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Title: Pareidolia-proneness, reality discrimination errors, and visual hallucination-like experiences in a non-clinical sample

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Abstract

Introduction: It has been proposed that hallucinations occur because of problems with reality discrimination (when internal, self-generated cognitions are misattributed to an external, non-self source) and because of elevated levels of top-down processing. In this study, we examined whether visual reality discrimination abilities and elevated top-down processing (assessed via face pareidolia-proneness) were associated with how often non-clinical participants report visual hallucination-like experiences.

Methods: Participants (*N* = 82, mean age = 23.12 years) completed a visual reality discrimination task and a face pareidolia task, as well as self-report measures of schizotypy and of the frequency of visual hallucination-like experiences.

Results: Regression analysis demonstrated that the number of false alarms made on the visual reality discrimination task and the number of hits made on the face pareidolia task were independent predictors of the frequency of visual hallucination-like experiences. Correlations between performance on the tasks and levels of schizotypy were not statistically significant.

Conclusions: These findings suggest that weaker visual reality discrimination abilities and elevated levels of top-down processing are associated with visual hallucination-proneness and are discussed in terms of the idea that clinical visual hallucinations and non-clinical visual hallucination-like experiences share similar cognitive mechanisms.

Keywords: pareidolia, reality discrimination, signal detection, visual hallucinations

Introduction

Cognitive models of hallucinations in psychosis suggest that they occur when internal, self-generated mental events (e.g., intrusive thoughts, visual imagery) are mistaken for external, non-self-generated events (e.g., Bentall, 1990; Frith, 1992; Hoffman, 1986). This process – of differentiating between internal, self-generated cognitions and external, non-self-generated events – has been investigated using reality monitoring (e.g., Brunelin et al., 2006) and reality discrimination (e.g., Varese, Barkus, & Bentall, 2012) paradigms.

Reality monitoring studies (e.g., Brunelin et al., 2006; Brébion, Ohlseon, Pilowsky, & David, 2008) require participants to perform a simple task where they are presented with an item or are asked to generate an item. Later, participants undertake a memory task where a series of items are presented to them. For each item, participants must judge whether it was presented to them or was something they generated, earlier in the testing session. Several studies have shown that hallucinating psychosis patients demonstrate biased reality monitoring, so that they tend to mistake self-generated items for items they were presented with (see Brookwell, Bentall, & Varese, 2013, for a meta-analysis). Moreover, there is some evidence that this bias is modality-specific, as it has been reported that psychosis patients with visual hallucinations (VH) show biases in visual reality monitoring that psychosis patients with auditory, but not visual, hallucinations do not (Brébion et al., 2008). Similarly, one study has shown that psychosis patients with olfactory hallucinations show biases in olfactory reality monitoring that psychosis patients with auditory, but not olfactory, hallucinations do not (Arguedas, Stevenson, & Langdon, 2012).

Reality discrimination studies (e.g., Varese et al., 2011, 2012) require participants to detect a stimulus under conditions of perceptual ambiguity. Most studies that have examined reality discrimination abilities in participants who report hallucinations have employed auditory reality discrimination tasks, presumably because auditory hallucinations (AH) are the most common form of hallucination in psychosis patients (e.g., Sartorius et al., 1986). In auditory reality discrimination tasks (e.g., Varese et al., 2011, 2012) participants try to detect a signal (typically one second of neutral, non-emotional speech) in an ambiguous auditory stimulus (typically five seconds of white noise). On some trials the speech is present, on other trials the speech is absent. Reality discrimination errors occur when a participant makes a false alarm – that is, when they perceive speech to be present in the white noise when it is absent. When a false alarm occurs, participants are thought to have mistaken their internal, self-generated representation of the speech for the external, 'real' speech.

