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Thomas, Lucretia; Torregrossa, Lenie; Reniers, Renate; Humpston, Clara

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Exploring Multimodal Hallucinations and Disturbances in the Basic and Bodily Self: A Cross-Sectional Study in a Non-Clinical Sample

Lucretia Thomas[1], Lénie Torregrossa[2], Renate Reniers[3] and Clara Humpston[4]

[1]Medical School, College of Medical and Dental Sciences, University of Birmingham, Edgbaston, B15 2GW, United Kingdom.

[2]Department of Psychology, Vanderbilt University, 111 21st Ave. S, Wilson Hall, Room 311, Nashville, TN 37240, United States of America.

[3]Institute for Clinical Sciences, University of Birmingham, Birmingham, B15 2TT, United Kingdom.

[4]Institute for Mental Health, University of Birmingham, Birmingham, B15 2TT, United Kingdom.

*Correspondence author: c.s.humpston@bham.ac.uk

Abstract

The bodily self is key to emotional embodiment, which is important for social functioning and emotion regulation. There is a paucity of research systematically assessing how basic and bodily self-disturbances relate to multimodal hallucinations. This study hypothesised that participants with greater hallucination-proneness would report greater degrees of basic and bodily self-disturbance and would demonstrate more ambiguous and less discrete mapping of emotional embodiment. Stage one screened non-clinical participants' degree of hallucination-proneness. Stage two participants completed seven further questionnaires. Hierarchical linear regression modelled the influence of hallucination-proneness and covariates on measures of basic and bodily self-disturbance and sensed presence. Stage two participants also completed a computerised body mapping task (EmBODY) which assessed emotional embodiment. Topographical maps were generated to compare patterns of embodiment between high and low hallucination-proneness groups. 55 respondents participated in stage two, with 18 participants from the high or low hallucination-proneness groups completing EmBODY. In the hierarchical regression analyses, the addition of a measure of hallucination proneness in the final step only increased predictive power where the dependent variable assessed sensed presence ($p = 0.035$ and $p = 0.009$, respectively). The EmBODY data revealed that participants with low hallucination-proneness consistently reported more bodily activation across 14 emotional states, whereas the high hallucination-proneness group reported more deactivation. In conclusion, hallucination-proneness was most strongly associated with sensed presence experiences. Patterns of embodiment appeared similar between the two groups, despite consistent differences in activation and deactivation. These findings are exploratory and need to be confirmed in a larger sample.

Keywords: Multimodal hallucinations, self-disturbance, bodily self, psychotic-like experiences, psychosis continuum, survey.

1. Introduction

The features of mental illness are being increasingly studied outside of diagnostic categories and in non-clinical populations (Ford et al., 2014; Pienkos et al., 2019). The psychosis continuum approach was established on the basis that 5-30% of the general population have had psychotic-like experiences during their lifetime without a need for care (Kråkvik et al., 2015; McGrath et al., 2015; Mitchell et al., 2017; Peters et al., 2016; Linscott, 2013). Parallels have been drawn between the experiences of individuals with psychotic-like experiences and those with a diagnosed schizophrenia spectrum disorder (SSD) (Ford et al., 2014; Peters et al., 2016).

Even within the continuum approach, psychosis research has largely centred on symptoms which are clinically overt and easier to assess, including hallucinations in the auditory and visual domains, observable deficits in affect, and delusions (Pienkos et al., 2019). Whereas subtle subjective experiences which are challenging to observe and for individuals to articulate, including self-disturbances, may have been neglected despite being associated with distress (Pienkos et al., 2019; Schultze-Lutter, 2009).

Basic and bodily self-disturbances were central to early conceptualisations of schizophrenia. Although the exact phenomenological nature of schizophrenia as a self-disturbance is subject to debate and there are multiple schools of thought regarding this, much evidence supports the role of self-disturbances in schizophrenia throughout the course of the illness including evidence from recent meta-analyses indicating a disproportional aggregation of self-disturbances in the schizophrenia spectrum (e.g. Raballo et al., 2021). Self-disturbances are considered relatively stable and are present in almost all stages of schizophrenia (Sass, 2019; Spark et al., 2021), however a consensus is yet to be reached as to their impact in other psychiatric disorders including dissociative and panic disorders which may extend beyond the usual basic and bodily self-disturbances commonly associated with schizophrenia. Indeed, there is very little research on disturbances of the narrative self in personality disorders, for example, despite potential interrelationship and overlap between levels of selfhood.

