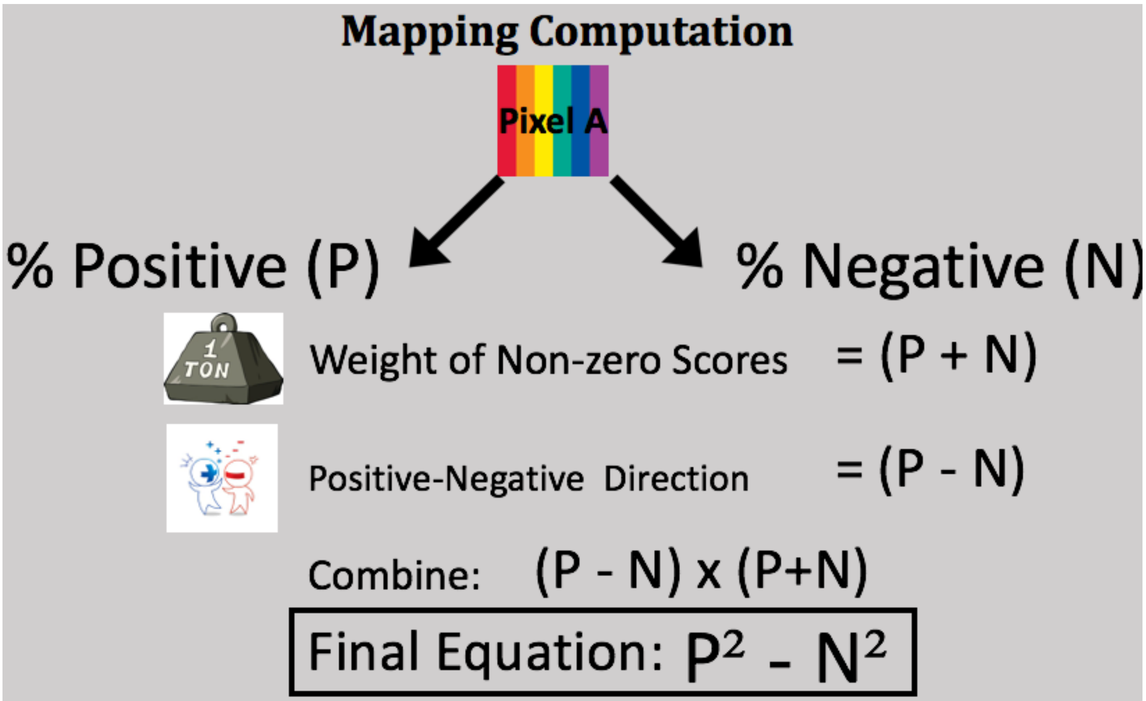
APPENDIX

APPENDIX A: Nonparametric method used to compute group maps.



To account for small sample sizes, the proportion of endorsements was taken as the significance indicator for a given pixel. The final equation yielded the value of each pixel that was used to generate the map. Maps were then thresholded at $p < 0.05$, FDR corrected.