When performing an auditory reality discrimination task, psychosis patients who experience hallucinations are more likely than psychosis patients who do not experience hallucinations to report that speech is present in the noise, even when it is absent, which is sometimes referred to as an externalizing bias (e.g., see Brookwell et al., 2013, for a meta-analysis). Many of the studies included in Brookwell et al.'s meta-analysis did not report in which modality (or modalities) participants were experiencing hallucinations. However, given that psychosis patients are much more likely to experience AH than hallucinations in other modalities (e.g., Bauer et al., 2011; McCarthy-Jones et al., 2017), it is likely that these studies primarily showed that participants experiencing AH exhibit biased auditory reality discrimination.

Only one study (Bristow et al., 2014) has examined whether psychosis participants who report VH exhibit modality specific problems with visual reality discrimination. In Bristow et al.'s study, participants completed a 40-trial task (termed a 'jumping to perceptions' task). In each trial, participants were presented with five seconds of visual noise. In half of the trials, the word 'who' was presented within the visual noise. The word was degraded (by having 50% of the pixels making up the word removed) and was presented for a very short period of time (100ms). It was, therefore, difficult for participants to determine whether or not the word was present in the visual noise. Bristow et al. reported that there was a small, but significant, association (*rho* = .22) between the severity of participants' VH and their response bias on the task (i.e., how likely they were to respond that the image had been presented, regardless of whether or not it had). Thus, it would appear that in psychosis patients, VH-proneness is associated with visual reality discrimination problems.

In contrast to psychosis patients, older adults with neurological disease (e.g., Parkinson's disease) or dementia (e.g., Lewy body dementia; DLB) are more likely to experience VH than AH. For example, in one recent study, 88% of Parkinson's disease patients reported VH and 45% reported AH (Llorca et al., 2016). Similarly, VH are reported by 72% of DLB patients, with 38% reporting AH (Ballard et al., 1999). Models of VH in older adults (e.g., Collerton, Perry, & McKeith, 2005) have focussed on the role of attention and perception problems and they suggest that these deficits result in elevated levels of top-down processing, which predispose a person towards experiencing VH.

Several recent studies (e.g., Mamiya et al., 2016; Uchiyama et al., 2012, 2015; Yokoi et al., 2014) have examined levels of pareidolia-proneness in DLB patients with VH. Pareidolia occur when a person perceives faces, or face-like objects in ambiguous visual stimuli, such as clouds, rock formations, or flocks of birds. Given that proneness to pareidolia is thought to reflect elevated levels of top-down processing (Liu et al., 2014), the findings of these studies support the idea that elevated levels of top-down processing play a role in the development of VH in older adults. For example, three studies (Mamiya et al., 2016; Uchiyama et al., 2012; Yokoi et al., 2014) have reported medium or large correlations (e.g., $r = .40$ to $r = .51$) between the severity of DLB patients' hallucinations and how many pareidolia they perceived during a task. Similarly, Uchiyama et al. (2015) reported a large correlation ($r = .51$) between the severity of Parkinson's patients' hallucinations and how many face pareidolia they perceived in a task. More recently, Bowman, Bruce, Colbourn, and

Collerton (2017) have reported a greater tendency to experience pareidolia in Parkinson's patients with VH than in Parkinson's patients without VH.

Thus, there is evidence that reality discrimination problems are associated with the presence of VH in psychosis patients and that pareidolia-proneness is associated with the frequency of VH in older adults with neurodegenerative disorders. Previous research has shown that many (but not all) of the cognitive mechanisms involved in the clinical AH are also involved in non-clinical AH-like experiences (Badcock & Hugdahl, 2012). However, little research has examined whether the same cognitive mechanisms are involved in clinical VH and non-clinical VH-like experiences, despite some evidence that non-clinical VH-like experiences may be more prevalent than non-clinical AH-like experiences (Kessler et al., 2005). One recent exception (Aynsworth, Némat, Collerton, Smailes, & Dudley, 2017) has suggested that visual reality monitoring biases are seen in both psychosis patients with VH and in non-clinical participants who are prone to VH. Thus, it is plausible that visual reality discrimination problems and pareidolia-proneness may also be associated with non-clinical VH-like experiences.