The basic self is the tacit sense that one's experiences, thoughts, and interactions with the world are one's own (Raballo et al., 2021; Sass, 2019). Since these experiences occur through one's body, the basic self is thought to be grounded in the bodily self (Ferri and Gallese, 2019). The bodily self is broadly defined as the stable sense of ownership, perception, and agency of one's body over time, which includes the distinction between the self and others (Costantini et al., 2020; di Cosmo et al., 2018; Ferri and Gallese, 2019; Tsakiris, 2017). The bodily self is key to emotional embodiment, which is defined as the recognition and labelling of the internal sensations which accompany different emotions; this process is important in interpreting one's own emotions and relating to those of others (Torregrossa et al., 2018).

Basic self-disturbances are typically subtle experiences which may be noticed by an individual as a deviation from their usual state; such experiences include a sense of depersonalisation and detachment (Raballo et al., 2021; Schultze-Lutter, 2009; Spark et al., 2021). Manifestations of bodily self-disturbances include alterations in the perception of the size and form of one's body, a blurred self-other boundary, and cenesthetic changes including electrical and thermal sensations (Costantini et al., 2020; Ferri and Gallese, 2019; Lee et al., 2021; Pienkos et al., 2019). Altered emotional embodiment may underlie deficits in social functioning observed in SSDs, including increased feelings of loneliness leading to social deafferentation (Michael and Park, 2016a; Torregrossa et al., 2018).

Sensed presence, defined as the feeling of another entity being present nearby in the absence of percept or sensory input, can be considered as being at the interface between a bodily self-disturbance and a hallucination (Barnby and Bell, 2017; Braithwaite et al., 2013; Larøi et al., 2019). Sensed presence experiences have been frequently observed in the general population and may be more common amongst individuals who experience hallucinations in other modalities (Barnby and Bell, 2017; Larøi et al., 2019). Sensed presence experiences may arise from a breakdown in the integration of multisensory information regarding the bodily self and the self-other boundary (Braithwaite et al., 2013; Cheyne, 2012; Lee et al., 2021). Given the proposed commonality of this experience (particularly in individuals suffering from grief responses and individuals engaging in certain religious practices), risks associated with sensed presence in relation to other psychotic symptoms and psychotic-like experiences have been practically negated. However, similar to other hallucinatory experiences, factors such as persistence, severity and distress associated with some cases of sensed presence may still signify heightened risk of developing clinical disorders and are worthy of investigation.

Empirical evidence regarding basic and bodily self-disturbances and sensed presence experiences has been gathered through various self-report measures and semi-structured interviewing techniques (Costantini et al., 2020; Ferri and Gallese, 2019; Parnas et al., 2005; Raballo et al., 2021; Spark et al., 2021). To assess emotional embodiment, Torregrossa and colleagues used a computer-based tool to demonstrate that the mapping of bodily sensations was less distinct between different emotions in participants with schizophrenia, compared to non-clinical controls (Torregrossa et al., 2018).

Multimodal hallucinations are defined as hallucinations that co-occur in different modalities, either in a simultaneous or in a sequential (serial) manner and are related in thematic content, as opposed to simply multisensory hallucinations (Montagnese et al., 2021; Toh, Bere, and Rossell, 2021). To our knowledge, no single study has systematically assessed disturbances in the basic and bodily self, alongside multimodal hallucinations, to unite these concepts and assess how they interrelate, particularly not in a non-clinical sample. This project aims to address this gap in the evidence base.

1.1 Objectives

This study aimed to investigate the concepts of the basic and bodily self and how disturbances in these relate to hallucinations across modalities. It was hypothesised that participants with greater hallucination-proneness would report greater degrees of basic and bodily self-disturbance and would demonstrate more ambiguous and less discrete patterns of emotional embodiment.

2. Materials and methods

2.1 Overview of study design

These objectives were explored in a two-stage cross-sectional study. In stage one, participants completed the Multi-Modality Unusual Sensory Experiences Questionnaire (MUSEQ) which assessed hallucination-proneness (Mitchell et al., 2017).

In stage two, participants completed further questionnaires and a computerised task which assessed emotional embodiment, called EmBODY (Nummenmaa et al., 2014; Torregrossa et al., 2018).

Data collection took place between February 10, 2020 and January 1, 2021 for stage one, and February 8, 2021 and April 1, 2021 for stage two.

2.2 Participant recruitment and sampling strategy

Adults without a current psychiatric or neurological disorder were recruited through the distribution of the stage one survey on social media and websites including mqmentalhealth.org. Before the introduction of COVID-19 restrictions in March 2020, the survey was also advertised via the distribution of posters at the University of Birmingham. Although convenience sampling carries the risk of selection bias, this was more feasible than random or systematic sampling methods since the target population was broadly defined (Barker et al., 2016). The inclusion and exclusion criteria are outlined in Table 1.

Table 1 around here

The study was conducted in line with the Declaration of Helsinki 2013 and full ethical approval was obtained from the University of Birmingham Science, Technology, Engineering and Mathematics Ethical Review Committee (ERN_19-0992). At both stages, participants were provided with information regarding the study rationale, procedure, inclusion and exclusion criteria, their right to withdraw without penalty, and how they would be compensated for their time. Participants had the opportunity to ask questions via email before providing informed consent. A participant information sheet and consent form were embedded into both surveys. Participants' data was stored on a secure server at the University of Birmingham, in line with data protection and confidentiality guidelines (University of Birmingham, 2018).

The initial purpose of stage one was to rank participants by their MUSEQ score and select the top and bottom quartiles to proceed to stage two, forming two high and low hallucination-proneness groups for comparison with an extreme groups approach (Preacher, 2015). Other approaches have been taken to select high and low hallucination proneness groups, including median split and selecting participants with scores ≥ 0.5 standard deviations from the mean (Stainsby and Lovell, 2014; Stirling et al., 2007; van 't Wout et al., 2004). However, selecting upper and lower quartiles was most feasible.

An *a priori* sample size calculation was conducted based on the premise of using an extreme groups approach. Based on previous studies which sampled high and low hallucination-proneness groups, the effect size was estimated to be 0.16 (Cohen's f^2) (Stainsby and Lovell, 2014; Stirling et al., 2007; van't Wout et al., 2004). Using G*power 3.1.9.7 for Windows, the minimum sample size required for stage two was estimated at 52, with the significance level (α) set at 0.05 and power (1-β) set at 0.8 (Buchner et al, 2020; Faul et al., 2009, 2007).

Given the number of stage one responses obtained (Figure 1) and accounting for attrition, it would not have been possible to meet this minimum sample size for stage two. Therefore, all participants who provided complete responses to the stage one survey and a valid email address were invited to participate in stage two instead of using an extreme groups approach. This has allowed the opportunity to collect data from the full sample, allowing the distribution of all continuous variables to be assessed and avoiding the inflation of effect size that is associated with an extreme groups approach (Preacher, 2015). However, high and low hallucination-proneness groups were still selected in the same manner for the purpose of analysing the EmBODY data as per previous studies using this task and completing a secondary analysis of the questionnaire data.

A *post hoc* power calculation was conducted using G*power 3.1.9.7 for Windows (Suppl. Table 1) (Buchner et al, 2020; Faul et al., 2009, 2007). The following equation was used to calculate the effect size for each of the six hierarchical regression models, where R_A^2 is the variance accounted for by the independent variables in step 1 and R_{AB}^2 is the variance accounted for by all independent variables in the final model (Selya et al., 2012).

$$f^2 = \frac{R_{AB}^2 - R_A^2}{1 - R_{AB}^2}$$

Figure 1 outlines the flow of participants. A response was counted if the participant has completed the consent form and responded 'Yes' to the question: 'I agree to complete the questionnaire as part of the study'.