The primary aims of the present study, therefore, were to examine whether visual reality discrimination problems and pareidolia-proneness were correlated with increased frequency of VH-like experiences in healthy young adults. We also sought to examine whether visual reality discrimination problems and pareidolia-proneness predicted variance in the frequency of VH-like experiences after controlling for levels of schizotypy more generally. This was because previous studies have shown that some variables that one would intuitively expect to play a specific role in the development of hallucinations have been shown to be as strongly related to levels of schizotypy as to levels of hallucination-proneness (e.g., van de Ven & Merckelbach, 2003, reported a correlation of r = .34 between vividness of mental imagery and schizotypy, and a correlation of r = .27 between vividness of mental imagery and hallucination-proneness).

Materials and Methods

Participants

Participants were 82 university students (45 males, 37 females), aged 18-53 years (M = 23.12 years, SD = 4.85), who received course credit, or a small payment, in return for their time. The majority of participants reported their ethnicity as 'White British/Irish' (n = 52), or as 'White Other' (n = 21), with nine reporting other ethnicities. Participants were eligible to take part if they had no history of mental health problems, head injury, or neurological problems, and had normal (or corrected-to-normal) vision.

Procedure

The study was approved by a departmental ethics committee and was conducted in accordance with the principles of the Declaration of Helsinki (with the exception of the study not being publicly registered prior to data collection). After providing informed consent, participants completed the visual reality discrimination and pareidolia tasks in a counter-balanced order (there was no effect of task order on task performance, p > .52), followed by a questionnaire pack, which included demographics measures and the measures below.

VH-Like Experiences

Frequency of VH-like experiences was assessed using the six items of the Cardiff Anomalous Perceptions Scale (CAPS; Bell, Halligan, & Ellis, 2006) that assess unusual visual experiences. These six items ask whether participants have experienced various unusual visual percepts (e.g., "Do you ever see things other people cannot?" and "Do you ever think that everyday things look abnormal to you?"). Participants rate how often they have had these experiences on a 6-point Likert scale (*0 = Never; 5 = Happens all the time*), so that scores can range from 0 to 30, with higher scores reflecting more frequent VH-like experiences. The scale had good internal reliability (α = .82).

Schizotypy

Participants completed the Cognitive Disorganisation, Introvertive Anhedonia, and Impulsive Nonconformity subscales of the Oxford-Liverpool Inventory of Feelings and Experiences (Mason, Linney, & Claridge, 2005). Participants were not asked to complete the Unusual Experiences subscale, given that frequency of hallucination-like experiences was assessed via the CAPS. Scores on these three subscales were summed to give an overall schizotypy score. Scores could range, therefore, from zero to 32, with higher scores reflecting higher levels of schizotypy. In this sample, this measure had a relatively low level of internal reliability (α = .68). However, this alpha-value is similar to the levels of reliability reported in Mason et al. (2005; where α-values ranged from .62 to .80).

Visual Reality Discrimination Task

This task consisted of 60 trials and was designed to be similar to the visual 'jumping to perceptions' task employed by Bristow et al. (2014). However, rather than asking participants to detect a written word, the task employed here required participants to detect a face, given that hallucinations of human faces are often reported by patients with VH (Collerton et al., 2005) and that hallucinations of written words are rarely reported (e.g., none of the 61 patients with VH in Dudley, Collerton, Nicholson, & Mosimann 2013, were reported to experience this type of VH).

In each trial, participants were presented with visual noise (similar to the black and white pixels found on an un-tuned television) for 3,500 milliseconds. Halfway through each trial, a smaller image was presented in the centre of the visual noise, for 50 milliseconds. In 36 trials, this smaller image was a black and white face. In 12 of these 36 trials, the face was relatively easy to detect. In 24 of these 36 trials, the face was much more difficult to detect. These difficult-to-detect faces had been degraded (using Microsoft Paint) to a level where, in pilot testing (n = 5), they could be detected by participants around 50% of the time. The faces were two-tone, black and white photographs of three male and three female adults expressing a neutral emotion. Each photograph was used six times (twice as a stimulus that was easy to detect, and four times as a stimulus that was difficult to detect). In the remaining 24 trials no face was presented, and the smaller image consisted only of more visual noise.