Figure 1 around here

2.3 Procedure

2.3.1 Validated questionnaires

The stage one and two surveys were administered via Qualtrics and contained demographic questions regarding age, gender, and handedness; Qualtrics was chosen due to its flexibility and security (Qualtrics for Faculty). Questionnaires were chosen for their good psychometric properties (including their overlap with measures of self-disturbance used in schizophrenia such as the Examination of Anomalous Self-Experiences or EASE; see Cicero et al., 2017) as pertinent to the research questions, their ease of administration and dissemination by self-report and minimisation of participant burden and distress.

The stage one questionnaire contained the Multi-Modality Unusual Sensory Experiences Questionnaire (MUSEQ) which was used to assess the participants' degree of hallucination-proneness (Mitchell et al., 2017). The MUSEQ is a 43-item questionnaire which assesses unusual sensory experiences in the general population across six modalities, on a five-point Likert scale (Mitchell et al., 2017). Internal validation studies indicated that the MUSEQ has good internal consistency alongside strong convergent and divergent validity, correlating strongly with other measures of unusual sensory experiences and poorly with those of schizotypy (Mitchell et al., 2017).

The stage two survey contained seven questionnaires: the Sensed Presence Questionnaire (SenPQ), the Benson et al. Body Disturbances Inventory (B-BODI), the Inventory of Anomalous Psychosis-Like Experiences (IPASE), the Cardiff Anomalous Perceptions Scale (CAPS), the Peter's et al. Delusions Inventory (PDI), the Hospital Anxiety and Depression Scale (HADS), and the UCLA loneliness scale (version three) (Barnby and Bell, 2017; Bell et al., 2005; Benson et al., 2019; Cicero et al., 2017; Peters et al., 2004; Russell, 1996; Zigmond and Snaith, 1983).

The SenPQ is the first validated questionnaire which has been developed solely for the assessment of sensed presence (Barnby and Bell, 2017). Respondents rate how frequently they experience the phenomena described in each of the 16 statements on a 5-point Likert scale. An internal validation study indicated good divergent and convergent validity when compared to similar scales, high internal consistency (Cronbach's $\alpha = 0.951$), and good discriminant validity when comparing religious and non-religious experiences (Barnby and Bell, 2017).

The B-BODI is a 26-item questionnaire which assesses bodily self-disturbance (Benson et al., 2019). Respondents confirm whether they have had an experience similar to that described in each statement, before rating its frequency, vividness, and the degree of distress it causes on three five-point Likert scales (Benson et al., 2019). The B-BODI includes images to support participant's understanding of each statement, alongside control items; these consist of four common bodily experiences: feeling itchy, feeling ticklish, the feeling of having butterflies in one's stomach, and headache (Benson et al., 2019). Participants must respond 'True' to at least one of the control items for their responses to be valid. In an internal validation study, the B-BODI was found to have good discriminant and convergent validity, and acceptable test-retest reliability and internal consistency (Cronbach's $\alpha = 0.891$ and 0.867) (Benson et al., 2019).

The IPASE is a 57-item scale which assesses basic self-disturbance; respondents rate their agreement with each statement on a five-point Likert scale (Cicero et al., 2017). An internal validation study found evidence of good internal consistency (Cronbach's $\alpha = 0.96$-0.98), and high construct and convergent validity (Cicero et al., 2017). This was supported by an external validation study, which reasserted the scale's good discriminant validity (Nelson et al., 2019).

The CAPS was administered as an additional measure of hallucination proneness with the intention of assessing its consistency with the MUSEQ score, however, there was insufficient sample size to include this as an independent variable without risking overfitting (Babyak, 2004; Bell et al., 2005).

Since these have been demonstrated to perform similarly, the 21-item PDI was chosen instead of the 40-item version, and the HADS was chosen instead of separate scales to assess anxiety and depression symptoms, to reduce respondent burden (Esser et al., 2018; Hansson et al., 2009; Hitchon et al., 2020; Marrie et al., 2018; Peters et al., 2004, 1999). The UCLA loneliness scale (version 3) is a 20-item scale which was used to assess loneliness (Russell, 1996). The reliability of each of these scales has been consistently demonstrated in the general population (Bjelland et al., 2002; Peters et al., 2004; Russell, 1996).

2.3.2 The EmBODY Task

Stage two participants also completed the computerised EmBODY task (Nummenmaa et al., 2014; Torregrossa et al., 2018). As demonstrated in Figure 2, participants were shown 16 words representing emotional, neutral and control states in a random order; respondents coloured in two body outlines using their mouse to indicate where they felt activity in their body increasing or decreasing during each state (Nummenmaa et al., 2014; Torregrossa et al., 2018). The 14 emotion words were fear, anger, disgust, sadness, happiness, loneliness, anxiety, love, depression, stress, pride, shame, jealousy and neutral. Migraine and nausea were included to verify that participants were responding appropriately, since these are associated with characteristic and universal sensations (Nummenmaa et al., 2018).

Figure 2 around here

2.4. Statistical methods

2.4.1 Analysis of questionnaire data

The questionnaire data was analysed using Stata release 16.1.(StataCorp, 2019a)

All data was analysed using descriptive statistics. The normality of each scale score and participant age was assessed by plotting the data on a histogram with a superimposed normality density curve, and by applying the Shapiro-Wilks test (Suppl. Table 2).

Six hierarchical linear regression models were constructed to model how hallucination-proneness impacted upon the values of the scale scores which measured self-disturbance and sensed presence experiences (SenPQ, B-BODI and IPASE), whilst adjusting for covariates. This method allowed for the assessment of whether the addition of the independent variables at each step led to a significant change in predictive power, indicated by the change in R^2 and the F statistic with its associated p value, and therefore which independent variables were the best predictors of basic and bodily self-disturbance.

To confirm whether the assumptions of hierarchical linear regression were met for each model, the normality of the residuals was assessed through plotting them on histograms with superimposed normal density curves and applying the Shapiro-Wilks test. The residuals were also plotted against the predicted values to test for homoscedasticity, and the built-in Stata command *vif* was used to test for multicollinearity.

Since there was some heteroscedasticity and skew in the residuals, and the MUSEQ, HADS and PDI scale scores were positively skewed, these independent variables were transformed. The most appropriate transformations were chosen using Tukey's ladder of powers, which was conducted using the built-in Stata commands *ladder, gladder* and *qladder;* these were found to be a square root transformation for PDI and HADS, and a natural log transformation for MUSEQ. Applying these transformations significantly improved the distribution of the residuals.

Since the percentage of incomplete responses was moderate for several questionnaires, above the threshold of ~5% that would be considered negligible, the pattern of missing data was analysed (Jakobsen et al., 2017). Following this, multivariate imputation using chained equations was conducted (StataCorp, 2019b). See supplementary methods 1 for further detail regarding methods used for multiple imputation and the analysis of missing data using Stata, including their justification.

In all six hierarchical linear regression models, the first and second steps were identical. In step one, √HADS and the UCLA loneliness scale were entered as a single block. These variables were included together since these may be associated with the positive symptoms of psychosis, self-disturbance and SSDs (Dodell-Feder et al., 2020; Herniman et al., 2019; Jaya et al., 2017; Lim et al., 2018; Michael and Park, 2016). √PDI was entered in the second step, since this is a covariate which measures a positive symptom of psychosis (Semple and Smyth, 2019).

In models 1-3, lnMUSEQ was included in the final step as a continuous measure of hallucination proneness. In models 4-6, high or low hallucination-proneness was included instead as a binary independent variable.

It was not possible to include demographic variables in the models since this carried the risk of overfitting, given the sample size for each model following listwise deletion (Babyak, 2004).