The visual noise was presented on a white background and measured approximately 820mm by 950mm, with the smaller image measuring approximately 460mm by 560mm. After each trial, participants were asked to respond by pressing ‘P’ for present if a face was detected and ‘A’ for absent if no face was detected. Between the response screen and the subsequent trial, a blank white screen was presented for 1,000 milliseconds.

Participants completed nine practice trials, before beginning the task. In the first three practice trials a face was clearly presented in the visual noise, in the middle three practice trials a degraded face was presented that was difficult to detect, and in the final three practice trials no face was presented. After completing the practice task, it was explained to participants that in the first three trials a face had been present and should have been relatively easy to detect, that in the middle three trials a face had been present, but that it should have been difficult to detect, and that in the last three trials no face had been presented. After confirming that they understood the task, participants began the main task and were instructed that they would be presented with 60 trials of visual noise, and that in 12 trials the face would be easy to see, in 24 trials a face would be present but would be more difficult to detect, and in 24 trials no face would be presented. The task was presented on a standard desktop computer, using E-Prime 2.0.

Our main outcome measure for this task was the number of ‘false alarms’ made (i.e., the number of trials where participants incorrectly responded that a face had been presented). We also recorded the number of ‘hits’ made (i.e., the number of trials where participants correctly responded that a face had been presented). Using these variables we calculated two signal detection theory parameters – non-parametric β and *d’* – for each participant. Non-parametric β is a measure of response bias and was found using the formula described in Barkus, Stirling, Hopkins, McKie, and Lewis (2007). It can vary from 1 to -1, with values near to 1 indicating a more conservative response bias (i.e., a bias towards responding that a face had not been presented), and values further from 1 indicate a more liberal response bias (i.e., a bias towards responding that a face had been presented). *d*’ is a measure of sensitivity (i.e., a measure of how able a participant was to discriminate between trials where a face was presented from trials where a face was not presented). Higher *d*’ values indicate better sensitivity.

Face Pareidolia Task

The face pareidolia task consisted of 36 trials. In 24 trials, participants were presented with an image that contained a face pareidolia. In the remaining 12 trials, participants were presented with an image that did not contain a face pareidolia. The presence or absence of a face pareidolia was established by presenting each image to a group of seven participants (who did not take part in the full study) in a pilot study. In this pilot study, participants were shown all 36 images and were given unlimited time to detect whether or not a face pareidolia was present or absent. Images were presented using Microsoft PowerPoint and were presented in a fixed, random order. All seven participants detected the face pareidolia in the ‘pareidolia present’ images. None of the participants detected a face pareidolia in the ‘pareidolia absent’ images.

In the face pareidolia task, each image was presented for 750 milliseconds, with the images presented in a random order. Immediately after the image had been presented, participants were asked to decide whether or not a face pareidolia had been present in the image. Responses were made using a button press on a standard computer keyboard, with participants pressing the P key to indicate that a face pareidolia had been present in the image, and pressing the A key to indicate that a face pareidolia had not been present in the image. There was no time limit on how long participants could take to respond.

Our main outcome was the number of ‘hits’ made (i.e., how often participants responded that a face pareidolia had been present in an image that did contain a face pareidolia). We also recorded the number of ‘false alarms’ made (i.e., how often a participant responded that a face pareidolia was present in an image that did not contain a face pareidolia). Thus, we were able to calculate non-parametric β and *d’* for this task, using the same method as for the visual reality discrimination task.

Prior to beginning the task, participants were given a written explanation of what a pareidolia was, and were shown three examples of face pareidolia (which were not used in the test phase of the task). The task was presented on a standard desktop computer, using E-Prime 2.0.

Sample Size Considerations

Based on the associations reported in research with clinical samples (r = .22 to r = .51; Bristow et al., 2014; Yokoi et al., 2014), it seemed plausible to expect moderate associations (i.e., r = .30) between performance on the pareidolia and visual reality discrimination tasks and frequency of VH-like experiences. Power analysis (conducted using G*Power 3.1; Faul, Erdfelder, Buchner, & Lang, 2009) indicated that to achieve 80% power to detect medium-sized correlations, a sample size of 82 participants was required. This sample size met Harrell's (2001) criterion of at least 10 subjects per variable for the subsequent regression analyses.

Data Analysis

Data were analysed using IBM SPSS version 24. Where participants had missed a questionnaire item, but had responded to more than 80% of the other items on that questionnaire/subscale, the mean score on the other items was calculated, and this was inputted as their response to the item that had been missed. Two participants had missing data (one missing data point each). We repeated the analysis reported below with their data excluded and found that the results of the correlational and regression analyses did not change in a meaningful way (see Supplementary Table 2 and Supplementary Table 3).

After examining correlations between the self-report measures and performance on the two tasks, we performed a hierarchical regression analysis. Scores on the CAPS were used as the outcome variable, with age, gender, ethnicity (dichotomized, so that participants were divided into those who had reported their ethnicity as 'White British/Irish/Other' and those who had reported any other ethnicity), schizotypy score, number of false alarms made on the reality discrimination task, and number of hits made on the pareidolia task entered as predictor variables.

Data and Task Availability

The data that support the findings reported here, as well as the tasks employed in this study, here are available on request via the corresponding author.

Results

Descriptive Statistics and Correlational Analyses

Descriptive statistics for self-report measures and performance on the two tasks, as well as correlations between these variables, are presented in Table 1. Participants made few false alarms on the visual reality discrimination task and detected faces on around half of the trials were a face was presented, which is consistent with non-clinical participants' performance on an auditory reality discrimination task (Smailes, Meins, & Fernyhough, 2015). Participants performed well on the face pareidolia task, detecting a face pareidolia on around 75% of the trials where one was present. All variables were not normally distributed. Thus, Spearman's ranked correlation coefficients are reported in Table 1. Importantly, there were significant, positive associations between CAPS VH score and number of false alarms made on the visual reality discrimination task and between CAPS VH score and number of hits made on the pareidolia task. Correlations between self-report measures and all four variables (hits, false alarms, β, and *d'*) representing performance on the two tasks are presented as supplementary materials.

[Table 1 about here]

Regression Analyses: Predicting Frequency of VH-Like Experiences

As shown in Table 2, in the first step of the regression, age, gender, ethnicity, and schizotypy score were entered as predictors. In the second step, the number of false alarms made on the reality discrimination task and the number of hits made on the pareidolia task were entered as predictor variables. The initial model was significant, $F(4, 77) = 6.45$, MSE = 19.44, $p < .001$, adjusted $R^2 = .21$. In this model, only schizotypy score was a significant predictor. The second model was significant, $F(6, 75) = 6.10$, MSE = 17.90, $p < .001$, $\Delta R^2 = .06$. In this model, schizotypy score, number of false alarms made on the reality discrimination task, and number of hits made on the pareidolia task were significant predictors. The average VIF value for the final regression model was 1.06, indicating that multicollinearity was not a concern. In the final model, there was no evidence of heteroscedasticity. Residuals appeared to be independent and normally distributed.

Discussion

The present study showed that there were significant, albeit modest, associations between how often healthy young adults report VH-like experiences, how often they made false alarms on a visual reality discrimination task, and how often they detected faces in a pareidolia task. Importantly, regression analysis suggested that the face pareidolia and visual reality discrimination tasks measure separable processes, and that performance on these tasks was specifically related to VH-proneness (rather than to levels of schizotypy more broadly).

These findings are consistent with the results of five clinical studies, which reported that DLB and Parkinson's patients with VH perceive pareidolia more often than patients without VH (Bowman et al., 2017; Mamiya et al., 2016; Uchiyama et al., 2012, 2015; Yokoi et al., 2014). Together, these findings provide support for the claim that VH may occur when the balance between top-down and bottom-up perceptual processes is biased too heavily towards top-down processes. More broadly, this is consistent with research (Teufel et al., 2015) and models (Behrendt, 1998; Grossberg, 2000) that have suggested that hallucinations in psychosis are associated with a shift in the balance between top-down and bottom-up processes.