2.4.2 Analysis of EmBODY data

Data obtained from the EmBODY task was analysed using MATLAB scripts adapted from those authored by Torregrossa, Nummenmaa and colleagues (MathWorks, 2020; Nummenmaa et al., 2014; Torregrossa et al., 2018).

Since it was not possible to conduct meaningful analyses using data collected from the entire cohort for the EmBODY task, the following analyses compared the data of participants in the high and low hallucination-proneness groups.

Participants who did not complete the task were excluded, since it was not possible to analyse incomplete responses. The maps created by each participant, including the control maps (migraine and nausea), were screened for anomalous or inappropriate responses, including letters or symbols.

Following smoothing with a Gaussian kernel, non-parametric methods were used to create proportional maps representing bodily activation and deactivation during each state, for the high and low hallucination-proneness group separately. Non-parametric methods were used to generate the maps, instead of mass univariate *t*-tests, due to the small sample size.

The two sets of proportional maps representing embodiment during each of the 16 states, for each group, were generated by calculating the frequency of positive and negative values assigned to each pixel, representing bodily activation and deactivation, respectively. For each state, the activation and deactivation counts for each pixel were summed across all the participants in the group and divided by the total number of participants, to produce an average value.

This produced two 50,364-by-16 matrices per state for each group, with one matrix containing the proportion of positive values (P) and the other containing the proportion of negative values (N).

The equation below produced the final matrices (F) which represented embodiment:

$$(P - N)\ \times (P + N) = F$$

Here, P - N indicates whether the type of embodiment represents activation (positive value) or deactivation (negative value). Whereas P + N represents the total number of individuals who coloured in that specific pixel during the task.

The values in these final matrices (F) ranged from -1 to 1, which corresponded to the gradient in the colour bar (Torregrossa et al., 2018).

Difference maps were also generated to visually represent where emotional embodiment differed between the groups. For each state, the difference between the two groups' matrices (F) was computed, producing difference matrices called $D_{deactivation}$ and $D_{activation}$ respectively. Colour was used to indicate where there was more activation or deactivation for either group, with magenta representing the high hallucination-proneness group, and green representing the low hallucination-proneness group. Given the relatively small sample size, we used a nonparametric method to generate the maps. This method uses the proportion of agreement within a group (i.e., how many people coloured a given pixel in red/blue) instead of the original, parametric, method (i.e., using mass-univariate t-tests at each pixel). Previous research has shown that the parametric and nonparametric techniques yield identical maps. The original (parametric) method is analogous to neuroimaging techniques (i.e., statistical tests are used to determine whether a brain/body region is activated). Thus, in a group map generated using the parametric method, anything that would appear in colour would be statistically significant. In our paper, we used a nonparametric method to generate the maps, which we consider as a proxy for the parametric maps that we would have used had our sample had been larger. The maps are used to illustrate the group difference in embodiment.

The pixel intensity representing activation only, deactivation only, and total embodiment (activation and deactivation combined) was compared between the two groups across all states, using three independent two-sample *t*-tests which were conducted using Stata 16.1. The purpose of this was to determine whether there was a significant difference in task engagement between the two groups. We report t-statistics for activation, deactivation, and both. This metric represents the overall intensity of the bodily sensation reported by a participant for a given emotion, which is one of several aspects of embodiment. In fact, while the body maps capture the amount (i.e., intensity), location, pattern, and precision of the bodily sensation for emotions, this metric is only concern with the amount.

3. Results

3.1. Demographics and descriptive statistics

Descriptive statistics summarising the questionnaire data is presented in Table 2. Analysis using an independent two-sample *t*-test and Pearson’s Chi-Squared tests indicated no significant difference in demographic characteristics between the high and low hallucination-proneness groups (Suppl. Tables 4 and 5).

Table 2 around here

3.2. Results from the analysis of questionnaire data

55 participants responded to the stage two questionnaire. Data regarding the incomplete and incomplete responses obtained is presented in Table 3, providing further justification for using multiple imputation to account for incompleteness (see Supplementary Materials for more detail).

Table 3 around here

The assumptions of all six hierarchical linear regression models were met and there was no evidence of multicollinearity.