The current findings are also consistent with those of Bristow et al. (2014), who reported that there was a significant association between the severity of psychosis patients' VH and their performance on a visual reality discrimination task. Taken together, the findings from these reality discrimination and parediola studies suggest that VH-proneness is related to problems with visual reality discrimination and to elevated levels of top-down processing in both clinical and non-clinical participants. This indicates that (at least) some of the cognitive mechanisms involved in clinical VH are involved in non-clinical VH-like experiences. Consistent with this claim, Aynsworth et al. (2017) recently reported that psychosis patients with VH and VH-prone non-clinical participants exhibit biased reality monitoring. This bias has been reported previously in a sample of psychosis patients with VH (Brébion et al., 2008), and in a sample of Parkinson's patients with VH (Barnes, Boubert, Harris, Lee, & David, 2003).

The findings of one recent study (Straughan, Collerton, & Bruce, 2016) are, however, inconsistent with these findings. Straughan et al. employed three visual priming paradigms in a sample consisting of Parkinson's patients with VH, Parkinson's patients without VH, and age-matched control participants. Across all three tasks, priming affected performance, but not to a greater extent in Parkinson's patients with VH. Straughan et al. argued that these results indicated normal levels of top-down processing in Parkinson's patients with VH, which seems inconsistent with the associations between performance on the face pareidolia task and frequency of VH-like experiences reported here, and with the associations between pareidolia-proneness and the presence of VH in past clinical studies (e.g., Bowman et al., 2017; Mamiya et al., 2016; Uchiyama et al., 2012, 2015; Yokoi et al., 2014).

One way of reconciling this inconsistency is to acknowledge that performance on pareidolia tasks may assess different aspects of top-down processing to the paradigms employed in Straughan et al.'s (2016) study. Research that examines how pareidolia-proneness relates to levels of top-down processing as assessed by other tasks (e.g., the tasks employed in Straughan et al. ~~as well as the task employed in Teufel et al., 2015~~) would be useful. It would be especially valuable to examine how different measures of pareidolia-proneness (i.e, hits, false alarms, and the signal detection parameters β and *d'*) relate to other indicators of top-down processing. For example, we employed the number of hits made on the face pareidolia task as our measure of pareidolia-proneness. It could be argued, however, that the number of false alarms made on the face pareidolia task would have better represented levels of pareidolia-proneness, and using this as our measure of pareidolia-proneness may have been more consistent with the outcomes employed in past research (e.g., Mamiya et al., 2016). Our view was that a false alarm on the face pareidolia task was, to some extent, conceptually equivalent to a false alarm on the visual reality discrimination task and so was more likely to reflect a failure in reality discrimination than elevated levels of top-down processing. This argument is supported by the medium-sized correlation between the number of false alarms made on the two tasks (see supplementary analyses). However, research assessing associations between performance on several different tasks, which are thought to assess levels of top-down processing, is required.

More broadly, future research should examine how performance on the tasks used here relates to performance on tasks that have been employed in studies investigating whether hallucinations can be explained within a predictive processing framework of perception (e.g., the tasks employed in Teufel et al., 2015, and in Powers et al., 2017). Researchers working within this framework (e.g., Powers et al., 2016) have explained hallucinations in terms of elevated levels of top-down effects on perception, through the operation of priors (i.e., predictions about what sensory information to expect in an environment) that are weighted too strongly when bottom-up and top-down information are integrated. Given that the face pareidolia task is thought to assess individual differences in levels of top-down processing, it seems likely that performance on this task will be strongly related to performance on tasks that assess individual differences in the strength of perceptual priors (e.g., Powers et al., 2017). Meanwhile, it has been argued that the predictive processing framework may provide a “deeper, computational foundation” for source monitoring account of hallucinations

(Griffin & Fletcher, 2017, p. 272). Given the overlap between source monitoring and reality discrimination accounts of hallucinations, it seems plausible that the predictive processing framework could provide this foundation for reality discrimination accounts of hallucinations. Research that examines the associations between these sets of tasks will be helpful in understanding how easily extant data on the relations between hallucinations, reality discrimination, and pareidolia-proneness can be integrated into a predictive processing account of hallucinations.