Tables 4 and 5 summarise the results of the hierarchical linear regression analyses. All models were statistically significant at all three stages. In models two, three, five and six where B-BODI and IPASE were the dependent variables, there was a significant increase in predictive power at stage two only, with the addition of √PDI; whereas in models one and four, where SenPQ was the dependent variable, there was a significant increase in predictive power at stage three as well as stage two with the addition of a measure of hallucination proneness, which was lnMUSEQ in model one and high or low hallucination-proneness in model four.

Tables 4 and 5 around here

The *post-hoc* sample size calculation indicated that all models had a statistical power of at least 80%, aside from model six where this was 58.1% (Suppl. Table 1).

Compared to listwise deletion, multiple imputation led to a consistent increase in the p value associated with the F statistic, the width of the confidence intervals, and the p value associated with the unstandardised coefficients (Suppl. Tables 6 and 7). Despite this, the F statistic associated with all models remained statistically significant, aside from model six where the p value increased to 0.0842.

3.3. Results from the analysis of EmBODY data

Following the exclusion of participants who provided incomplete data, there were eight participants in the high hallucination-proneness group, and ten participants in the low hallucination-proneness group. No participants were excluded after screening the maps.

Figure 3 shows the proportional maps, where embodiment is compared between the low and high hallucination-proneness groups. The greatest proportion of endorsement was 0.64 for both the high and low hallucination-proneness groups.

In both groups, the patterns of activation and deactivation appear to be distinct across the 13 emotions and the neutral state. Visually, the proportional maps in Figure 3 does not reveal any clear distinction in the patterns of embodiment between the groups. Furthermore, the patterns of embodiment for both groups appear to be consistent with those that have been previously reported for non-clinical populations (Nummenmaa et al., 2014; Torregrossa et al., 2018).

Figure 3 around here

Qualitative inspection of the difference maps in Figure 4 indicates that participants in the low hallucination-proneness group consistently reported more bodily activation than the high hallucination-proneness group for 10 out of the 14 states. Participants in the high hallucination-proneness group consistently reported more deactivation than the low hallucination-proneness group in seven of the 14 states.

Figure 4 around here

The results of the analyses comparing the pixel intensities for embodiment (activation and deactivation combined), activation and deactivation, between the groups across all states is shown in Table 6. Total embodiment across all states was found to be greater in the low hallucination-proneness group compared to the high hallucination-proneness group, however, this difference was not observed for activation or deactivation alone.

Table 6 around here

4. Discussion

All hierarchical regression models were statistically significant at step one, where the UCLA loneliness scale and √HADS were included as independent variables. This indicates that loneliness, anxiety, and depression may be independently associated with self-disturbances and sensed presence experiences. This is consistent with literature indicating that loneliness may be associated with susceptibility to self-disturbances and psychosis-like experiences, and that affective symptoms may mediate this relationship (Dodell-Feder et al., 2020; Jaya et al., 2017; Michael and Park, 2016). Depressive symptoms also appear to be more common amongst individuals with SSDs, compared to the general population (Herniman et al., 2019).

In all models, the inclusion of √PDI as an independent variable led to a significant increase in predictive power, indicating that delusion-proneness is a strong predictor of sensed presence experiences and self-disturbances. Since delusions are one of the positive symptoms of psychosis, this appears to be in line with evidence that individuals with psychotic-like experiences are more likely to experience sensed presence experiences and self-disturbances, compared to the general population (Nelson et al., 2012; Raballo et al., 2021; Spark et al., 2021).

The inclusion of a measure of hallucination-proneness in step three only led to a statistically significant increase in the predictive power of models one and four, where SenPQ was the dependent variable. These findings appear to be supported by evidence that sensed presence experiences occur more frequently in non-clinical individuals who also report hallucinations in other modalities (Larøi et al., 2019). Sensed presence has also been conceptualised as a type of anomalous bodily experience, a hallucination, and as a hallucinatory bodily experience, alongside it being hypothesised that sensed presence experiences may arise from the aberrant integration of multisensory information regarding the bodily self and the self-other boundary (Braithwaite et al., 2013; Cheyne, 2012; Larøi et al., 2019). Therefore, sensed presence experiences appear to be at the interface between a bodily self-disturbance and a hallucination. Sensed presence experiences can also be seen as examples of 'true' multimodal hallucinations in that they occur not only in multiple modalities but are also concurrent and thematically related. As such, our findings shed new light on the relationships between multimodal hallucinations, self-disturbances and other psychotic-like experiences.