This study suffered from some limitations. First, while the sample size was sufficient to detect medium-sized correlations between variables with 80% power, these correlations tend to stabilize when $N > 180$ (Schönbrodt & Perugini, 2013). It would be helpful, therefore, for the study to be replicated using a larger sample, as this would result in a more reliable estimate of the true association between performance on the two tasks and frequency of VH-like experiences. Second, while this study showed that performance on both tasks was related to frequency of VH-like experiences after controlling for levels of schizotypy, this measure of schizotypy consisted only of the cognitive disorganization, impulsive nonconformity, and introvertive anhedonia subscales; that is, the unusual experiences subscale was not used (given that it includes two items that assess unusual visual percepts). Further research examining the associations between performance on the tasks employed here and frequency of VH-like experiences after controlling for other types of unusual experiences (e.g., intrusive thoughts, intrusive imagery, hallucinatory experiences in other modalities) would be useful. Finally, while several studies have examined the frequency and/or correlates of VH-like experiences in non-clinical participants (e.g., Morrison, Wells, & Nothard, 2002; Ohayon, 2000), we have little knowledge of the phenomenology of these experiences. The present study did not address this issue and further research that examines in more detail the kinds of VH-like experiences participants report (e.g., the presence of simple VH-like experiences versus the frequency of complex VH-like experiences), and whether these different kinds of VH-like experiences are associated with different cognitive processes, is required.

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Table 1. Descriptive statistics for, and correlations between, self-report measures and task performance

	Mean	SD	2	3	4
1. CAPS VH Score	7.07	4.97	.50***	.33**	.25*
2. Schizotypy Score	10.74	5.31		.20	.05
3. Reality Discrimination Task False Alarms	2.87	3.05			.03
4. Face Pareidolia Task Hits	18.41	2.90			

*$p < .05$, **$p < .01$, ***$p < .001$; two-tailed tests.

Table 2. Summary of hierarchical regression analysis predicting frequency of VH-like experiences

Variable	B	SE B	β
Step 1			
Age	-0.10	0.10	-0.10
Gender	1.00	0.99	0.10
Ethnicity	1.69	1.57	0.11
Schizotypy Score	0.44	0.09	0.47***
Step 2			
Age	-0.03	0.10	-0.03
Gender	0.80	0.96	0.08
Ethnicity	2.31	1.52	0.15
Schizotypy Score	0.40	0.09	0.43***
Reality Discrimination Task False Alarms	0.34	0.16	0.21*
Face Pareidolia Task Hits	0.36	0.17	0.21*

*$p < .05$, **$p < .01$, ***$p < .001$

Supplementary Materials

Supplementary Table 1. Descriptive statistics for, and correlations between, self-report measures and task variables (*N* = 82).

	Mean	SD	2	3	4	5	6	7	8	9	10	11	12	13
1. CAPS VH Score	7.07	4.97	.42	.24	.48	.50	.33	.26	-.31	-.26	.28	.25	-.30	-.03
2. Cognitive Disorganisation Score	5.27	2.92	-	.56	.45	.89	.09	.02	-.10	-.11	.00	.08	.00	.00
3. Introvertive Anhedonia Score	1.91	1.97		-	.25	.74	.20	.04	-.19	-.21	-.09	-.04	.08	-.01
4. Impulsive Nonconformity Score	3.56	1.93			-	.68	.21	.15	-.23	-.14	.00	.06	-.01	.01
5. Total Schizotypy Score	10.74	5.31				-	.20	.08	-.21	-.18	-.04	.05	.03	.00
6. Visual Reality Discrimination Task False Alarms	2.87	3.05					-	.66	-.98	-.73	.32	.03	-.32	-.25
7. Visual Reality Discrimination Task Hits	18.87	5.35						-	-.70	-.03	.18	.28	-.23	.08
8. Visual Reality Discrimination Task β	0.52	0.38							-	.64	-.29	-.06	.29	.21
9. Visual Reality Discrimination Task *d'*	1.42	0.50								-	-.30	.18	.27	.38
10. Face Pareidolia Task False Alarms	0.78	1.21									-	.07	-.98	-.59
11. Face Pareidolia Task Hits	18.41	2.90										-	-.18	.68
12. Face Pareidolia Task β	0.64	0.44											-	.49
13. Face Pareidolia Task *d'*	2.27	0.57												-

Note: All variables other than Face Pareidolia Task *d'* were not normally distributed. All correlations above are, therefore, Spearman's rho correlations.

Supplementary Table 2. Descriptive statistics for, and correlations between, self-report measures and task variables (N = 80; participants with missing data removed from analysis).

	Mean	SD	2	3	4	5	6	7	8	9	10	11	12	13
1. CAPS VH Score	7.01	5.02	.42	.24	.48	.50	.32	.26	-.30	-.25	.27	.25	-.29	-.02
2. Cognitive Disorganisation Score	5.25	2.95	-	.56	.45	.90	.08	.02	-.09	-.10	-.02	.07	.01	.01
3. Introvertive Anhedonia Score	1.92	1.99		-	.25	.75	.20	.04	-.19	-.21	-.10	-.03	.10	.00
4. Impulsive Nonconformity Score	3.53	1.94			-	.68	.18	.14	-.21	-.11	-.01	.05	.00	.01
5. Total Schizotypy Score	10.69	5.37				-	.19	.08	-.20	-.17	-.05	.05	.04	.00
6. Visual Reality Discrimination Task False Alarms	2.78	2.99					-	.67	-.98	-.72	.30	.02	-.30	-.24
7. Visual Reality Discrimination Task Hits	18.83	5.41						-	-.71	-.02	.18	.27	-.24	.07
8. Visual Reality Discrimination Task β	0.53	0.38							-	.63	-.28	-.05	.28	.20
9. Visual Reality Discrimination Task *d'*	1.44	0.49								-	-.39	.19	.25	.37
10. Face Pareidolia Task False Alarms	0.78	1.21									-	.08	-.98	-.58
11. Face Pareidolia Task Hits	18.37	2.92										-	-.19	.68
12. Face Pareidolia Task β	0.65	0.44											-	.47
13. Face Pareidolia Task *d'*	2.26	0.57												-

Note: All variables other than Face Pareidolia Task *d'* were not normally distributed. All correlations above are, therefore, Spearman's rho correlations.

Supplementary Table 3. Summary of hierarchical regression analysis predicting frequency of VH-like experiences (N = 80; participants with missing data removed from analysis)

Variable	B	SE B	β
Step 1			
Age	-0.09	0.10	-0.09
Gender	1.06	1.01	0.11
Ethnicity	1.76	1.58	0.11
Schizotypy Score	0.42	0.10	0.44***
Step 2			
Age	-0.03	0.10	-0.03
Gender	0.86	0.98	0.09
Ethnicity	2.34	1.54	0.15
Schizotypy Score	0.39	0.10	0.41***
Reality Discrimination Task False Alarms	0.34	0.16	0.21*
Face Pareidolia Task Hits	0.34	0.17	0.20*

$^*p < .05$, $^{**}p < .01$, $^{***}p < .001$

As shown in the table above, the results of this regression are not meaningfully different to the original, N = 82 analysis, where we imputed the missing data for two participants. In this analysis, the first model was significant, $F(4, 75) = 5.49$, MSE = 19.75, $p = .001$, adjusted R^2 = .19. Only schizotypy score was a significant predictor (as in the original N = 82 analysis). The second model was significant, $F(6, 73) = 5.29$, MSE = 18.27, $p < .001$, $\Delta R^2 = .06$. Schizotypy score, number of false alarms made on the reality discrimination task, and number of hits made on the pareidolia task were significant predictors in this model (as in the original N = 82 analysis).