The proportional maps representing the EmBODY data did not demonstrate a clear difference in the pattern of emotional embodiment between the high and low hallucination-proneness groups. However, closer inspection of the difference maps revealed a subtle but consistent difference in embodiment between the two groups, with the low hallucination-proneness group reporting more activation across the majority of states and the high group showing this for deactivation. These findings may indicate that an individual's degree of hallucination-proneness may be associated with how they embody emotions. The significant difference in pixel intensity representing total embodiment between the groups may indicate that individuals in the low hallucination-proneness group were more engaged in the task compared to the high group.

This study was limited by its small sample size. This meant it was not possible to include demographic variables in the hierarchical regression models to elicit how much of the variance these may have explained. A *post-hoc* power calculation indicated that all regression models had adequate power, aside from model six (Suppl. Table 1).

It is important to note that the findings of the hierarchical regression analyses could be biased, since the data was found to not be missing completely at random. However, the results of the multiple imputation analyses appeared to confirm the statistical significance of the overall model, in models 1-5, increasing the confidence that can be placed in these findings.

Convenience sampling and the significant attrition between the two stages may have introduced selection bias. This attrition may be partly attributable to the high respondent burden which was associated with the stage two survey. Respondent burden is also likely to have been responsible for the moderate percentages of missing data obtained in stage two, which limited the sample size of the hierarchical regression models. However, it was not possible to have recruited more participants for stage one given the overall study duration of 12 months and despite being widely advertised, the survey website was only available for a limited period of time.

Future directions include the investigation of the hypothesis in a larger non-clinical sample, as well as in clinical populations with SSDs. Apart from higher predicted levels of symptom frequency and severity, individuals with SSDs are likely to be more distressed and impaired by their self-disturbances with significantly reduced ownership and controllability over their hallucinations. Although speculative, clinical populations may also experience more concurrence in the multi-modality and complexity of hallucinations. Qualitative methods could be used to explore the subjective experiences of clinical and non-clinical participants who experience multimodal hallucinations, sensed presence experiences, and self-disturbances, with a focus on exploring how these experiences interrelate. This may include using the EASE and other semi-structured phenomenological interviews. Lastly, other risk factors such as substance misuse and its relationships with various psychotic-like experiences deserve further exploration.

There is considerable discourse in the field regarding the roles of hallucination-proneness and psychosis-proneness in an individual's potential conversion to a diagnosable psychotic disorder from an at-risk mental state. In a very recent meta-analysis (de Pablo et al., 2021), around 25% of individuals considered at clinical high-risk for psychosis developed a psychotic disorder within three years, and such risk continued to increase over time. However, the present study did not systematically assess clinical risk for psychosis, and although there was considerable variability in the levels of hallucination-proneness and psychotic-like experiences, the participants were all classed as nonclinical individuals with low risk, distress and impairment. It would be interesting to replicate the current study with a longitudinal design and follow up clinical high-risk individuals for their trajectories in psychopathology and levels of functioning.

In conclusion, hallucination-proneness appears to be a stronger predictor of sensed presence, compared to other measures of basic and bodily self-disturbance. Findings from the EmBODY task indicate that hallucination-proneness may be associated with emotional embodiment.

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Author Contributions

Lucretia Thomas – Data curation; Formal analysis; Writing - original draft; Writing – review and editing.

Lénie Torregrossa – Methodology; Visualisation; Writing – review and editing.

Renate Reniers – Conceptualisation; Supervision; Writing – review and editing.

Clara Humpston – Conceptualisation; Methodology; Supervision; Writing – review and editing.

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